The Food of Young Clupeoids.

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With One Figure in the Text.

WHILST investigating the food of young fishes in general (Lebour, 1918–1919–1920) some thousands of young Clupeoids were examined, with the result that by far the larger proportion of post-larvæ were found to be empty. Here and there, however, food was present, and by bringing these records of 1917 to 1919 together, with some from 1920 and 1921, we have a good idea of the food of our three common Clupeoids—Herring, Sprat and Pilchard—in their young stages.

A probable reason for this apparent absence of food in the transparent stages is that the food must be very quickly digested on account of its being so conspicuous; thus it is probably taken only at long intervals and rapidly got rid of. It would follow that under these circumstances we should only occasionally catch the fish when food was inside it.

The observations on the food of the young Herring are perhaps the most interesting of the three on account of the fact that it eats solid food some time before the yolk sac is absorbed, the mouth being open when the fish is hatched, whereas the Sprat and Pilchard, being much less advanced, are only able to feed on outside food much nearer the time when the yolk sac disappears. Unfortunately we have no records of Pilchard food in the very young stages (under 12 mm.), green food remains being found in those of the Sprat before the yolk sac has completely disappeared.

Later transparent stages show that the food of all three species is mainly composed of copepods or copepod eggs, the latter apparently being a favourite food of the Pilchard. In the small, fully metamorphosed forms the food seems to be different in each species, even if they are caught together. Examination of these shows that the small Pilchards from the estuaries seem to be feeding nearer the bottom than the Sprat and the Herring caught with them. The Herring, which are larger than the Sprat and the Pilchard, eating larger food which sometimes consists of fish, presumably other Clupeoids.

The few records of the post-larval Pilchard food are interesting on

account of the small amount of information hitherto recorded on this subject and the very large proportion of empty fishes.

CLUPEA HARENGUS L. Herring.

Newly hatched Herring are commonly caught in the tow-nets in all parts of the Sound in January and February, usually disappearing in March. Young stages up to about 18 mm. occur also, but only rarely in later spring, summer and autumn, the usual time for them being from February to March.

Of these young Herring, those from 7 to 8 mm. long, nearly always possessed a yolk sac, from 8 to 9 mm. the yolk sac was usually still present, and up to 10 mm. it often persisted. Even at 12 mm. remnants of the yolk sac could sometimes still be recognised.

In the following table the food of 140 specimens, from 7 to 12 mm. long and still retaining at least part of the yolk sac, is given. Over a thousand caught at the same times were empty, but the food present gives a good idea of what is eaten :—

No. of Specimens.	Length in mm.	Date. 1917	Locality.	Food.
2	8·5	Feb.	West Channel *	Larval gastropod.
2	8·5	1		Green food remains.
2	9			,, ,, ,,
1	9			3 larval gastropods.
2	9·5			Larval gastropod.
1	9·5			Green food remains.
10	9		Off White Patch	,, ,, ,,
7	9			Larval gastropod.
1	9			2 larval gastropods.
1	9			Larval bivalve.
1	9			Larval bivalve, *Paralia sulcata*.
1	9			Copepod nauplius.
1	9			Green food remains, larval gastropod, *Prorocentrum micans*, *Goniaulax spinifera*.
1	9			Harpacticid.
1	9·5			,,
1	10			,,
1	10			Larval gastropod.
1	10			2 larval gastropods, 1 larval bivalve.
1	10·5	6	Jennycliff Bay	Copepod egg (?).
1	11·5	6	Jennycliff Bay	3 larval gastropods.
1	12			*Temora* nauplius.
1	10·5		Batten Bay	Larval bivalve, 2 larval gastropods.
1	11			Copepod egg (?).
1	11·5		Off Breakwater	Green food remains.
1	11·5			Larval gastropod.
1	12			,, ,,
2	12			*Temora* nauplius.

* For plan of Sound see Lebour, 1918, p. 459.

