The Food of Plankton Organisms.

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With 3 Figures in the Text.

INTRODUCTION.

Following the researches on the food of young fishes, it was thought advisable to investigate the food of the planktonic invertebrates. Whenever possible, therefore, the food of the larger animals brought in by the tow-nets was noted, and also that of many of the smaller creatures down to some of the unicellular organisms, such as the tintinnids and those members of the Peridiniales which are holozoic.

With the larger animals it was hoped to find which of them actually ate the young fishes, and by investigating their food in general ascertain how much they were actually competitors with the fishes.

The present work is offered as a preliminary, and it is hoped to continue it, following it up especially with more experimental work on the living animals.

The tow-nettings were examined fresh and the food noted. Sometimes a few hours elapsed between the taking of the sample and the examination, so that some of the catch was moribund in the jar. There is always the objection that the food might have been taken in the jar whilst the plankton was being brought in, and it is a matter of general observation that many medusæ and various pelagic animals will devour young fishes and almost anything living when crowded up with them in the hauls. In many of the organisms examined, however, the nature of the food was so consistent in various hauls and from various localities that it seems almost impossible to believe that it is merely accidental, and it is probable that what food one usually finds inside any planktonic animal is natural to it.

The Cœlenterates are the most important of the larger plankton organisms, and it is especially in these that one finds young fishes, often almost

wholly digested. The smaller medusæ (*Phialidium*, *Obelia*, etc.), which are very miscellaneous feeders, and also Ctenophores, frequently contained fishes, all of which were very small, either newly hatched or in the young post-larval stages. Clupeoids were commonly taken, also whiting, wrasse, *Cottus* and many others.

The question arose as to whether these cœlenterates catch the fishes alive and eat them in the sea under natural conditions, or only take the moribund fishes when caught in the hauls. In the interesting experiments of Delap (1903–1905), where she reared various medusæ, although a variety of food was taken, no fishes are mentioned. Browne (1898), who also reared many medusæ, gave them no fishes.

In order to ascertain whether medusæ could catch and eat live fishes a large plunger jar was put up in the Laboratory similar to the original plunger apparatus of Browne (1898). The preliminary results of this experiment are shown in the first part of the present paper under the heading of *Experimental Work*. Although this has only been going on for about two to three months the results show that certain medusæ can, and do, catch and eat live fishes on which they thrive, and there seems no doubt that this is a perfectly natural diet.

Sagitta perhaps comes next in importance amongst the larger animals, its food being sometimes its own species, more usually copepods, but young fishes (herring) have also been found in these.

It was interesting to ascertain what such extremely delicate and transparent worms as *Tomopteris* and larval *Pœcilochætus* feed on. These very seldom have any food at all inside, but a few records show that this food is of the most minute kind. Larval annelids of different species vary as to their diet, most of them being principally diatom feeders, but an interesting case occurred where the larva of *Magelona* was found to feed exclusively on larval bivalves.

Amongst the copepods a good deal of work has already been done by other investigators, but in the present records it is shown that some feed differently from others. The majority are diatom feeders, but a few feed on Crustacea, and it is the same with the decapod larvæ. When kept alive in the plunger jar both the diatom-eating copepods and decapod larvæ would eat the débris (chiefly organic) collected at the bottom of the jar.

Such larval forms as *Actinotrocha*, on the one hand, and *Cyphonautes*, *Tornaria*, Echinoderm larvæ and larval mollusks, on the other, feed differently; *Actinotrocha* living almost entirely on Peridinians, the others on diatoms. The tintinnids are also almost entirely Peridinian feeders.

In many cases there have not been sufficient specimens examined to show that all the above-mentioned facts hold good, but the records are

given as a preliminary, and this year it is hoped to continue them more fully. At present the records for 1922 agree entirely with those given here.

The records have been divided into those from the *Inner Grounds*, including the Sound to Rame Head, and the *Outer Grounds*, including those from Rame Head outwards. The food does not apparently change much in inner and outer grounds.

Certain seasonal changes in the quality of the plankton do affect the general food. For instance, in the spring and throughout the early summer the alga *Phæocystis* is very abundant in the area investigated, forming large gelatinous masses, which clog all the nets and interfere very much with fishing. *Phæocystis* serves as a food for many of the plankton organisms, including *Calanus*, *Temora* and *Evadne*. The very young flounder *Pleuronectes flesus* has been shown to feed on *Phæocystis* (Lebour, 1920), and it is also much eaten by unicellular organisms, such as the unarmoured peridinians. At the time when very large quantities of *Rhizosolenia Shrubsolei* and *R. alata* were present in the plankton they were eaten by *Calanus* to the exclusion of the other diatoms usually taken, such as *Coscinodiscus* and *Thalassiosira*. In the autumn, when *Sagitta* was abundant, it was much eaten by the medusæ *Phialidium* and *Obelia*.

Some organisms seem to be only abundant at the time when the food that they usually eat is abundant. Thus the tintinnid *Cittarocyclis serrata* is specially common in the summer, when the peridinians on which it feeds abound, and it disappears when they disappear.

Flagellates seem to form a large part of the food of the organisms that eat diatoms and peridinians, but as these are very easily destroyed it is difficult to identify them. *Phæocystis*, as is shown, is a most important food. Coccoliths are so frequently found inside the diatom-eating species that the coccospheres from which they come must be much commoner than we are led to believe from the examination of centrifuged water in the district. The coccoliths usually occurring apparently belong to a small species of *Coccosphera*, found fairly frequently in water samples and not as yet identified.

In previous papers (Lebour, 1918–19–20) it has been shown what kind of organisms the young fishes chiefly feed on. As all the food ultimately depends on the plant life, it is interesting to find out the various chains of food formed from the plants upwards until we reach the fishes. For instance, young Clupeoids in their very early stages feed chiefly on larval mollusks. So far as we have examined them all larval mollusks feed on diatoms. Those most commonly found inside them were small forms of the naviculoid type ; also other single-celled species, such as *Coscinodiscus* and *Pleurosigma* and colonial diatoms, such as *Thalassiothrix* and

Thalassiosira. These are all kinds found all the year round, and not specially dependent on the seasons. Records for 1922, not yet published, show this much more fully than those given in the present paper. In order that the young Herring may have a sufficiency of mollusk food, it is thus essential that there should be plenty of these diatoms. Later on the small post-larval Clupeoids and nearly all the other post-larval fishes eat copepods. These, as is already well known, depend largely on the diatoms for food, in fact many seem to be almost wholly diatom feeders. This seems to be the case with *Pseudocalanus*, which is the main food of so many of the little fishes, also with *Acartia Clausi*, *Paracalanus parvus* and probably many others. *Temora longicornis*, although feeding largely on diatoms, also sometimes eats copepods, and it is the same with *Calanus finmarchicus* and *Centropages typicus*. All of these also eat flagellates more or less, probably more than we can prove, on account of their being easily destroyed. With all these diatom-eating copepods, however, it is striking that disc-shaped forms, such as *Coscinodiscus* and *Thalassiosira*, are by far the most commonly eaten. *Paralia sulcata* is also common. This when broken up is also disc-shaped. It is possible that it may be an easier shape to be drawn in by the currents created by the mouth parts. All the copepods seem to crush up the diatoms that they eat. A few cases occur of many *Calanus* eating the needle-like species of *Rhizosolenia* when they are very abundant, and these also occur occasionally in other copepods. Dakin (1908) found in the copepods at Kiel that *Coscinodiscus* and *Thalassiosira* were the commonest food. He also found that *Calanus* ate *Biddulphia*. Although this genus is so common it is very seldom found in the Plymouth copepods, probably being too large except to be taken occasionally (e.g. *Calanus* in November in these records). Esterley (1916), who gives an account of the mechanism of feeding in copepods, also finds *Coscinodiscus* to be the commonest food of *Calanus*. He shows how currents created by the copepod bring food to it which is formed into a ball and swept into the mouth, the mandibles probably crushing the larger diatom shells. It is almost certain that in the absence of the disc-shaped diatoms those of other shapes would be taken instead;* but both *Coscinodiscus* and *Thalassiosira* are common most of the year, and there is a distinct preponderance of the disc-shaped diatoms as food for the diatom-eating copepods in the Plymouth district and also at Kiel and in America.

The copepods so far examined seem to group themselves into three natural groups according to the food taken, always allowing for the fact that a sufficient number has not yet been examined for this to be anything

* The *Calanus finmarchicus* reared by Crawshay in the Plymouth Laboratory were fed on a pure culture of *Nitzschia closterium*.

but a suggestion, and that flagellates are also much eaten by those that eat diatoms and a mixed diet :—

Diatom Feeders.	*Mixed Diet* (chiefly diatoms & copepods).	*Copepod Feeders.*
Pseudocalanus elongatus.	Temora longicornis.	Anomalocera Pattersoni.
Acartia Clausi.	Centropages typicus.	Labidocera Wollastoni.
Paracalanus parvus.	Calanus finmarchicus.	
Oithona similis.		
Corycæus anglicus.		

