SARSIA 3

THE ASSOCIATION BETWEEN YOUNG WHITING, *GADUS MERLANGUS*, AND THE JELLY-FISH *CYANEA CAPILLATA*[1]

By
ERIK DAHL
Zoological Institute, Lund

ABSTRACT

Young whiting probably profit from the protection offered by jelly-fish. They feed upon plankton organisms, mainly copepods, and do not normally attack the jelly-fish, although in the aquarium they may take minced jelly-fish tissue. They take *Hyperia galba* when offered. They appear to have obtained a certain degree of immunity from the nematocysts of *Cyanea*. This is probably due to the properties of their body surface, for contact with tentacles does not produce large-scale discharge of nematocysts.

INTRODUCTION

Fairly little is still known concerning the relationships between the large jelly-fish and the animals more or less regularly associated with them. In Scandinavian waters the latter comprise in the first place the hyperiid amphipod *Hyperia galba*, young gadiid fishes, especially whiting (*Gadus merlangus*), and young horse-mackerel (*Trachurus*).

Recently the present writer (1959 a, b) could show that *Hyperia galba* in the adult and later juvenile stages found together with *Cyanea capillata* is an ectoparasite, apparently taking no other food than the tissues of its host, including large quantities of nematocysts. After the publishing of the papers referred to further observations have confirmed this conclusion.

The evidence concerning the relationship between *Cyanea* and the fishes is more contradictory. MALM (1852) in a paper which has been almost entirely overlooked by later writers, states conclusively that young horse-mackerel attack the jelly-fish and take, in the first place, the embryos developing in the mouth arms. In the case of the whiting, however, no agreement has been reached. According to some writers the fishes associate with the jelly-fish for shade or protection, or in order to catch small plankton organisms stunned or caught by the tentacles, or in order to catch *Hyperia* (cf. i.a. HARDY, 1956; RUUD and BEYER, 1959). Experiments carried out by SCHEURING (1915) indicated quite a different explanation. However, SCHEURING's paper, although quoted by one or two subsequent writers, has, on the whole, shared the fate of MALM's paper of 1852. His main results therefore will be briefly summarized here.

[1] Contribution from the Biological Station, Espegrend.

During his experiments at Heligoland SCHEURING put young whiting into aquaria and offered them i.a. copepod plankton, live *Hyperia*, and small pieces of jelly-fish tissue. According to his paper the last food-item was the only one taken by the whiting which also selected it from food mixtures. He suggested that the 0-group of whiting may depend upon jelly-fish and particularly *Cyanea capillata* for its nourishment.

This is hardly compatible with present views on the feeding habits of young whiting, the staple food of which appears to be zooplankton and especially copepods. Nevertheless I found it desirable to repeat and extend the experiments made by SCHEURING and to make further observations on whiting and *Cyanea* in the open sea. The work recorded in this paper was carried out at the Biological Station of the University of Bergen during July 1960. I am greatly indebted to Professor H. BRATTSTRÖM, Førsteamanuensis H. TAMBS-LYCHE and the staff of the Station for all facilities and aid received in the course of my work. I am also indebted to Mrs. K. LIEBERATH for technical assistance.

Although many questions are still open and further investigations on the subject are in progress some of the observations made seem to be of sufficient interest to justify a brief report.

GENERAL BEHAVIOUR OF WHITING AND CONTROLS AND THE EFFECT OF CONTACT WITH TENTACLES OF *CYANEA*

The experiments with whiting and *Cyanea* were carried out in aquaria large enough to give the fishes a certain freedom of movement also when one or two specimens of jelly-fish were present. In all a dozen whiting measuring between 3 and 9 cm in length were used for the experiments.

The whiting turned out to be rather upset by the transfer to aquaria and needed at least 24 hours to adapt themselves to the environment. After that period they appeared to have calmed down and to react normally. It was impossible, however, to move one specimen from one aquarium to another in the course of one particular experiment, for after being handled they were again scared and uneasy for several hours.

Sometimes the transfer from the sea to the aquarium brought about panic reactions. On two occasions when whiting 4 and 9 cm in length respectively were put into aquaria together with the jelly-fish in the company of which they had been caught, they rushed wildly about and entangled themselves among the tentacles. Both of them were drawn up among the mouth arms. The smaller fish hung there for about 1 minute almost motionless, only breathing slowly. After that period, however, it tore itself free by some violent wriggling and afterwards showed no ill effect whatever. Exactly the same happened in the case of the larger specimen. The only difference was that it was entangled twice and hung among the mouth-arms for abt. 3 minutes and half a minute respec-

tively. In both cases it jerked itself free and no deleterious effect was seen. A fragment of a tentacle hung attached to its tail-fin for some hours but then disappeared.