No. of Specimens.	Length in mm.	Date. 1917	Locality.	Food.
1	8	9	New Grounds	2 larval gastropods.
1	9			3 larval gastropods, green food remains.
2	9		Off White Patch	Copepod egg (?).
1	9			Larval gastropod.
1	9			Larval gastropod, copepod remains, green food remains.
1	8		Jennycliff Bay	Copepod egg (?).
3	9			,, ,,
1	10			,, ,,
1	9			Larval gastropod.
1	10			,, ,,
1	9		West Channel	Copepod remains.
1	9			Copepod egg (?).
1	8	13	Off White Patch	Green food remains.
1	8·5	27	Panther Buoy	,, ,, ,,
1	10			2 *Balanus* nauplii.
		1919		
2	9	Jan. 13	Knap–Panther	Larval gastropod.
1	9			*Corycœus anglicus* (juv.).
1	8		West Channel to Breakwater	2 larval gastropods.
1	9			Green food remains.
1	9			Copepod (juv.).
1	9			2 larval gastropods.
1	9			Larval gastropod.
1	8		Knap to Penlee	,, ,,
2	9			,, ,,
1	9			2 larval gastropods.
1	8·5	15	West Channel	3 ,, ,,
1	8·5		to Breakwater	5 larval gastropods, larval bivalve.
4	9			Larval gastropod.
3	9			2 larval gastropods.
2	9			3 ,, ,,
1	9			3 larval gastropods, larval bivalve.
1	9			5 larval gastropods.
1	9			Larval gastropod.
1	9			3 larval gastropods.
1	7			3 larval gastropods, larval bivalve.
1	8			6 larval gastropods.
1	9			Larval gastropod.
8	9		Breakwater	,, ,,
6	9		to New Grounds	2 larval gastropods.
6	9			3 ,, ,,
5	9			4 ,, ,,
1	9			5 ,, ,,
1	9			6 ,, ,,
1	7	17	Panther Buoy	Green food remains.
3	8·5			Larval gastropod.
1	8·5			4 larval gastropods.
1	9		West Channel to Middle Sound	Larval gastropod.
1	8		Breakwater	Larval gastropod.
1	9			,, ,,
1	8·5	Feb. 7	White Patch to Middle Sound	*Balanus* nauplius.

No. of Specimens.	Length in mm.	Date. 1917 1921 Jan.	Locality.	Food.
1	9	19	New Grounds	3 larval bivalves.
1	9·5	20	Penlee–Breakwater	3 larval bivalves, *Tintinnopsis beroidea*.
1	9·5			3 larval bivalves.
1	11			2 ,, ,,
1	10	24	Breakwater	3 larval gastropods.
1	10			4 copepod eggs.
1	9·5	26	East Channel	Larval gastropod.
1	9	27	New Grounds	Larval bivalve.
1	9·5			,, ,,

The food of these 140 was as follows: Larval gastropods in 91; green food remains in 22; larval bivalves in 13; copepod eggs in 11; copepod nauplii in 4; harpacticids (juv.) in 3; copepod remains indet. in

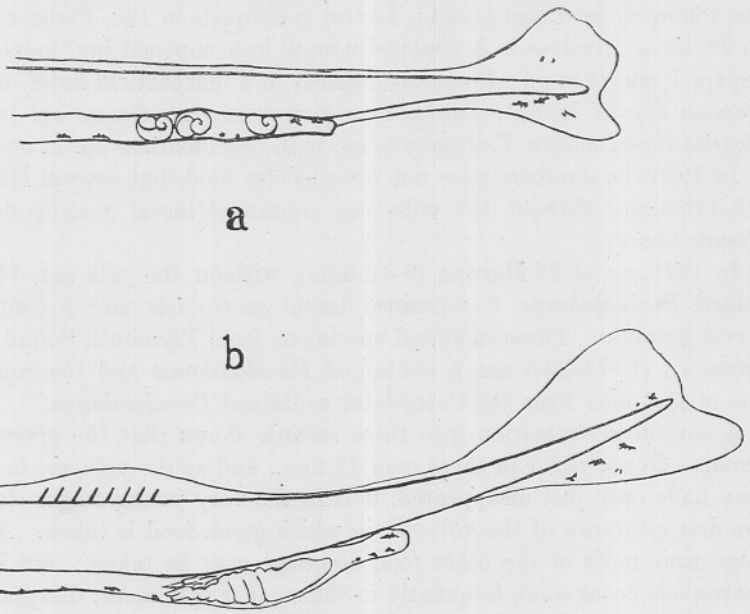

FIG. 1.

(*a*) Young Herring, 0·9 mm., with remains of yolk sac. Tail end showing food, consisting of 3 larval gastropods. Tow-nets, Penlee–Breakwater (January 20th, 1921).
(*b*) Young Herring, 10·5 mm., after the disappearance of yolk sac. Tail end showing food, consisting of *Pseudocalanus*. Tow-nets, Breakwater (January 24th, 1921).