It is to be noted, however, that the food given above is the predominant food, and other organisms generally occur as well in less amount. The records for 1922 so far seem to confirm this. In the same way we seem to be able to divide the larval decapods according to their food, but in this case they are nearly all predominantly diatom feeders. The only striking exception seems to be the larval lobster, which in two specimens examined were full of crustacea remains. Most of the crab zoëæ eat diatoms, but in one case bits of copepod were found. One megalopa was found to be full of bits of decapod larvæ. Calcareous remains of what are probably larval mollusks are often found in the decapod larvæ, together with diatoms ; also bits of the spines of Echinoderm larvæ, showing Metazoa as well as unicellular organisms are eaten. We can roughly divide most of the plankton organisms into diatom feeders (including other minute unicellular organisms), Peridinian feeders (Peridinians being the predominant food, but also other unicellular organisms being taken), Mollusk feeders, Crustacea feeders and Miscellaneous feeders (the miscellaneous being chiefly Cœlenterates and *Sagitta*) :—

Diatom Feeders.

Copepods (most of the common species excluding Anomalocera and Labidocera and probably most of the Harpacticids).

Decapod larvæ (excluding the larval lobster and crab megalopæ).

Echinoderm larvæ.

Mollusk ,,

Annelid larvæ (most of the common forms excluding Magelona).

Cyphonautes.

Tornaria.

Tomopteris heligolandicus.

PERIDINIAN FEEDERS.

Actinotrocha.
Tintinnids.

MOLLUSK FEEDERS.

Magelona larva.

CRUSTACEA FEEDERS.

Anomalocera.
Labidocera.
Larval lobster.
Crab megalopa.
Sarsia tubulosa.
Many other medusæ.

MISCELLANEOUS FEEDERS.

Most medusæ.
Pleurobrachia.
Beroë.
Sagitta.

Amongst these are many that eat fishes :—

Aurelia (including the ephyra), ephyra of Chrysaora.
Phialidium.
Obelia.
Turris.
Arachnactis larva.
Rathkea.

With these so-called miscellaneous feeders there seems to be generally some food more frequently taken than the rest, the reason probably being that it is present at the moment more abundantly. Thus when *Beroë* and *Pleurobrachia* are both commonly present the latter is eaten by *Beroë*, but it is not always the commonest creatures in the tow-nets that are taken as food. *Magelona* larva manages to obtain bivalves, although gastropods may be much commoner, and the tintinnids nearly always eat Peridinians in spite of the fact that diatoms are more numerous.

Experimental Work.

A large glass aquarium (about 50 litres capacity) was put up in the Laboratory early in February, 1922. This was fitted up with a glass plunger, as described by Browne (1898), and the water has not yet been changed (at the end of April). In this it was possible to keep medusæ and other plankton organisms alive and study their food and methods of feeding. The following notes for the first three months are given as a preliminary, and it is hoped to continue experiments with other animals. So far those studied were *Aurelia* ephyra and the metamorphosed form, *Phialidium hemispherica*, *Turris pileata*, *Sarsia tubulosa* and *Arachnactis Bournei*. A variety of mixed plankton was put in with these, including many Crustacea. Whenever possible newly hatched and very young fishes were put in also alive, the latter from tow-nets and Young Fish Trawl, the former hatched in the Laboratory, and these were eaten by all the above-mentioned Cœlenterates except *Sarsia*, which always ate copepods.

The following young fishes were used :—

Ammodytes tobianus, with small amount of yolk-sac, about 6–7 mm. long, from tow-nets and Young Fish Trawl.

Cottus bubalis, newly hatched in Laboratory, ca 5 mm. long.

Agonus cataphractus, probably a few days old, from tow-nets, ca 8 mm. long.

Solea vulgaris, newly hatched from eggs in the Young Fish Trawl, ca 3–3·5 mm. long.

Gobius minutus, newly hatched in the Laboratory, ca 3 mm. long.

Blennius pholis, newly hatched in the Laboratory, ca 4 mm. long.

Nerophis lumbriciformis, newly hatched in Laboratory, ca 12 mm. long.

Aurelia aurita Lam.

Delap's (1905) experiments showed the ephyræ of *Aurelia* to eat when very young *Obelia* and *Phialidium*, small copepods and fish eggs, afterwards small Ctenophores and Pteropods and big *Calanus*. Gemmill (1921) has recently shown that the newly liberated ephyræ can feed upon ciliate Infusoria, which they catch by means of stinging cells on the lappets and carry to the stomach by means of currents set up by ciliary action. This method of feeding went on for at least two weeks.

Ephyræ of Aurelia in the plunger jar in the Laboratory at a very young stage, and probably not more than a few days old, ate young fishes. As they required a great deal of food, only one was allowed to remain in the

Aquarium. This was put in on February 9th and measured about 5 mm. It repeatedly caught and ate the young fishes, the method of catching them being apparently just to sting them with the lappet's edge, and then envelope them with the whole of the umbrella until the fish is well fixed in the manubrium, when it is digested. The live fish brushes against the edge of the lappets and is caught, but usually struggles for some time before it is eaten. Occasionally a crab zoëa was eaten, and this was caught in the same way. On March 13th the ephyra had grown into an *Aurelia*, which still ate the young fishes, but with a greatly increased appetite. These are now caught by the marginal tentacles, and presumably stung, and then helped by the long lips into the manubrium. These lips may also sting the fish, which are sometimes seen attached to them by a thread. The *Aurelia* was, on the 24th of March, transferred to another jar, in which it continued to eat fishes whenever these were given to it. One dab, just metamorphosed and measuring about 16 mm., was put into the jar and not eaten, presumably because the *Aurelia* could not catch it when it was close to the glass, as it usually was. Another dab, 15 mm., not yet fully metamorphosed and quite transparent which swam about freely, was eaten by the Aurelia. Sixteen small fishes, *Cottus* or *Blennius*, made a usual meal for the Aurelia, and would take less than half an hour to catch. When fishes were not available, amphipods, crab zoëæ and other crustacea, even small copepods were taken, and also medusæ. The *Aurelia* is still alive (April 24th), measuring about 25 mm., and the dab is also alive in the jar with it.

The following notes show the food of this *Aurelia* :—

Date.	*Time.*	*Food.*
Feb. 17.	9.30 a.m.	Young *Ammodytes tobianus*. Not wholly digested at 7 p.m.
,, 21.	9.30 a.m.	Young *Ammodytes tobianus*, 12.30, not completely digested. Disappeared by 4.30.
,, 27.	10 a.m.	Young *Cottus bubalis*, very lively, 3 p.m. From tail to anus digested. Disappeared next morning.
,, 28.	9 a.m.	Young *Cottus bubalis*.
March 1.	11.30 a.m.	Young *Cottus bubalis*, digests up to near its head, gets rid of the rest.
	6 p.m.	Another young *Cottus bubalis*.
,, 2.	9 a.m.	Young *Cottus bubalis*, eats half of it.
,, 3.	8 p.m.	Young *Cottus bubalis*.
,, 6.	9.15 a.m.	Remains of a *Cottus* inside it.
,, 10.	11 a.m.	A crab zoëa (very few fish in jar).

Date.	*Time.*	*Food.*
March 13.		Changed into young *Aurelia*. Eats 6 live gobies (*Gobius minutus*).
	2.30 p.m.	At least two more eaten, later the stomach was full of them.
,, 20/21.		Still eating gobies. Caught and ate a newly hatched *Nerophis lumbriciformis*.
,, 22.	9.30 a.m.	Two *Nerophis*, now partly digested.
	12.30 p.m.	Another *Nerophis*.
,, 23.	9.30 a.m.	One *Nerophis*.
	3 p.m.	Another *Nerophis*.
,, 24.	9.30 a.m.	One *Nerophis*, *Sarsia tubulosa*. It is now transferred to another jar.
,, 30.		Eats 20 newly hatched *Cottus* within half an hour, and goes on eating them until they are finished.

After this there is a period when fishes are scarce. The dab, 15 mm., is put in but not eaten. Amphipods, crab zoëæ (including Corystes) and other Crustacea are eaten.

April 21. Several newly hatched *Blennius pholis* eaten.

,, 22. Several *Blennius* and a dab not yet completely metamorphosed (15 mm.) eaten.

,, 23/24. Continues eating blennies until they are all done.

It is thus evident that fishes can form an important part of the food of *Aurelia* from very early ephyra stages up to a large size. The records stop here (the MSS. going to press), but the *Aurelia* is still feeding freely on fishes and growing fast. We do not know if it will continue to eat fishes in its adult stage. Further observations will be interesting.*

A young ephyra of *Chrysaora* also ate young fishes in the same way as *Aurelia*.† Unfortunately it disappeared, being probably eaten by some medusa in the jar.

* Since writing the above, Orton's observations on the feeding of *Aurelia* (*Nature*, August, 5, 1922) show that adults feed normally on plankton which is collected on the bell surface and transferred by ciliary currents to the margin of the bell and removed by the lips of manubrium to the mouth.

† Delap (1901) reared *Chrysaora isoscelcs* up to 13 inches. This caught a young fish about an inch in length, but released it without doing it any harm. Other small fish were also kept with it, which it did not attempt to catch. Its chief food was cœlenterates.

PHIALIDIUM HEMISPHERICUM (Gron.).

Many *Phialidium* were seen to catch and eat the young fishes. In the plunger jar they throve well, growing to a large size. The medusa would float about in the jar with its tentacles outstretched to the finest threads, several times longer than the diameter of the bell, and wait for some living thing to come along. Directly this touched the tentacle it reacted and presumably stung the prey. Several more tentacles then came into use and together entangled the fish, or whatever the food caught might be. The fish would struggle, and the long tentacles would play it until it was exhausted. Very rarely the fish would escape and run away with the tentacle. Usually it would be caught and killed in a few minutes.