These are the only instances of whiting caught in the tentacles of *C. capillata* which I have had the opportunity to watch, and they both took place within the first quarter of an hour after transfer from the sea to the aquarium.

In the aquaria the whiting generally did not show any close association with *Cyanea*. For long periods they moved about quite independently of them but now and then a fish would post itself among the dangling tentacles, generally swimming with slow undulating movements well adjusted to those of the bell of the jelly-fish and the swinging and contractions of the tentacles. It was impressive to watch the ease with which they moved among the dense curtains of tentacles, keeping clear of them apparently without the slightest effort. Nevertheless it happened now and then that a whiting got into contact with a tentacle, but if the contact was light the tentacle often did not adhere to the body of the fish. Sometimes it did, however, and then the fish would generally make a quick dash, stretching and shaking the tentacle which then invariably lost its hold. It also happened a few times that the fish remained in position with the tentacle attached for one or two minutes before it rushed off and freed itself.

Several times I have heard statements indicating that when young whiting in the sea are suddenly frightened and rush in to hide below jelly-fish a few of them are likely to get caught. Observations of this kind were also quoted by Ruud and Beyer (1959). I have never been fortunate enough to see this taking place in the sea but the observations are entirely consistent with the observations on whiting recently introduced into aquaria, which were recorded above. The crucial point seems to be whether the fishes caught in this manner are really killed and devoured. Although this may happen from time to time it seems more likely that most of the young whiting caught in this manner jerk themselves free again after a shorter or longer interval. When *C. capillata* and whiting are caught in a tow-net and the catch emptied into a tub with sea-water the fishes will generally be found to swim among the jelly-fish without being attached to the tentacles, despite the rather violent contact which will have taken place.

Only in one instance have I seen a whiting being killed when in close contact with *C. capillata*. One specimen was accidentally left in a pail with sea-water containing three large specimens of *Cyanea* for half an hour on a warm summer day. When discovered the fish was dying among the tentacles. It was not firmly attached and it seems not unlikely that it was exposure to unfavourable conditions rather than to nematocysts which proved fatal. Some of the observations on nematocysts discharge recorded on p. 51 rather support this view. It may also be worth recording that although I have in the course of the last few years examined the tentacles and mouth-arms of many hundred speci-

mens of *C. capillata* I have not yet found any dead whiting among them, Again. this is of course no proof that whiting are not caught and killed from time to time.

That association with jelly-fish may sometimes prove fatal to fishes was observed by BEEBE (1927) when watching young *Chloroscombrus chrysurus* sheltering under the bell of *Tamoya haplonema*. He saw several specimens of the fish being killed or hanging dead among the tentacles.

In order to compare the behaviour of the whiting with a fish not adapted to the company of *C. capillata* some *Gobius flavescens* were put into aquaria and after they had had time to adjust themselves to the environment specimens of *Cyanea* were introduced. In all five specimens of *G. flavescens* were used in these experiments which were always carried out with one fish at a time. Four of the gobies were rapidly killed. They showed no fright of the tentacles and very soon got into contact with them. Upon contact the tentacles always attached themselves firmly to the fins and body of the goby. Sometimes the fish managed to tear itself free but the four specimens referred to were rapidly caught again by the tentacles. The fish would rush away and stretch the tentacle to which it was attached but the tentacle would then contract drawing the fish closer to the mouth arms. In the course of this process one or more further tentacles were likely to attach themselves to the body of the fish. After some further attempts to escape the goby would, generally within two or three minutes, be drawn in among the mouth arms where it soon died. One fish managed with a last effort to jerk itself free but died on the bottom of the aquarium within a few minutes.

The fifth specimen of *G. flavescens* was more successful. After one or two initial slight contacts from which it managed to escape it learnt to be extremely cautious and actively to avoid the tentacles. It survived for ten days in the aquarium always in the company of one or two specimens of *Cyanea*, and displayed great skill in keeping clear of the tentacles. After that period the experiment was closed and the goby appeared to be in perfect condition.