2; Balanus nauplii in 2; Peridinians, diatoms and a tintinnid each in 1. Larval gastropods thus head the list of food taken by these larval Herrings. The green remains are probably the remains of unicellular plants; these make up the rest of the food with larval bivalves, small crustacea, chiefly young copepodid stages and nauplii, and eggs which

are probably those of *Calanus finmarchicus*. Full-grown copepods, such as *Pseudocalanus elongatus*, were taken as soon as the yolk sac had gone, but were not seen before.

In 1917 out of 436 specimens (8–18 mm.), the smallest of which had lost the yolk sac, many were empty, but the following food was found :—

Green food remains in 74, Balanus nauplii in 69, larval gastropods in 39, copepod eggs in 33, larval bivalves in 24, *Pseudocalanus* in 20, *Euterpina acutifrons* in 9, copepod remains in 9, harpacticids indet. in 4, *Oithona similis* in 4, *Corycœus anglicus* in one, *Oncœa* sp. in one, *Evadne Nordmanni* in one, *Campylodiscus* sp. in one, *Coscinodiscus radiatus* in one. Sand grains occurred in a few specimens.

In 1918 out of 87 (17–29 mm.) the only food was *Pseudocalanus* in 17 specimens.

In 1919 out of 536 (8·5–15 mm.), the smallest without the yolk sac, the following food was found : Larval gastropods in 128, *Pseudocalanus* in 29, larval bivalves in 8, copepod nauplii in 6, copepod juv. indet. in 6, copepod egg (?) in one, *Corycœus anglicus* in 3, harpacticid indet. in one, *Oithona similis* in one, *Paracalanus parvus* in one, *Oncœa* sp. in one, *Acartia clausi* in one, *Tintinnopsis* sp. in 3, *Coscinodiscus* sp. in one.

In 1920 the numbers were not recorded for food, but several Herring, 9·5–11·5 mm., without the yolk sac, contained larval gastropods and *Pseudocalanus*.

In 1921 out of 22 Herring (9–13 mm.), without the yolk sac, 14 contained *Pseudocalanus*, 5 contained larval gastropods and 3 contained larval bivalves. Three mounted specimens from Plymouth Sound, date unknown (18·75–23·5 mm.), contained *Pseudocalanus* and *Centropages ;* one of 12·5 mm. from the Cattewater contained *Pseudocalanus*.

A careful investigation into these records shows that the green food remains do not occur in those over 12 mm., and as the yolk sac in these may have only just disappeared, it is in the very young stages close to the disappearance of the yolk sac in which green food is taken. At the same time most of the other food recorded may be taken ; but larval gastropods occur more frequently in the smaller specimens, disappearing altogether after about 12 mm., and crustacea becoming the chief food. In the older specimens *Pseudocalanus* occurs most frequently, *Centropages* and other copepods also being found. The largest post-larval specimen containing food measured 28·5 mm., the food being copepods, genus indistinguishable.

Owing to lack of specimens no further records of the food of the post-larvæ were taken.

Food of metamorphosed forms caught with Sprat and Pilchard in various localities inshore showed that they were feeding on crustacea, chiefly mysids and amphipods. In certain cases remains of fish and

clupeoid scales in the stomach showed that they were probably eating the Sprat and Pilchard which lived side by side with them.

Herring (98–105 mm.) from the Lynher River (Sept. 17th, 1920) contained many *Praunus flexuosus* and several mysids. Out of 54 larger specimens (115–145 mm.) from Saltash (Sept. 24th, 1920) 31 contained clupeoid scales, sometimes with remains of fish ; a few were empty, and the remainder contained mysids and amphipods.

From the oyster beds at the River Yealm (Oct. 13th, 1920) 4 Herring (74–130 mm.) contained mysids, *Crangon*, *Caprella* and other amphipods, and many copepods. Three Herring (110–125 mm.) from Anthony Passage, Lynher River, Saltash, contained *Pranus inermis*. From copepods the Herrings thus go on to feed on larger crustacea and fish.