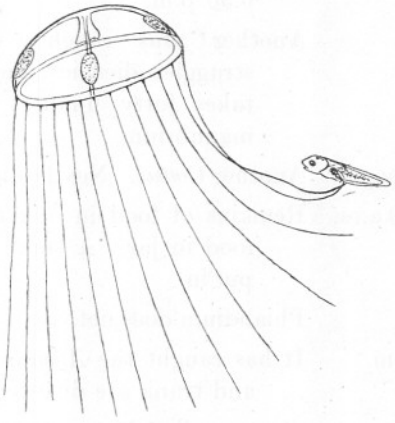

FIG. 1.—Phialidium (ca 10 mm. across) catching a *Cottus*.

The tentacles would then, helped by the umbrella folded in, proceed to deposit the fish in the manubrium. Sometimes this would only take a few minutes; at other times more difficulty would be encountered, and after twenty minutes or more the umbrella would turn upside down and the fish would be dropped into the manubrium. From a few hours to half a day or, rarely, more was taken to digest the fish, sometimes the head part being disgorged. *Phialidium* was seen to eat young *Cottus bubalis*, *Ammodytes tobianus*, *Agonus cataphractus*, *Solea vulgaris*, *Gobius minutus* and *Blennius pholis*.

The following notes were made on one put into the jar on February 17th, which measured about 6 mm. across. This grew to about 12 mm. across when it had 24 tentacles. After March 15th it disappeared, probably eaten by something else.

Date.	*Time.*	*Food.*
Feb. 22.		A solid mass, probably a fish, in manubrium.
,, 27.	9.15 a.m.	Two *Cottus bubalis*, one half digested.
	4.30	Almost completely digested.
,, 28.	9 a.m.	A partly digested *Cottus*.
March 1.	10.15 a.m.	Caught a live *Ammodytes tobianus*. Inside manubrium by 10.30, within an hour it is an opaque mass, only distinguishable as a fish by its eyes. Almost entirely digested by 3 p.m.
	6 p.m.	Caught a *Cottus*.
March 2.	9 a.m.	Another *Cottus* caught, completely digested by 6.30 p.m.
,, 3.	9.20.	Another *Cottus* caught, which after frantic struggles dies in about ten minutes. It takes forty minutes to get it into the manubrium.
,, 4.	12 noon.	Another *Cottus*. Nearly digested at 6.30 p.m.
,, 5.	11.30 a.m.	Remains of food in manubrium. Hardly any food in jar. A small *Agonus cataphractus* put in.
,, 7–9.		Phialidium does not eat.
,, 10.	11 a.m.	It has caught the *Agonus*. At 6 p.m. the tail and trunk are digested, the rest got rid of.
,, 13.		Some small *Gobius minutus* put in.
	12 noon.	It has caught one.
	12.15 p.m.	It has caught another. These both helped by the umbrella edge into manubrium.
	3 p.m.	It has caught 2 more.

It is now about 10 mm. across with 24 tentacles. Disappears on March 15th.

Other specimens of *Phialidium* ate *Solea vulgaris* and *Blennius pholis* besides the above-mentioned fishes. One which was very lively on April 2nd fed on several young fishes, and on April 10th caught and ate a live *Sagitta* in just the same way as it caught and ate the fishes. Small Crustacea were also occasionally taken, but these more often escaped, especially the copepods. On the whole when the young fishes were abundant it seemed that they were much more often taken as food than Crustacea, which were also present in numbers.

On the other hand, *Sagitta*, if put into the jar, was caught and eaten almost at once. Unfortunately only few *Sagitta* were obtained alive in these months. It is hoped to put in more later, for judging from the specimens examined from the tow-nets, *Sagitta* is an important food of *Phialidium*. Amongst *Crustacea* taken Cirripede nauplii were noticed.

We thus see from these notes that *Phialidium* can, and does, capture live fishes and eat them, and if these are present in any quantity they seem to be able to serve as its whole diet. The fishes are all very young,

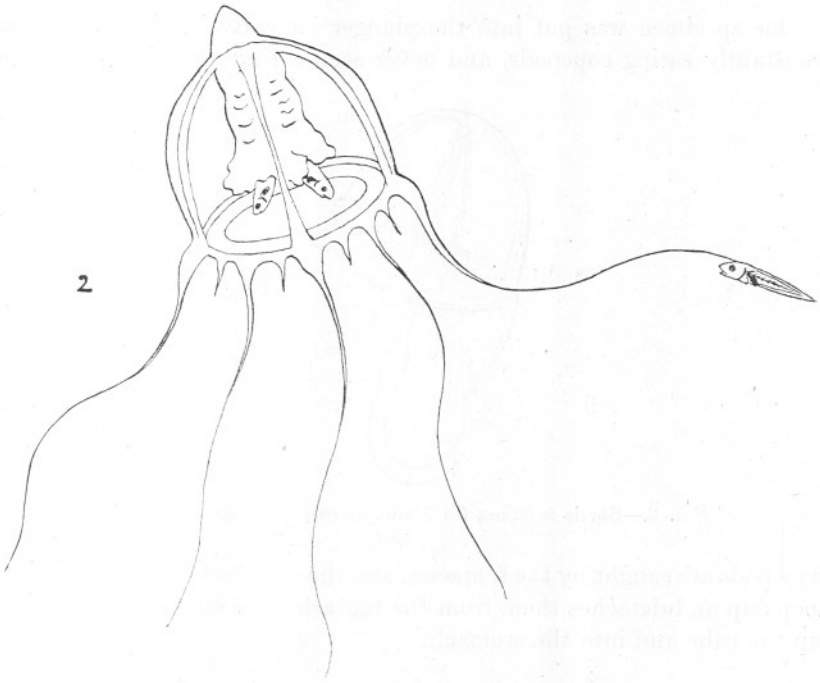

FIG. 2.—Turris (ca 10 mm. across) catching a *Cottus*.

but may measure more than half the diameter of the medusa's umbrella. From the records of the food from the tow-nets given below most of the fishes were taken in the spring and summer, *Sagitta* and other organisms more especially in the autumn.

TURRIS PILEATA (Forskål).

It was difficult to keep *Turris* alive in the plunger jar. One specimen which lived several days ate a young squid, which was longer than its own body and which completely filled its stomach and took several days to digest. Three days afterwards (March 30th) it had two young *Cottus bubalis* inside it, and with its tentacles greatly elongated it was seen to

catch another in the same way as *Phialidium*. After playing it for over ten minutes the medusa lost the fish, which ran away with the tentacle. Another *Turris* caught and ate young *Blennius pholis*, and there seems no doubt that this is its natural method of feeding, and that it can, and does, catch and eat live fishes, although it certainly does feed upon a great variety of other organisms, especially Crustacea. One of these was seen to eat crab zoëæ.

Sarsia tubulosa (Sars.).

One specimen was put into the plunger jar early in March. It was constantly eating copepods, and never seen eating anything else. The

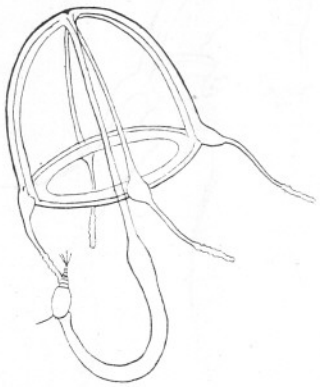

Fig. 3.—Sarsia tubulosa (ca 7 mm. across) catching a Copepod.

copepods are caught by the tentacles, and the extremely long manubrium loops up and detaches them from the tentacle, and thus they are taken up the tube and into the stomach.

The following notes were made on its food from March 13th to the 24th, on which day it was eaten by the *Aurelia*.

Date.	*Food.*
March 13.	Caught and ate 2 *Pseudocalanus elongatus*.
,, 14.	,, ,, ,, several *Acartia Clausii*.
,, 17.	,, ,, ,, ,, ,, ,,
,, 20.	,, ,, ,, a *Calanus finmarchicus*.
,, 22.	,, ,, ,, several *Temora longicornis* and *Acartia Clausii*.
,, 23.	,, ,, ,, several Acartia and Pseudocalanus.
,, 24.	,, ,, ,, eaten by Aurelia.

Mr. Smith (1898) noticed large *Sarsia tubulosa* up the River Tamar by the quay above Saltash Bridge, feeding on mysid larvæ. Forbes (1848) describes this species devouring small Crustacea, and also attacking and beginning to swallow *Lizzia* (*Rathkea*) *octopunctata*. It seems evident that small Crustacea are its natural food, and it was never seen to eat a fish, although many were in the jar with it.

Arachnactis Bournei Fowler.

This is the larva of a *Cerianthus*, probably *Cerianthus Lloydi* Gosse. Fowler (1897) shows that it is different from *Arachnactis albida* both in structure and colour. Several of these were kept in the plunger jar and grew to a large size with from 10 to 12 marginal tentacles. They also ate the young fishes, several being observed inside them. Only once was one seen actually catching a fish, a young *Solea vulgaris*. Whilst catching it two long threads were protruded from somewhere between the tentacles and the fish caught by one of these. It is probable that these were long threads of stinging cells. They were, however, so long that they had the appearance of the fine tentacles in Phialidium. *Cottus bubalis* and *Blennius pholis* were also eaten by *Arachnactis*.

The above notes on the feeding of plankton organisms in a plunger jar are only a beginning. From them we see that the following Cœlenterates catch and eat young fishes :—

Aurelia aurita (including the ephyræ).