It was interesting to see, however, how the pattern of movement of the gobies produced contact with the tentacles much more easily than that of the whiting. While the slow and undulating movements of the whiting helped to keep them clear of the tentacles the quicker and more jerky movements of the gobies had the opposite effect.

It was also obvious that upon contact the tentacles of the jelly-fish attached themselves much more firmly to the gobies than to the whiting.

OBSERVATIONS ON NEMATOCYST DISCHARGE AND EFFECT

The small size of the nematocysts and the velocity of the discharged threads make direct observations of their effect upon living fish impossible. The differences observed with respect to attachment of tentacles to whiting

and gobies, however, made some further observations desirable. Therefore the fishes used in the course of the experiments were preserved in Bouin's fluid together with some further specimens caught in the sea and not used for experiments. Parts of some specimens were embedded in polyester wax, serially sectioned and stained in Heidenhain's Azan.

The slides were then examined for nematocysts attached to the skin of the specimens. It should be noted that the handling previous to and during embedding is likely to result in the loss of nematocysts. In fact parts of the epidermis is likely to fall off. Consequently the absence of nematocysts from the body surface of a fish exposed to contact with tentacles is no absolute proof that no discharge has taken place. On the other hand large and consistent differences in the number of nematocysts attached to the skin will in all probability have some degree of significance. As shown in the table such differences exist between the whiting and the goby examined.

Fish	Part of body	Nematocysts attached per sq.mm
G. merlangus found dead in pail with *Cyanea* (p. 49)	Anterior part of body wall	5—20
	Tail	5—10
G. merlangus caught among *Cyanea* and preserved immediately	Anterior part of body wall	0
	Tail	<1
G. flavescens killed by *Cyanea*	Anterior part of body wall	100—300
	Tail	100—200

The figures in the table tend to show either that nematocysts are more likely to be discharged upon contact with the body of a goby than with that of a whiting or that the attachment of the nematocysts is stronger in the previous case. Although no definite evidence on this point is yet available the former alternative would seem to be the more likely one. Davenport and Norris (1958) have shown that after a period af adaptation the mucus secreted by *Amphiprion percula* prevents discharge of the nematocysts of the sea-anemone *Stoichactis*. Rees (1961) recently suggested that a similar mechanism might be effective in the relationship between *Nomeus* and *Physalia*.

The distribution of discharged and attached nematocysts actually gives some support to a similar interpretation. In the case of *G. flavescens* it is obvious that contact results in the discharge of whole nematocyst batteries (Fig. 1) while in the whiting the attached nematocysts were always found singly or at most two or three together.

In the case of *G. flavescens* the nematocysts in various instances have been seen to penetrate the epidermis and attach their threads firmly in the cutis. Perhaps owing to the comparative scarcity of the material no such deep penetration has been seen in the whiting.