The food of the young Herring may be tabulated thus :—

Stage.	Food.
Before disappearance of yolk sac.	Larval gastropods, green food (probably diatoms and flagellates), larval bivalves, nauplii and other young stages of small crustacea, including their eggs.
After disappearance of yolk sac up to about 12 mm.	The same, but with small adult copepods.
After 12 mm. and probably until metamorphosis.	Copepods.
After metamorphosis.	Copepods, decapod, crustacea, amphipods, fish.

CLUPEA SPRATTUS L. Sprat.

The records of food of the early stages of the Sprat show that it eats green food before and for some time after the yolk sac is absorbed.

Only a few records show food taken before the absorption of the yolk :—

No. of Specimens.	Length in mm.	Date. 1917	Locality.	Food.
2	4·5	Jan. 30	White Patch	Green remains.
1	4·5	Feb. 27	Panther	,, ,,
1	4·5			,, ,,
2	4	March 30	New Grounds	,, ,,

In 1917–18–19, out of 106 which had lost the yolk sac (4·5–8·5 mm.) 60 contained green remains, amongst which could occasionally be recognised a diatom (*Thalassiothrix nitzschioides*, *Pleurosigma* sp., *Navicula* sp.,

Coscinodiscus sp.), or, in the larger specimens, copepod eggs and copepod nauplii. *Tintinnopsis ventricosa* occurred in one of 5 mm. The only adult copepods seen were in 3 (15–27 mm.) containing *Pseudocalanus*, and an harpacticid and a copepod egg in one of 20 mm. A very large number of the post-larval Sprat were empty.

Records from Whitsand Bay (May 30th, 1906) of older post-larvæ (32–40 mm.) show the food to be copepods, chiefly *Pseudocalanus* and harpacticids.

We then come to the small metamorphosed forms :—

No. of Specimens.	Length in mm.	Date.	Locality.	Food.
		1918		
1	32	Sept. 16	Middle Sound	*Cypris* cirripede larvæ and larval gastropods.
		1919		
1	55	July 2	(?)	*Porcellana* larva, copepod remains.
		1920		
15	43–45	Sept. 17	Lynher River	Harpacticids.
50	51–80	23	River Yealm oyster bed	Bivalve larvæ (probably oyster spat), one with also an harpacticid, one with an ostracod.
1	70	28 Oct.	Whitsand Bay	Copepods and larval gastropods.
8	42–90	4	Anthony Passage, Saltash	Copepod remains, chiefly harpacticids.
7	48–52	13	River Yealm oyster bed	Copepods and young amphipods.

The young Sprat from its metamorphosis to 90 mm. or more thus feeds on small crustacea and molluscs. Up the rivers harpacticids seem to be the chief food unless larval molluscs are in great abundance, and then apparently every Sprat in the locality feeds upon these, which are presumably the spat of the Oyster. Thus they take different food from the slightly larger Herring which are with them, the Herring taking the larger crustacea or fish.

The food of the Sprat can be tabulated thus :—

Stage.	Food.
Before disappearance of yolk sac.	Green food (probably diatoms and flagellates).
After disappearance of yolk sac up to about 8·5 mm.	The same, with small copepod nauplii and eggs.
From about 8·5 mm. to metamorphosis.	Chiefly copepods.
After metamorphosis up to at least 90 mm.	Cirripedes, copepods and larval molluscs.

SARDINA (CLUPEA) PILCHARDUS (WALB.). PILCHARD.

No food was found in any of the Pilchards with a yolk sac and for some time afterwards, the smallest seen with food being 12 mm. long.

In 1918, September 27th, one of 26 mm. contained a copepod.

The following records in 1919–21 are given in detail, as so little is known of the food of the post-larvæ. This shows the whole amount of the food from 400 specimens examined—39 with food, 361 empty. These all came from the Young Fish Trawl material taken by Mr. Clark :—

No. of Specimens.	Length in mm.	Date. 1919	Locality.	Food.
		July	Rame N. 37° W.	
1	15	7	1¼ miles	Copepod egg.
1	16			,, ,,
1	18			,, ,,
1	24			Copepod remains.
1	13	9	Eddystone E.N.E. 6 miles	Copepod nauplius remains.
1	15			*Pseudocalanus*.
1	19			,,
1	20			Copepod remains.
1	20	10	Rame N. 14° E. 4½ miles	*Calanus* nauplii.
1	14	21	Rame E. ¼ N. 5¼ miles	*Acartia* (juv.).
1	14			*Oithona similis*.
		August		
1	12	1	Rame N. 60° E. 3½ miles	Copepod nauplius remains.
1	19			Copepod nauplius.
1	22	8	Eddystone W.S.W. 2¼ miles	Copepod nauplius, 3 copepod eggs.
1	22	1920 July		2 copepod eggs.
1	22	6	Rame N. 45° W. 1½ miles	Many *Calanus* eggs.
23	21–27	15	Eddystone S. 60° W. 4¾ miles	,, ,, ,,