Chrysaora isosceles (ephyra).

Phialidium hemisphericum.

Turris pileata.

Arachnactis Bournei.

And that *Sarsia tubulosa* lives almost entirely on copepods and other small Crustacea.

FOOD RECORDS.

In the following notes each group is taken and all the records of food given. Some of these are only single and most are entirely inadequate at present, but they are offered as a preliminary and it is hoped to continue the work in more detail.

A short summary for each month throughout the year 1921 follows :—

January.

Very young herrings were abundant in the plankton. These were eaten by *Phialidium*, which also ate sprat eggs. *Coscinodiscus excentricus*

was the commonest diatom, probably the species of *Coscinodiscus* chiefly eaten by *Calanus*, *Pseudocalanus* and *Acartia*.

February.

Coscinodiscus, chiefly *C. excentricus*, is again the commonest diatom in the plankton, and is eaten by terebellid, spionid and polynoid larvæ, *Pseudocalanus* and *Temora*, Cirripede nauplius, *Galathea* larva and zoëa of *Carcinus mœnas*. *Phialidium* took *Sagitta*, whilst *Sagitta* ate *Pseudocalanus*.

March.

Phæocystis appeared abundantly, and was eaten by *Temora* and also *Evadne*, which had just begun. *Aurelia* ephyra was eating *Gobius*. Amongst the *Phæocystis* were many small creatures feeding on it.

April.

Phæocystis predominates with many *Amphidinium* and other unicellular organisms feeding on it; also *Calanus* eating it largely, but also eating *Coscinodiscus* and *Thalassiosira*. The green cells in *Evadne* and in the Cirripede nauplii and also in many of the copepods are probably *Phæocystis*. *Magelona* larva begins and eats larval bivalves, other larval annelids eating *Coscinodiscus*, *Thalassiosira* and *Skeletonema*, all common in the plankton. Peridinians plentiful, *Actinotrocha* feeding on them.

May.

By the middle of the month *Phæocystis* is nearly all gone. *Actinotrocha* continues feeding on Peridinians. *Centropages typicus* takes a variety of diatoms with a few copepods. *Phialidium* abundant, eating fish, and many *Sagitta*. Obelia very common, eaten by *Phialidium*, and *Obelia* itself eating *Sagitta* and *Calanus*.

June.

Obelia and *Phialidium* still eating fish as well as Crustacea. *Turris* abundant and chiefly eating crab zoëa. *Cyphonantes* very common and eating a variety of small diatoms, but not *Rhizosolenia*, which is the commonest diatom this month. *Actinotrocha* still eating Peridinians. Many larval decapods eating larval mollusks, larval echinoderms, diatoms and coccospheres.

July.

Much *Rhizosolenia*, chiefly *R. alata* and *R. Shrubsolei*, these are eaten by *Calanus* in large quantities, but a few have eaten other diatoms, principally

Coscinodiscus, and bits of copepods. *Cittarocyclis* eating many peridinians, especially *Protoceratium* and *Dinophysis*, which are very abundant. *Porcellana* larva eating a variety of diatoms, including *Rhizosolenia*, with coccospheres, and is itself eaten by *Pleurobrachia*. *Obelia* and *Phialidium* eating fish and Crustacea. *Oikopleura*, which is common, eaten by *Sarsia*, *Stomotoca* and *Phialidium*.

August.

Many *Cittarocyclis* eating chiefly *Prorocentrum*. Many *Sagitta* chiefly, eaten by *Phialidium*, and themselves eating *Calanus*. *Calanus* eating diatoms (Skeletonema), flagellates and bits of copepods. Decapod larvæ eating diatoms (*Calocaris* larva containing *Rhizosolenia setigera*). Echinodum larvæ eating small flagellates, peridinians and diatoms (*Thalassicthrix*), *Magelona* larva still eating larval bivalves. *Pleurobrachia* eating many *Calanus*.

September.

No records for September.

October.

Very rich plankton. *Rhizosolenia Shrubsolei* and *R. alata* still very common, also *Biddulphia sinensis*. *Rhizosolenia* eaten by larval terebellids, *Calanus* and *Anomalocera*, *Biddulphia* by terebellid larvæ. Larval bivalves very common, eaten by *Magelona* larva. *Calanus* eating much *Thalassiosira* and *Coscinodiscus*. Larval decapods eating many small diatoms, chiefly *Coscinodiscus*, *Navicula* and *Paralia*, also coccospheres. Many *Sagitta* eaten by *Phialidium*, *Obelia*, *Cosmetira* and *Pleurobrachia*.

November.

Rhizosolenia Shrubsolei and *R. alata* still common, eaten by terebellid larva, *Paracalanus*, *Ebalia* zoëa and *Galathea* larva. Other Crustacea, including *Calanus*, eating chiefly *Coscinodiscus* and *Thalassiosira*. *Sagitta* common, eating copepods, and eaten by *Obelia*, *Phialidium* and *Stomotoca*. *Biddulphia sinensis* eaten by *Calanus*.

December.

Much *Sagitta* eating *Sagitta* and eaten by *Obelia* and *Phialidium*. Copepods and larval decapods eating chiefly *Coscinodiscus*, *Paralia* and *Thalassiosira*. *Actinotrocha* still present, but eating more diatoms, as there are fewer peridinians.

PROTOZOA.

Peridiniales.

Amphidinium sp.

Whenever *Phæocystis* was present in abundance, a small *Amphidinium*, apparently closely related to *A. crassum* Lohmann, to be worked out later, was feeding on it and was nearly always full of remains of the spores. Other unarmoured peridinians also fed on it (*Gymnodinium triangularis*, Lebour, 1917; *G. rhomboides* Schütt), and it seems to collect many animals round it. As has been frequently pointed out, the unarmoured peridinians ingest solid food to a large extent, and various unicellular organisms have been recognised inside many species. In *Polykrikos*, which is armed with large nematocysts, various other peridinians have been found, notably a pink peridinian, probably *Peridiniopsis asymmetrica*, and Kofoid (1921), who figures many other Peridinians with food, states that many planktonic organisms have been recognised inside it, both Metazoa and Protozoa. A diatom (*Thalassiosira*) was found once (Lebour, 1917) in *Gymnodinium rhomboides*, but usually the food recognised in these unarmoured peridinians are peridinians also, except when *Phæocystis* is eaten, and probably many of the greenish brown masses to be seen in these are remains of flagellates.

It is well known also that Noctiluca (now regarded as a peridinian) devours many micro-organisms, such as diatoms, flagellates and Peridinians, and Stein (1883) has figured some of these (Plate XXV). The following organisms were found in *Noctiluca* from Wembury Bay, June, 1898: Halosphæra viridis in many, Paralia sulcata in 3, Pleurosigma in 2, Pleurosigma, Paralia sulcata, Prorocentrum micans in 1.

The only other unicellular organisms examined for food were the tintinnids, chiefly Cittarocyclis serrata. It was interesting to find that in these the food was almost entirely peridinians.

Cittarocyclis serrata (Möbius).

Inner Grounds, 1921, *July*. Prorocentrum micans in 1, Dinophysis acuminata, Peridinium pellucidum in 2, Protoceratium reticulatum (1–7) in 8, Protoceratium, Dinophysis reticulatum, Exuviella perforata in 1, Dinophysis acuminata, Protoceratium, Prorocentrum micans in 1, Dinophysis acuminata in 1, Dinophysis acuminata, Peridinium indet. in 1, remains of Peridinians indet. in 5, Skeletonema costatum in 1, Goniaulax sp., small triangular bodies indet. in 1. *August*, Prorocentrum micans, Peridinium sp., small Peridinians indet. in 1, Dinophysis sp. in 3, Tintinnoposis beroidea, Prorocentrum micans in 1, Prorocentrum micans in 2, Prorocentrum micans, Goniaulax spinifera in 1.

Outer Grounds, 1921, *July*. Prorocentrum micans in 2, Peridinium sp., Peridinian remains in 1, Peridinian remains in 1, Dinophysis sp. in 1, Prorocentrum micans, Peridinium pallidum, Dinophysis sp., triangular bodies indet. in 1.

Thus out of 36, 35 contained Peridinians, one also a Tintinnopsis and one a diatom.

Remains of Peridinians also occurred in one specimen of Tintinnopsis beroidea and one of Tintinnopsis campanula (July, 1921).

As the tintinnids occur in large numbers only in the summer and also the Peridinians, their abundance would be easily explainable by the amount of Peridinians present.

CŒLENTERATA.

Hybocodon prolifer L. Ag.

Outer Grounds, 1921, *April*. Calanus finmarchicus in 1. In 1922 nearly all were eating copepods.

Steenstrupia rubra Forbes.

Inner Grounds, 1921, *May*. Fish eggs in 2, Temora longicornis in 1, Porcellana larva in 1, Corycæus anglicus in 1, Gebia larva in 1.

The presence of fish eggs in 2 out of 6 is interesting.

Sarsia prolifera Forbes.

Inner Grounds, 1920, *June*. Labrus sp. (bergylta type) juv. in 1. *July*, Oikopleura dioica in 1, Centropages typicus in 1.

Outer Grounds, 1920, *July*. Large annelid indet. in 1. Copepod egg in 1.

The Labrus in one of these tiny medusæ was very large for it and much more than filled the manubrium.

Sarsia gemmifera Forbes.

Outer Grounds, 1921, *July*. Calanus finmarchicus in 1.