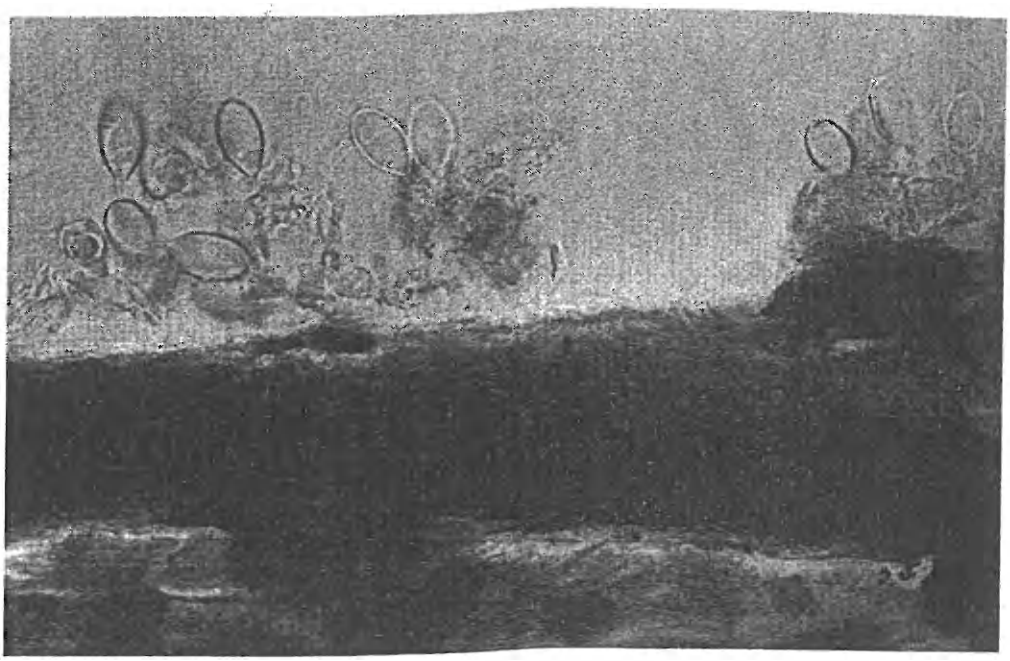

Fig. 1

Section through body wall of *Gobius flavescens* previously exposed to contact with tentacles of *Cyanea capillata* with fatal effect. Violent stimulation of nematocysts has taken place resulting in the discharge of whole batteries. Magnification abt. 900x. Photo B. MORAWETZ.

FEEDING HABITS OF YOUNG WHITING ASSOCIATED WITH *CYANEA*

Observations on the feeding habits of young whiting in the company of *Cyanea* were made both on specimens preserved directly upon capture and in the course of aquarium experiments.

A number of whiting caught among *Cyanea* near the surface of the Raunefjord were preserved in Bouin's fluid. The stomach and intestinal contents were examined by means of dissection under the microscope (3 specimens) or after sectioning in polyester wax (4 specimens).

In all 7 specimens the food contained in the alimentary canal was found to consist of plankton organisms, and the main items were found to be calanoid copepods (particularly *Calanus finmarchicus* but also other species), decapod larvae, and Chaetognatha. A few Cladocera were also found. A few further items could not be identified. Nothing was seen which could be interpreted as jelly-fish tissue. Special care was taken to search for remains of this kind. Eggs and embryos of jelly-fish are of course likely to disintegrate rapidly in the alimentary canal of the whiting. On the other hand it is practically impossible for the whiting to take any part of the jelly-fish without also getting some nematocysts, and all experience from *Hyperia* tends to show that nematocyst shells

are extremely resistant to the effect of digestive juices. As a further control the alimentary canal of one specimen of whiting which had been seen to take fragments of jelly-fish tissue in the aquarium was sectioned. By means of the nematocysts small fragments of *Cyanea* were in this case readily identified. These observations tend to show that the tissues of *Cyanea* are definitely not the staple food of the young whiting associated with them.

In order to elucidate this point somewhat further some feeding experiments were carried out. The objects of these experiments were to find out, 1) how young whiting feed, 2) which are the reactions of whiting when offered live copepods, live *Hyperia*, and minced jelly-fish tissue, 3) whether whiting actually attack *Cyanea* in order to feed upon them.

It was found that feeding takes place by means of individual attacks on objects up to about 1 cm in length or occasionally slightly larger ones. Actively moving animals are more likely to be attacked than suspended motionless objects, though the latter are by no means rejected. Both copepods and *Hyperia* were readily taken. Small whiting, 4—6 cm in length, apparently had difficulties in swallowing large *Hyperia*, and they sometimes ejected them after the first attempt only to make new ones until the prey was successfully devoured. One specimen which measured 9 cm in length took 13 *Hyperia* in the course of 2 hours. No *Hyperia* swimming in the aquarium survived more than a few minutes if whiting were present, and often they were caught within a few seconds after having been dropped into the water. If they managed to reach a *Cyanea*, which always appeared to take place entirely by accident, they were generally safe. Only in one case did I see a whiting actually snatching a specimen of *Hyperia* away from the surface of the subumbrella of a jelly-fish. When specimens of *Hyperia* were swimming the whiting often discovered them in distances of 50 cm and more and attacked them with great speed.

Several experiments were made in which the whiting were offered minced *Cyanea* tissue. Both tentacles, mouth arms, and pieces of umbrella were used. Often enough some of the slowly sinking fragments were taken As far as I could see, however, these pieces of jelly-fish tissue were generally ejected again within a few seconds. In some cases, however, they were retained and swallowed. Small jelly-fish fragments occasionally encountered in the water were treated in a similar manner. As already mentioned above the alimentary canal of one of the specimens which had been seen to take small pieces of jelly-fish tissue was sectioned and the jelly-fish remains identified.

Thus the experience both from the field and the aquarium tends to show that the plankton animals most readily available constitute the main source of food of the young whiting. Nevertheless any moving or suspended small object is likely to be tried. In the sea *Hyperia* probably not exposes itself to attack often enough to be a main food item, when it does it will be eaten. When pieces of jelly-fish tissue were taken by whiting in the aquarium they were

often ejected again, sometimes with great force indicating that the experience had been unpleasant.