It is thus shown that all food seen in the post-larval Pilchards from 12–27 mm. is copepod food, either eggs, nauplii or adults. No green food of any kind was seen and no remains of diatoms nor peridinians, an interesting fact when one refers to observations on the food of the smaller metamorphosed forms (Cépède, 1907, Mangin, 1912, and many others, including the present records).

The following table shows the food of young metamorphosed Pilchards, taken by Mr. Clark, chiefly from up the estuaries in the autumn of 1920 :—

No. of Specimens.	Length in mm.	Date. 1920	Locality.	Food.
1	65	Sept. 17	Lynher River	Fine mud containing small organisms, many *Prorocentrum micans*, *Halosphæra viridis* and *Navicula* sp.
1	68			Fine mud containing many *Prorocentrum micans*, *Paralia sulcata*, *Lithodesmium undulatum*.
Many	65–82			Mud with diatoms and *Prorocentrum micans*.
1	66			Mud and diatoms, many *Prorocentrum micans*, one harpacticid.
5	61–65	23	Oyster bed, River Yealm	Mud with diatoms and *Prorocentrum micans*, a few larval bivalves (probably oyster spat).
4	58–68	28 Oct.	Whitsand Bay	Copepod remains, including *Temora*.
12	60–75	4	Anthony Passage, Saltash	Fine mud, with diatoms and *Prorocentrum micans*.

The food of the young Pilchards may be tabulated thus :—

Stage.	Food.
Post-larvæ from 12–27 mm. and probably up to the time of metamorphosis.	Copepods, adults, larvæ and eggs.
Metamorphosed forms up to at least 82 mm.	Usually mud with unicellular organisms, chiefly *Prorocentrum micans* and diatoms. Occasionally copepods or larval molluscs.

There seems here to be a distinct change in diet at metamorphosis. The pelagic post-larvæ in the open sea feeding on copepods and their eggs, the metamorphosed forms coming inshore and probably usually feeding near the bottom on mud with unicellular organisms. The only metamorphosed specimens in our records which did not contain mud were from Whitsand Bay, and these contained sand and copepods, including *Temora*, one of the commonest of the planktonic copepods. All those from up the estuaries had evidently been feeding near the bottom on microscopic unicellular food taken in with the mud. This agrees with the observations of Cépède and Mangin, who found that the small metamorphosed Pilchards feed on a minute vegetable diet, peridinians being specially taken, with occasional zooplankton.

Fage (1920) gives a summary of the food of the Pilchard from the small metamorphosed forms to the adults from the Channel and the Bay of Biscay, showing first a predominantly vegetable diet, afterwards the animal portion increasing. According to Swithinbank and Bullen (1914), the adult Cornish Pilchards feed on a varied plankton predominantly zooplanktonic.

Peridinians are evidently a favourite food of the young metamorphosed Pilchards. *Prorocentrum micans* is usually at its maximum in September in this district and perhaps the commonest Peridinian species up the estuaries. It is not surprising, therefore, that this should form a large part of the Pilchard's food.

In comparing the food of the young Herring, Sprat and Pilchard we thus find that for the post-larvæ it is much the same for all three species, except that the very young Herring is specially fond of larval gastropods. They all eat much the same sort of pelagic food, copepods being the commonest in all after about 12 mm. The metamorphosed forms, however, occurring together up the rivers usually feed on different organisms, the Pilchards feeding near the bottom chiefly on mud and unicellular organisms, the Sprats above them feeding chiefly on copepods or larval molluscs, and the Herring, which are larger, on decapod larvæ, amphipods and fish. The diet is seldom very much mixed, and each fish generally keeps to one kind of food at one time. Thus the Herring will eat mysids and amphipods in one place, fish in another ; the Sprat will eat copepods in one place and all of them will be full of larval bivalves (probably Oyster spat) in another. Whatever is most abundant and also suitable is taken, but usually one kind of food at one time.

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