Sarsia tubulosa (Sars).

As is shown above this medusa in the plunger jar fed entirely on copepods (page 656).

Stomotoca dinema L. Ag.

Inner Grounds, 1920, 1921, *June*. Cosmetira pilosella in 1. *July*, Oikopleura dioica in 1. *October*, Calanus finmarchicus in 1. *November*, Phialidium sp. in 1, Sagitta bipunctata in 2.

Outer Grounds, 1921, *October*. Calanus finmarchicus in 2. *December*, Sagitta bipunctata in 1.

TURRIS PILEATA (Forskål).

Inner Grounds, 1920, 1921, *June*. Carcinus mænas zoëa in 2, Carcinus mænas zoëa and Cosmetira pilosella in 1, Carcinus mænas zoëa and Porcellana larva in 1, Crab zoëa indet. in 3, Crab zoëa indet. and Centropages typicus in 1, Acartia Clausi in 2, Galathea larva in 1, Cottus bubalis in 1, Phialidium sp. in 2. *July*, Crab zoëa indet. in 3, Phialidium sp. and Hybocodon prolifer in 1, Cosmetira pilosella in 1. *August*, Pseudocalanus elongatus in 1. *September*, Crab zoëa indet. in 2, Calanus finmarchicus in 6, Pseudocalanus elongatus in 1. *October*, Temora longicornis and Calanus finmarchicus in 4, Calanus finmarchicus in 1.

Outer Grounds, 1920, 1921, *June*. Gebia larva in 1. *July*, Calanus finmarchicus in 1. *August*, Calanus finmarchicus in 3.

Those examined, which came chiefly from the Inner Grounds, 39 in all, had principally fed on Crustacea, in one case a young fish was present and 5 contained medusæ. Crab zoëa were the commonest food.

As is shown above (page 655), *Turris* in the plunger jar caught and ate a cephalopod and young fishes.

RATHKEA OCTOPUNCTATA Hæckel.

Inner Grounds, 1921, *February*. Oikopleura in 1. *April*, Crab zoëa indet. in 2, Pseudocalanus elongatus in 2, Poecilochætus larva in 1.

Outer Grounds, 1921, *April*. Young Pilchard in 2.

LAODICEA CRUCIATA L. Ag.

Inner Grounds, 1920, *August*. Calanus finmarchicus in many.

A large number were in the sample and all had eaten Calanus.

OBELIA sp. (including *geniculata* Allman and *nigra* Browne).

Inner Grounds, 1920, 1921, *March*. Oikopleura dioica in 1. *April* Oikopleura dioica in 4, Acartia Clausi in 1. *May*, Sagitta bipunctata in 2, Calanus finmarchicus in 1. *June*, Fish egg in 1, Crab zoëa in 1, Evadne Nordmanni in 1, Pseudocalanus elongatus in 1, Steenstrupia rubra in 1. *July*, Calanus eggs in 1, Calanus finmarchicus in 1, young fish indet. in 1. *August*, Sagitta bipunctata in 6, Calanus finmarchicus in 2, Podon intermedius in 1, Tomopteris heligolandicus in 1, Temora longicornis in many. *September*, Sagitta bipunctata in 5, Oikopleura dioica in 2, Calanus finmarchicus in 1. *October*, Sagitta bipunctata in 6, Obelia medusa in 1, Pseudocalanus elongatus in 1. *November*, Sagitta bipunctata in several, Paracalanus parvus in 1.

Outer Grounds, 1920–1921, *March*. Oikopleura dioica in 1. *April*, young pilchards in 3. *May*, Sagitta bipunctata in 2. *September*, Sagitta

bipunctata in 7, Calanus nauplii in 1. *October*, Sagitta bipunctata in 1. *November*, Sagitta bipunctata in a few. *December*, Sagitta bipunctata in several. Sagitta is certainly the most frequent food of Obelia. In one large sample from Station E 1 (14 miles S. of Breakwater) in November, 1921, every specimen had one or two Sagitta inside it, and besides these out of over 60 examined over two-thirds contained Sagitta. One sample in August, 1920, from the region of the Knap buoy had all eaten Temora longicornis. A few odd ones had eaten Calanus, Pseudocalanus and Acartia at various times, and once a Crab zoëa, Evadne and Podon. Four contained fish and one a fish egg. The fact that 3 contained young pilchards proclaims them an enemy of the little fish.

PHIALIDIUM sp. (chiefly *P. hemisphericum* Gron., but probably including *P. buskianum* Browne).

Inner Grounds, 1920–1921, *January*. Young Herring in 5, Sprat egg in 1, Sagitta bipunctata in 2. *February*, Onos egg in 1, Sagitta bipunctata in 1. *April*, Oikopleura dioica in 1. *May*, young Whiting in 1, fish egg in 1, Crab zoëa in 4, Gebia larva in 1, Porcellana larva in 1, Sagitta bipunctata in many, Obelia medusæ in many. *June*, Cottus bubalis juv. in 3, Labrus juv. (bergylta type) in 1, fish eggs in 5. Temora longicornis in 1, Calanus eggs in 1, zoëa of Carcinus mænas in 1, Crab zoëa indet. in 2, Acartia Clausi in 2, Pandalus larva in 2, Gebia larva in 1, Hippolyte larva in 1, Sagitta bipunctata in 4. *July*, Labrus juv. (bergylta type) in 1, Blennius ocellaris juv. in 1, young Whiting in 1, young fish indet. in 1, fish eggs indet. in 2, Sagitta bipunctata in 6, Sarsia prolifera in 2, Obelia medusa in 1, Gebia larva in 3, Pandalus larva in 1, Polychast larva in 2. *August*, Sagitta bipunctata in many, Calanus finmarchicus in many, Cosmetira pilosella in 1, fish remains in 1, Sagitta bipunctata and Onos egg in 1. *September*, Acartia Clausi in 4, Calanus finmarchicus in 3, Temora longicornis in 1, Sagitta bipunctata in 1. *October*, Acartia Clausi in 1. *November*, larval spionid in 1, Sagitta bipunctata in many, Obelia medusa in 2, Phialidium sp. in 1, Crab zoëa in 1, Oikopleura dioica in 5, Paracalanus parvus in 1. *December*, Pseudocalanus elongatus in 2, Pseudocalanus elongatus and Sagitta bipunctata in 1, Sagitta bipunctata in many.

Outer Grounds, 1920–1921, *April*. Gobius juv. in 1, Callionymus juv. in 1, young Pilchard in 2, Pseudocalanus elongatus in 1. *May*, Sagitta bipunctata in 7. *June*, Calanus finmarchicus in 1. *July*, Sagitta bipunctata in 6, Calanus eggs (16) in 1, Callionymus eggs in 2, Crab zoëa in 1, Oikopleura dioica in 3, Muggiæa atlantica in 1. *August*, Sagitta bipunctata in several, Calanus finmarchicus in 2. *September*, Sagitta bipunctata in 3, Gobius juv. in 1, Temora longicornis in 1, Oikopleura dioica in 1. *October*, Sagitta bipunctata in many. *November*, Sagitta bipunctata in

many, Crab zoëa in 1. *December*, Crangon larva in 1, Phialidium sp. in several, Sagitta bipunctata in many.

It will be seen from the records given above that Sagitta is certainly the commonest food of Phialidium, in several samples examined containing many specimens almost every one was eating Sagitta. On two occasions they were all eating Obelia medusæ, and once they were all eating Calanus. At other times, out of over 150 examined, over 60 were eating Sagitta. Phialidium, however, also certainly eats young fishes which have been noted from 39 specimens, young pilchards, herrings and sprat eggs being among those eaten. Various Crustacea were in over 30, Medusæ other than Obelia were in 2, Muggiæa in 1, Oikopleura in 10 and Annelids in 6.

In the late autumn of 1921 Sagitta was very abundant, and at that time served specially as food for Phialidium from both Inner and Outer Grounds. The food taken inside and outside differed hardly at all.

From the records in the plunger jar (page 653) it is seen that it is quite natural for Phialidium to catch and eat the young fishes.

Cosmetira pilosella Hartlaub.

Inner Grounds, 1921, *June*. Crab zoëæ in 4, Caligus rapax in 1.

Outer Grounds, 1920–1921, *July*. Lepadogaster gouani juv. in 1, Autolytus sp. in 1, Sagitta bipunctata in 1. *October*, Sagitta bipunctata in 1.

Saphenia gracilis Forbes & Goodsir.

Inner Grounds, 1921, *July*. Gebia larva in 1.

Aglantha digitale Hæckel.

Outer Grounds, 1920, *July*. Calanus finmarchicus in 2.

Aurelia ephyra.

Inner Grounds, 1921, *February*. Larval gastropod in 1. *March*, Gobius juv. in 3, Crab zoëa in 1.

From the plunger jar records (page 650) it is seen that the ephyræ eat many fishes.

Pleurobrachia pileus (Fab.).

Inner Grounds, 1920–1921, *July*. Calanus finmarchicus in 1, Crab zoëa in 1. *October*, Calanus finmarchicus in 2, Calanus finmarchicus and Sagitta bipunctata in 1, Gebia larva in 1.

Outer Grounds, 1920, 1921, *July*. Calanus finmarchicus in many, Calanus finmarchicus with a few Centropages typicus in a few, Porcellana larva in 1, Crab zoëa in 1, Labrus juv. in 1. *August*, Calanus finmarchicus in several, Centropages typicus in 1. *October*, Sagitta bipunctata in 1.