It remains to discuss the question whether whiting feed directly upon the jelly-fish. In the course of many hours of observation I only saw three highly doubtful instances which might possibly be interpreted as indicating something of this kind. In all three cases a whiting stationed among the tentacles swam up to within 1 or 2 cm from the mouth arms. After what appeared to be a very close inspection it nibbled upon the surface of one of them for a fraction of a second. It was impossible to see whether anything was actually taken, if so it must have been a very small object or piece of tissue. The whiting were never seen to take anything attached to the tentacles.

Thus the present writer when repeating the experiments of SCHEURING (1915) was, on the whole, unable to confirm his conclusions. When adapted to aquarium conditions young whiting readily take food offered to them, but they obviously prefer copepods and *Hyperia* to pieces of jelly-fish tissue. Nor do they normally attack the jelly-fish themselves in order to feed upon them.

SUMMARY AND CONCLUSIONS

1. The present investigation tends to confirm the view that young whiting seek the company of *C. capillata* mainly because of the protection offered. When frightened by objects moving above or in the water they are likely to hide among the tentacles but sometimes also dive towards the depths away from the jelly-fish. In that case they can sometimes be seen to return to it after a short while. In the aquarium this pattern of behaviour can be recognized but there it is less pronounced.

2. Contact with the tentacles of jelly-fish does not appear to be very dangerous to the whiting. Even when entangled in the mouth arms they are likely sooner or later to liberate themselves and afterwards their condition appears to be quite normal. To specimens of *Gobius flavescens* used as controls a similar experience was fatal.

3. Histological examination of whiting exposed to contact with tentacles of *Cyanea* revealed only few and scattered nematocysts attached to the skin while in the gobies great numbers were encountered indicating the discharge of entire nematocyst batteries. It is considered likely that the body surface of the whiting is not very liable to produce the discharge of nematocysts. It is suggested that this is probably an adaptation to the association with jelly-fish, recalling the relationship existing between *Amphiprion* and *Stoichactis* and probably also between *Nomeus* and *Physalia*.

4. The alimentary canal of young whiting caught in the sea together with *Cyanea* and preserved immediately contained zooplankton, in the first place copepods, and no remnants of jelly-fish tissue were found. Of the 7 specimens examined none contained any specimens of *Hyperia*.

5. In the aquarium young whiting readily took live copepods and *Hyperia*. Pieces of jelly-fish tissue were also taken but much less greedily, and they were often ejected within few seconds. To some extent, however, they were actually swallowed.

6. No proof could be produced to show that whiting normally attack jelly-fish in order to feed upon them. A few possible instances observed need further confirmation. Nor were the whiting seen to snatch away prey caught by the jelly-fish.

7. The present investigation does not confirm the opinion expressed by SCHEURING (1915) that the young whiting depend upon the jelly-fish as their main source of food.

REFERENCES

BEEBE, W., 1927. *Beneath tropic seas.* New York.

DAHL, E., 1959a. The Amphipod, *Hyperia galba*, an Ectoparasite of the Jelly-fish, *Cyanea capillata*. *Nature Lond.* **183**.

— , 1959b. The hyperiid amphipod, *Hyperia galba*, a true ecto-parasite on jelly-fish. *Univ. Bergen Årbok* 1959. *naturv. R.* (9).

DAVENPORT, D. and K. S. NORRIS, 1958. Observations on the symbiosis of the sea anemone *Stoichactis* and the pomacentrid fish, *Amphiprion percula*. *Biol. Bull.* **115**.

HARDY, A. C., 1956. *The open sea.* Lond.

MALM, A. W., 1852. Om yngel af *Caranx trachurus*, såsom ett slags parasit hos *Cyanea*

RUUD, J. T. and F. BEYER, 1959. Dyr som driver i sjøen. *Norges Dyreliv* **4**. Oslo.

REES, W. J., 1961. The Portuguese Man-of-War. *Nature Lond.* **190**.

capillata. *Öfvers Vetensk. Akad. Förh.* **9**.

SCHEURING, L., 1915. Beobachtungen über den Parasitismus pelagischer Jungfische. *Biol. Zbl.* **35**.

Received for publication 23 May 1961
Printed 30 November 1961