In other years where records were not kept Pleurobrachia was often seen to be eating young fishes, although only one is recorded here. Calanus seems to be the commonest food, and large masses of Pleurobrachia and Calanus often occur together, especially in the outside waters.

Beroë cucumis Fab.

Inner Grounds, 1920–1921, *July*. Pleurobrachia pileus (many) in 2. *October*, Calanus finmarchicus in 1.

Outer Grounds, 1920, *September*. Pseudocalanus elongatus in 1, Pseudocalanus and Podon intermedius in 1, Pseudocalanus elongatus and Centropages typicus in 1.

One of those in July was packed tight with Pleurobrachia.

From these records of the food of the Cœlenterates in general we find that many of them eat young fishes, the worst offender being *Phialidium*. We also find that *Sagitta* is a favourite food both of *Phialidium* and *Obelia*, and is also taken by several other medusæ. These, however, also eat a good many Crustacea, and *Turris pileata* takes more Crustacea than anything else, although it can eat fishes and Cephalopods. *Calanus* is by far the most commonly eaten, other copepods, decapod larvæ and *Podon* and *Evadne* much more rarely and a few annelids. Occasionally other medusæ are taken. *Pleurobrachia* eats more *Calanus* than anything else, but also eats decapod larvæ, other copepods, *Sagitta* and very young fishes. *Beroë* eats Crustacea and *Pleurobrachia*.

CHÆTOGNATHA.

Sagitta bipunctata (Quoy & Gaimard).

Inner Grounds, 1920–1921, *February*. Pseudocalanus elongatus in 2. *September*, Temora longicornis in 1, Sagitta bipunctata in 1. *October*, Sagitta bipunctata in 9, Acartia Clausi in 3, Temora longicornis in 2, Calanus finmarchicus and Pseudocalanus elongatus in 1, copepod remains in 1. *November*, Pseudocalanus elongatus in 1, copepod remains in 4. *December*, Pseudocalanus elongatus in 2.

Outer Grounds, 1920–1921, *February*. Centropages typicus in 1. *August*, Calanus finmarchicus in 1. *September*, Sagitta bipunctata in 1, Calanus finmarchicus in 5, Centropages typicus in 1. *October*, Corycæus anglicus in many. *November*, Sagitta bipunctata in 3. *December*, Sagitta bipunctata in 1, Corycæus anglicus in 3.

Although in the above records copepods form the chief food of Sagitta, in other years they have very frequently been seen eating one another and also feeding on newly hatched herrings.*

* In January, 1922, large hauls of Sagitta came in from outside, nearly all of which had eaten other Sagitta, a few having eaten very young herrings.

PHORONIDEA.

Actinotrocha.

Inner Grounds, 1920–1921, *May*. Many small peridinians, Peridinium brevipes, Tintinnus subulatus, Tintinnopsis beroidea, coccoliths in 1. *June*, many Peridinians in 1. *July*, copepod egg, Peridinium sp. in 1, Skeletonema costatum, peridinian indet. in 1, Skeletonema costatum, Prorocentrum micans, Peridinium ovatum, Goniaulax sp. in 1. *August*, many Peridinians indet, in 3. *October*, several small flagellates in 1. *November*, many peridinians and disc-shaped diatoms, including Peridinium ovatum and Coscinodiscus in 1, Peridinium leonis, Tintinnopsis beroidea, Coscinodiscus Grani in 1.

Outer Grounds, 1920–1921, *April*. Peridinians indet. in 1, Peridinians and Coscinodiscus sp. in 1, Coscinodiscus excentricus, Peridinians indet, and Tintinnopsis sp. in 1. *October*, many small Peridinians in 1, Peridinium depressum and other Peridinians indet. in 1, Peridinium depressum, Peridiniopsis asymmetrica, other small Peridinians indet. in 2. Coscinodiscus radiatus, C. excentricus, Thalassiothrix nitzschioides, Pleurosigma sp., Navicula sp., Cerataulina Bergoni, Peridinium conicum, P. brevipes, many small Peridinians indet. in 1, Calanus egg, Peridinians and diatoms indet. in 1, Coscinodiscus Grani, C. excentricus, Thalassiothrix gravida, Peridinians indet. in 1, Coscinodiscus Granii, Peridinium depressum, Peridiniopsis asymmetrica, other small Peridinians indet. in 1. *November*, Larval bivalve, many Coscinodiscus excentricus, Peridinium conicum, many Peridinians indet. in 1, Coscinodiscus Grani, Peridinium ovatum, several small Peridinians indet. in 1, Dictyocha fibula, Navicula sp., Echinospira, Peridinium conicum, many small Peridinians indet. in 1. *December*, Coscinodiscus sp., Thalassiosira sp., Navicula sp., Peridinium conicum, Peridinium indet., Rhizosolenia Shrubsolei stuck in throat in 1, Coscinodiscus excentricus, C. radiatus, Thalassiosira sp., Peridinium depressum, P. indet. in 1.

It is thus seen that Actinotrocha is essentially a Peridinian eater, although diatoms, tintinnids and other unicellular organisms, besides an occasionally larval mollusk or copepod egg, are also taken, all these being swept into the mouth by the currents set up by the cilia. Diatoms and Peridinians of a rounded shape are most frequently eaten, these probably being most easily swept into the mouth. A very great many organisms can be inside at the same time, the alimentary canal usually being full and chiefly with Peridinians. No difference is apparent in those from Inner and Outer Grounds.

POLYZOA.

Cyphonautes.

The various species were not distinguished.

Inner Grounds, 1921, *May*. Coscinodiscus excentricus, Peridinium sp. in 1. *June*, Thalassiothrix Nitzschioides, Biddulphia sinensis, Eucampia zoodiacus, Pleurosigma sp., Goniaulax spinifera in 1, Navicula sp., Thalassiosira Nordenskiöldii, Goniaulax spinifera, Tintinnopsis beroidea in 1, Nitzschia seriata, Thalassiosira Nordenskiöldii in 1, Tintinnopsis beroidea, Navicula sp., Nitzschia seriata, Peridinium sp. in 1, Nitzschia seriata, Peridinium sp. in 1, Licmophora sp., Goniaulax spinifera in 1.

Outer Grounds, 1921, *April*. Coscinodiscus sp. and green cells in 1, Tintinnopsis sp. and green cells in 1. *December*, Coscinodiscus sp., Navicula sp., coccolith in 1.

Although there are very few records these show that the various Cyphonautes are regular diatom feeders, with occasional peridinians and tintinnids.

ANNELIDA.

Tomopteris heligolandicus Greef.

Inner Grounds, 1921, *June*. Fragments of diatoms in 1.

Outer Grounds, 1921, *October*. Indistinguishable cells in brownish débris in 1, green cells (flagellates ?) and brown débris in 1.

These three were the only specimens seen with anything inside, although many empty specimens occurred. The food is apparently minute and mixed with a clear slime.

Larva of Pœcilochætus sp.

Outer Grounds, 1921, *April*. Slime with bits of diatoms and a gastrula larva in 1, slime with small green cells in 1, slime with indistinguishable débris in 1. *October*, brownish débris indistinguishable in 1.

Here again these were the only specimens with anything inside. Many were quite empty.

Larva of Magelona papillicornis Fr. Müller.

Inner Grounds, 1920–1921, *April*. Larval bivalve in 1. *August*, larval bivalve in many (at least 30%, the rest empty). *September*, larval bivalve in 14. *October*, larval bivalve in 3.

Outer Grounds, 1920–1921, *September*. Larval bivalve in 9. *October*, larval bivalve in many. *November*, larval bivalve in 2.

It is striking that the only food ever seen in the larva of Magelona is larval bivalves, and a very large number have been examined. It is evident that this is the natural food, which it probably catches with its two long tentacles whilst swimming about. The tentacles are not ciliated, and the nature of the food may explain this, as the larval bivalves seem to be too big to be drawn in by ciliary currents. It is more likely that the tentacles encircle the mollusks and draw them into the mouth, as is the case with the Polydora, which were seen to devour young gobies (Lebour, 1920).

Larvæ of TEREBELLA sp.

Two kinds of terebellid larvæ are common in the tow-nets, one with a soft gelatinous tube much wider than the worm, the other with a pipe-like stiff hyaline case, wider at the top than the bottom, open at both ends and sometimes plastered with small organisms, diatoms, coccoliths, or with sponge spicules. Most of the records are from those with the hyaline tubes.

Hyaline Tubes.

Inner Grounds, 1917 and 1921, 1921, *February*. Coscinodiscus excentricus in 1. *March* (1917), Thalassiosira sp. (many) in 2, Thalassiosira sp. (many), Navicula sp. in 1. 1921 *April*, Coscinodiscus sp. in 2, Lauderia borealis in 1.

Outer Grounds, 1921, *April*. Coscinodiscus sp. and green remains in 3. *October*, bits of Biddulphia sinensis, coccoliths in 1, bits of diatoms and coccoliths in 4, bits of diatoms, encysted Peridinians in 1, coccoliths, bits of Pleurosigma sp. and Rhizosolenia Shrubsolei in 1. *November*, Paralia sulcata, Rhizosolenia Shrubsolei, coccoliths in 1.

Gelatinous Tube.

Inner Grounds, 1921, *February*. Navicula sp., Nitzschia closterium, coccoliths in 1. *December*, coccoliths and Navicula sp. in 1.

The larval terebellids are evidently predominantly diatom feeders, coccospheres and peridinians also being eaten.

SPIONID larva.

Two specimens only examined, from the Inner Grounds, one in April, 1917, contained Coscinodiscus and Thalassiosira spp., the other in February, 1921, contained Coscinodiscus excentricus.

POLYNOID larva.

Inner Grounds, 1917 and 1921, *February*. Coscinodiscus excentricus in 1. *April*, Prorocentrum micans, Thalassiosira gravida (many), Skeletonema costatum, coccolith in 1, Coscinodiscus Granii, Thalassiosira gravida in 1, Peridinium pallidum in 1.

NEMERTEA.

Pilidium larva.

Most of these were empty, one from Outer Grounds, *October*, contained small peridinians and one large one indet.

CRUSTACEA.

Evadne Nordmanni Lovén.

Inner Grounds, 1921, *April*. Green cells, probably Phæocystis, in 1.

Outer Grounds, 1921, *March*. Phæocystis spores in 1.

Podon intermedius Lillj.

Soft brown remains with no apparent structure in several from Inner Grounds, *August*, 1921.

Cirripede nauplius.

Inner Grounds, 1921, *January*. Green cells, probably flagellates, in several. *February*, Coscinodiscus sp. in 1. *April*, green cells, probably Phæocystis, in 1.

Calanus finmarchicus (Gunn.).

Inner Grounds, 1920–1921, *January*. Green remains containing pieces of diatoms in 4. *February*, green cells in 1. *June*, remains of Phæocystis in 1. *August*, bits of diatoms, Skeletonema in 1. *November*, Thalassiosira sp. in 1, coccoliths, bits of diatoms in 1.

Outer Grounds, 1921, *April*. Many Thalassiosira sp. in 3, many Thalassiosira and Coscinodiscus sp. in 1, Phæocystis in many, Phæocystis and Peridinium pellucidum in 1, Phæocystis and Thalassiosira in 1, Phæocystis, Thalassiosira sp., bits of Chætoceres and other diatoms in 1. *July*, remains of Rhizosolenia (chiefly R. alata) in many, remains of Rhizosolenia sp., coccoliths and black débris in 1, remains of Rhizosolenia alata, Coscinodiscus radiatus, bits of copepods, green cells in 1, remains of Rhizosolenia alata, bits of copepods, bits of green alga, green cells in 2, remains of Rhizosolenia sp., bits of copepods, green cells in 2, green cells and bits of copepods in 1. *August*, bits of diatoms, flagellates, bits of copepods in 1, bits of copepods, flagellates, Pontosphæra Huxleyi in 1, remains of diatoms in 1, several coccospheres, flagellates, bits of copepods in 1, coccoliths, bits of diatoms, bits of copepods in 1. *October*, many Thalassiosira sp. in many. Many Thalassiosira sp., Coscinodiscus radiatus, bits of Rhizosolenia sp. in 2, many Thalassiosira sp., Coscinodiscus radiatus, Rhizosolenia Shrubsolei, coccolith in 1, many Thalas-

siosira sp., Coscinodiscus radiatus, Dytilium Brightwelli, bits of copepods in 1. *November*, many Paralia sulcata and Thalassiosira sp. in 2, Thalassiosira sp. in 1, Paralia sulcata, Thalassiosira sp., Biddulphia sinensis in 1. *December*, remains of Paracalanus parvin, Paralia sulcata, Coscinodiscus sp. in 1, many Thalassiosira sp. and Coscinodiscus sp. in 1.

Thus in the spring when Phæocystis abounds it serves as food for Calanus, although diatoms are also taken; in two samples nearly all the many Calanus were feeding on green cells, one lot certainly Calanus, the other almost certainly so, also others examined singly contained Phæcocystis. Diatoms form the food of Calanus to a very great extent; in one sample many were feeding on Rhizosolenia alata and Shrubsolei at the time when these were very abundant. In the autumn Thalassiosira was the commonest food. Sometimes bits of copepods were found inside mixed with the other débris. The food from inside and outside was not essentially different. It has been described by Esterley (1916) how copepods eat the minute food, rolling it up in a ball, and they certainly crush the hard shells, such as the diatom shells, very few of which come through whole, except very small valves such as Thalassiosira. Diatoms may be said to be the chief food of Calanus, flagellates probably coming very near; but as they are much more quickly digested it is difficult to identify them and estimate their numbers. In the plunger jar organic débris from the bottom seemed to be the main food of *Calanus*.

Pseudocalanus elongatus Boeck.

Inner Grounds, 1921, *January*. Green remains and bits of diatoms in 4, Coscinodiscus sp. in 1, Coscinodiscus sp. and Paralia sulcata in 4, green remains, Navicula sp., bits of diatoms in 1. *February*, remains of diatoms in 2, green remains and bits of diatoms in 4, Coscinodiscus sp. in 1, Navicula sp. in 1.

Outer Grounds, 1921, *November*. Paralia sulcata, Thalassiosira sp., coccoliths in 1, many Paralia sulcata in 1, coccoliths, bits of diatoms in 1.

These few records show that Pseudocalanus is essentially a diatom feeder.

Paracalanus parvus (Claus).

Inner Grounds, 1921, *November*. Thalassiosira sp. in 4, Thalassiosira sp., Navicula sp. in 1, Thalassiosira sp. and coccoliths in 1, bits of Chætoceros in 1, bits of Chætoceros and diatoms indet. in 1, bits of Coscinodiscus sp. and Rhizosolenia Shrubsolei in 1, bits of diatoms indet. in 4, Thalassiosira sp. and Paralia sulcata in 1. *December*, Thalassiosira sp. in 1.

Paracalanus was only examined in the late autumn and Thalassiosira was its chief food. It seems to feed on much the same as Pseudocalanus.

ACARTIA CLAUSI Giesbrecht.

Inner Grounds, 1921, *January*. Green remains and bits of diatoms in 5. *February*, bits of diatoms in 1. *April*, green remains, probably Phæocystis, in many.

OITHONA SIMILIS Claus.

Inner Grounds, 1921, *January*. Green remains and bits of diatoms.

TEMORA LONGICORNIS (O. F. Müller).

Inner Grounds, 1921, *January*. Remains of Crustacea, probably copepods, in 1. *February*, green cells in 1, Navicula sp., Nitzschia sp., bits of Coscinodiscus excentricus in 1. *April*, green cells, Peridinium sp. in 2, bits of copepods in 2. *May*, remains of diatoms, Paralia sulcata in 1, bits of diatoms, Coscinodiscus sp., bits of diatoms, Navicula sp. in 2, green remains, bits of diatoms, coccoliths in 1.

Outer Grounds, 1921, *March*. Green cells, probably Phæocystis, in 1. *April*, green remains in 1.

Temora is rather a miscellaneous feeder, eating more copepods than Calanus, but also feeding on diatoms and flagellates.

CENTROPAGES TYPICUS Kröyer.

Inner Grounds, 1921, *February*. Thread-like green alga in 1, remains of copepod nauplius, bits of larval mollusk in 1, remains of copepods in 2, remains of copepods and green cells in 1, bits of mollusk shell in 1. *May*, brownish remains, indistinguishable in many, bits of copepods in 1, Paralia sulcata, other diatoms in 1, bits of diatoms, Prorocentrum micans, coccoliths in 1, bits of diatoms, Coscinodiscus radiatus, Tintinnus subulatus (3), coccoliths in 1, bits of diatoms in 1, Navicula sp., Thalassiothrix Nitzschioides, Ceratium tripos, Phæocystis spores in 1.

Outer Grounds, 1921, *March*. Green cells and Thalassiosira gravida in 1. *April*, green cells, probably Phæocystis, in 1, many Thalassiosira in 1, Peridinians indet., green cells in 1. *December*, bits of Coscinodiscus sp. and Paralia sulcata in 1, spores of alga, bits of diatoms in 1.

Again several copepods were eaten, besides flagellates and peridinians, but mostly diatoms.

CORYCÆUS ANGLICUS Lubbock.

Inner Grounds, 1921, *February*. Peridinium sp. (cf. depressum), green remains and bits of diatoms in 1.

Outer Grounds, 1921, *March*. Phæocystis in several. *October*, Navicula sp., small flagellate in 1, Navicula sp., coccoliths in 1, bits of larval mollusks (?), coccoliths in 1, coccoliths and remains of flagellates in 1. *November*, green flagellates in 1. *December*, Navicula sp. in 1.

These are too few records to be of much interest, but flagellates, including coccospheres, seem to be an important food.

Labidocera Wollastoni Lubbock.

Inner Grounds, 1921, *May*. Bits of copepods in 1.

Outer Grounds, 1921, *April*. Green remains. *July*, bits of copepods and diatoms.

Anomalocera Pattersoni Templeton.

Outer Grounds, 1921, *March*. Phæocystis in 2. *July*, Crustacea remains, flagellates (?) in 1, many green cells (flagellates ?) in 2, copepod remains and green cells in 1. *October*, many bits of Harpacticid copepods, probably Euterpina acutifrous, Rhizosolenia Shrubsolei in 1, remains of copepods in 2.

Euterpina acutifrous (Dana).

Outer Grounds, 1921, *November*. Green fluid in several (nothing solid). *December*, bits of copepods, green fluid in 1.

In looking at the food of these copepods, we find some that are certainly typically diatom feeders, such as Pseudocalanus, Paracalanus and Acartia, also Calanus, Centropages and Temora, although they also occasionally eat copepods. On the other hand, although only very few have been examined, Anomalocera and Labidocera seem to eat more copepods; these are probably typically Crustacean feeders, large masses of copepod remains having been found in most of those examined. Harpacticids are known to feed on dead organic matter. Flagellates form a large part of the food of many of the copepods, especially Phæocystis, when it is present in quantities every spring, and from the number of coccoliths found coccosphæres must be eaten largely. Peridinians also form part of the food.

It is striking that disc-shaped diatoms are much eaten by the copepods, Thalassiosira and Coscinodiscus specially. Masses of the siliceous skeletons of these come away from their devourers, either broken or whole valves. Thalassiosira usually comes through in whole valves massed together tightly. It is possible that these are more easily manipulated than long or spiny diatoms such as Biddulphia or Rhizosolenia, which are only occasionally found inside the copepods, although quite as abundant as the others, or more so, in the same hauls. Rhizosolenia was, however, in July, when very abundant, found to be in a large number of Calanus.

Zoëa of CARCINUS MÆNAS (Pennant).

One from the *Inner Grounds*, *February*, 1921, contained masses of broken Coscinodiscus and Skeletonema.

Zoëa of EBALIA sp.

Outer Grounds, 1921, *November*. Crushed diatoms, chiefly Coscinodiscus, in 1, Paralia sulcata, Rhizosoleni Shrubsolei in 1.

CRAB ZOËÆ indet.

Inner Grounds, 1920–1921, *February*. Green cells and bits of diatoms in 1, green remains in 1. *April*, bits of Crustacea in 1. *June*, Rhizosolenia hebetata f. semisperia, Phæocystis, burst egg (?) capsules in 1, Rhizosolenia hebetata f. semisperia in 1, Phæocystis in 1. *December*, many Coscinodiscus in 1.

Outer Grounds, 1921, *October*. Peridinium ovatum, bits of Coscinodiscus in 1.

In these few records diatoms are shown to be the chief food of the crab zoëæ, and more recent records in 1922 agree with this. Coscinodiscus is a great favourite.

CRAB MEGALOPA.

Inner Grounds, 1920, *June*. Chewed decapod larvæ.

PORCELLANA LARVA.

Inner Grounds, 1920–1921, *June*. Green filamentous alga in 3, green spores, probably Phæocystis, in 1, siliceous fragments, probably diatoms, in 1. *July*, coccoliths, bits of diatoms and Peridinians in 1, bits of diatoms and echinoderm larvæ in 1, bits of diatoms (small Naviculoid), bits of Peridinians in 1, bits of Foraminifera, Rhizosolenia and other diatoms in 1, coccoliths, bits of diatoms in 1, Paralia sulcata, bits of other diatoms, coccoliths in 1.

Rather miscellaneous feeders, although diatoms form a large part of the food.

GALATHEA LARVA.

Inner Grounds, 1921, *February*. Coscinodiscus excentricus, green cells in 1, green remains in 1. *March*, bits of larval mollusks in 1. *June*, Calcareous fragments in 1. *November*, masses of bits of Coscinodiscus and Rhizosolenia in 1.

Young GALATHEA.

Outer Grounds, 1921, *July*. Bits of mollusks, Crustacea and diatoms in 1, mud, bits of diatoms, coccoliths in 1.

Homarus vulgaris Milne-Edwards. Young Lobster.

Inner Grounds, 1921, *May*. Remains of larval decapods and copepods in 1. *July*, remains of larval decapods in 1.

Gebia larva.

Inner Grounds, 1921, *June*. Pleurosigma, Asterionella japonica, calcareous fragments, probably larval mollusks, in 6. *December*, many bits of Coscinodiscus in 1.

Pandalus larva (including Nika).

Inner Grounds, 1921, *June*. Calcareous fragments, probably mollusks, in 2, bits of mollusks (?), coccoliths, spines of larval echinoderms in 1.

Outer Grounds, 1921, *November*. Coccoliths, bits of mollusks, Coscinodiscus in 1, coccoliths, bits of mollusks, echinoderm larva spines in 1, Coscinodiscus radiatus, bits of diatoms indet. in 1. *December*, coccoliths in 1.

A Nika larva in the plunger jar ate the débris at the bottom, which consisted of diatoms and much dead organic matter.

Axius larva.

Inner Grounds, 1921, *June*. Bits of diatoms, Nitzschia delicatissima in 1. *July*, bits of diatoms, Navicula sp. in 1. *August*, coccoliths, bits of echinoderm larva spines, diatoms indet.

Eupagurus larva.

Inner Grounds, 1921, *June*. Coccoliths, sand grains, in 1.

Larva of Crangon vulgaris (L.).

Outer Grounds, 1921, *October*. Bits of mollusks, diatoms and coccoliths in 1. *November*, coccoliths, bits of copepods, sand in 1. *December*, Navicula sp., spines of Chætoceros in 1, Paralia, Coscinodiscus in 1, many Paralia in 1, coccoliths and débris indet. in 1, many Nitzschia in 1, Navicula, Pleurosigma in 1.

Chiefly a diatom feeder.

Larva of Ægeon trispinosus (Hailstone).

Inner Grounds, 1921, *July*. Bits of mollusks (?) diatoms, Licmophora sp., bits of Ceratium sp. in 1. *August*, calcareous and siliceous particles, bits of Echinoderm larva spines, diatoms in 1.

Calocaris larva.

Inner Grounds, 1921, *August*. Bits of diatoms in 1.

Outer Grounds, 1921, *August*. Bits of Peridinians and diatoms in 1, Exuviella perforata, coccoliths, bits of Rhizosolenia setigera in 1, Exuviella perforata, bits of diatoms, coccoliths in 1, bits of diatoms in 1, Paralia sulcata, bits of other diatoms in 1, coccoliths, bits of diatoms in 1.

Chiefly diatoms, Peridians and Coccospheres.

Euphausiid larva.

Outer Grounds, 1921, *October*. Bits of mollusks, diatoms and coccoliths in 1, bits of mollusks and coccoliths in 1, coccoliths, bits of Coscinodiscus, Navicula and Paralia in 1. *November*, fine débris with coccoliths in 1.

Nyctipanes Couchii T. Bell. juv.

Outer Grounds, 1921, *October*. Bits of green weed, bits of mollusks and diatoms in 1.

Hyperia sp.

Outer Grounds, 1921, *July*. Copepod remains in 1.

Caprella sp. juv.

Inner Grounds, 1921, *July*. Coccoliths, bits of diatoms and larval mollusks in 1.

These food records for the larval and young Crustacea are too fragmentary to be of much value, but from them we find that diatoms are largely eaten together with other unicellular plankton, and that larval mollusks and echinoderms are also taken. All are crushed up and the hard fragments are found among a greenish brown débris. Except in the case of the lobster and crab megalopa, it is very unusual to find any trace of Crustacea inside these larvæ.

MOLLUSCA.

Echinospira (larva of Lamellaria).

Inner Grounds, 1921, *February*. Coccolith, Navicula sp., bits of diatoms, green cells in 1. *December*, bits of diatoms in 1, bits of diatoms, Surrirella in 1, Navicula, coccoliths in 1.

Outer Grounds, 1921, *November*. Pleurosigma, Coscinodiscus, Thalassiosira in 1. *December*, many small Navicula in 1, Navicula, Pleurosigma, coccoliths in 1.

LARVAL GASTROPOD indet.

Outer Grounds, 1921, *November*. Remains of diatoms, Navicula in 1, Paralia sulcata, Coscinodiscus excentricus, Thalassiosira sp., Navicula sp. in 1, Thalassiosira sp. in 1, much Paralia sulcata in 1.

LIMACINA RETROVERSA auth. (?)

Outer Grounds, 1921, *October*. Paralia sulcata and other diatom remains in 1.

LARVAL BIVALVE indet.

Outer Grounds, 1921, *December*. Navicula, Coscinodiscus, Paralia in 1, Navicula, flagellates in 1, Thalassiosira in 1, coccoliths, Surrirella in 1, Navicula sp. in 1, Coscinodiscus in 1, Paralia in 1.

These few records show that all these pelagic mollusk larvæ and one Pteropod are pre-eminently diatom feeders. Larval mollusks seem to be eaten by various decapod larvæ.

ECHINODERMATA.

OPHIOPLUTEUS.

Inner Grounds, 1921, *August*. Thalassiothrix nitzschioides in 1, small green flagellates in 3, small peridinians indet. in 1.

Outer Grounds, 1921, *July*. Skeletonema costatum in 1.

BIPINNARIA.

Inner Grounds, 1921, *August*. Chætoceros curvisetus in 1.

ECHINOPLUTEUS of ECHINUS MILIARIS L.

Outer Grounds, 1921, *October*. Coccoliths, bits of diatoms, Thalassiosira, Navicula sp. in 1.

By far the greater portion of the echinoderm larvæ examined were empty, and it was very difficult to distinguish food inside them. The few records show, as is already known, that they are diatom feeders, with small flagellates and Peridinians. Echinoderm larvæ are themselves eaten by several of the larval Crustacea.

ENTEROPNEUSTA.

TORNARIA LARVA.

Nearly all the Tornaria larvæ examined were empty, but two contained a faint slime with diatoms.

Outer Grounds, 1921, *October*. Thalassiosira Nordenskiöldii, Navicula (very small) in 1. *November*, Rhizosolenia Stolterfothii in 1.

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