

The Habits of the Angler-fish, *Lophius piscatorius* L., in the Plymouth Aquarium.

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With Plate I and 2 Figures in the Text.

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INTRODUCTION.

THE Angler-fish (*Lophius piscatorius* L.), also known as the Fishing-frog, Monk-fish, Sea-devil, etc., is notoriously difficult to keep in captivity. It has rarely survived in an aquarium for any length of time and published accounts of observations made from life are somewhat conflicting. Much that has been written about the habits of the species has been based on deduction from the structural features of dead specimens. It seems therefore worth while putting on record the details of some recent observations made at Plymouth, where a number of angler-fishes have been kept alive and in health for periods varying from a few weeks to nearly a year.

Although living angler-fishes are regularly brought ashore by the S.S. *Salpa* very few survive for more than a few hours. It is probable that the soft and flabby nature of the body, particularly of the abdominal wall,

exposes the fish to severe internal injuries in the trawl. All survivors have been small and had apparently in some way escaped the usual bruising that takes place when the cod-end is hauled. It is noteworthy that one brought up in unusually good condition was taken in a small Agassiz trawl, an instrument which is much less severe on its captives.

The colour of a healthy angler-fish generally distinguishes it at once from those that are dead or dying. The latter exhibit a fine speckling of pigment that from a little distance imparts an almost uniform chocolate brown appearance to the greater part of the head and back. In a healthy specimen the colour is usually paler and yellower, being often coarsely mottled with light and dark patches, especially when it has presumably come off a gravelly bottom.

With the exception of the first specimen (later referred to as Angler-fish No. 1) all have been kept in a glass-fronted slate table-tank, five feet long, two feet four inches wide, and with a water depth of nearly fifteen inches. The greater part of the bottom was thickly strewn with a gravelly sand containing much fragmented shell (see Plate I): at one end there were a few large rocks. A few small starfishes, Aphrodite, Scaphander Holothuria, and some small fishes shared the tank.

In nearly every instance hand feeding was necessary for the first few weeks, because living fishes of species attractive to angler-fishes were not at the time available. Dead wrasses (generally *Ctenolabrus rupestris*, sometimes *Labrus bergylta*), gobies (*Gobius minutus* and *G. paganellus*), and an occasional gadoid were given. As remarked later some individuals took more readily to this treatment than did others. The fish was always inserted into the angler's mouth head first. If the jaws gripped it, it would almost invariably be swallowed, but very frequently the mouth would be opened as wide as possible and by a convulsive movement the food "coughed" out. Repeated insertions might be necessary before the angler-fish would bite. One or two angler-fishes that were at first difficult to feed seemed to learn through experience and later on gave, on the whole, less trouble.

In order to make observations on the use of the lure living fish were from time to time placed in the tank. If newly caught from the sea, however, they would be too bruised and frightened to react to the angler's lure. Fish netted from a tank where they had lived for some time were better, but even so were generally too scared to behave naturally. Removing the angler-fishes themselves to a tank containing small fishes, which had been living there long enough to be fully accustomed to their surroundings, gave greatly improved results. This tank was twice the length of the angler's own and was strewn with sand; it housed starfishes of several kinds and some *Corystes* crabs. The angler-fishes were never seriously

disturbed by their transference (in a large bowl of water) and would usually at once settle themselves in a sandy hollow and begin to fish.

I should specially like to thank Capt. V. Lord and the crew of the S.S. *Salpa* for the care they have taken with the angler-fishes they have caught alive. Mr. G. M. Spooner has from time to time attended them, and kept notes for me when I have been away, and to him I am also grateful.

HISTORICAL.

The literature relating to angler-fishes and their habits is extensive. From Aristotle onwards the curiosity of naturalists has been aroused, but few writers appear to have watched the fish alive, either in its natural environment or in the confines of an aquarium tank, and many stories of its habits are based largely or solely on imagination. I propose to mention here chiefly those more recent authors who have recorded observations on the living animal.

One cannot, however, ignore Aristotle. His remarks show that he must have spent much time watching the creature through the surface of the sea. He saw angler-fishes stirring up the sand and mud when settling themselves on the bottom; he saw the dorsal fin-rays used as baits, and the capture of little fishes. He records the unusual thinness of angler-fishes caught after the loss of the tips of their fishing rods. All that later writers can do is to amplify his remarks by filling in the details.

In more modern times a few naturalists have made some first-hand observations. In 1874 Saville Kent kept an angler—apparently for a few days only—in the old Manchester Aquarium. He compared it to a rock, the irregular bordering tags of skin resembling *Grantia*, ascidians, etc., organisms such as hang down from rocky ledges. The dorsal spines he likened to young *Laminaria* fronds, and the eyes to acorn-barnacles. He apparently did not see his specimen feed, but supposed that fishes misled by this mimicry would approach near enough to be snapped up: he seems to have doubted stories of angling activities.

Guitel (1891) kept a *Lophius*, sixty centimetres long, for two months in the laboratory aquarium at Arago. He never saw the lure in use; it was always folded back out of the way. His fish captured a bass half its own length and two large *Sargus* fishes when they happened to swim too close above the mouth.

Bigelow and Welsh (1925) record some observations by W. F. Clapp, who frequently watched the feeding habits of this fish at low-tide in Duxbury Bay, Mass. It is described as lying motionless among the eel-grass with the "bait on the tip of the first dorsal ray swaying to and fro over the mouth, either with the current or by some voluntary motion so slight as to be invisible." It was observed to take tomcod (*Microgadus tomcod* Walbaum) which were caught when they swam too near to the

bait. The species of angler-fish here mentioned is given as *Lophius piscatorius* Linnæus, but Berrill (1929) has more recently brought forward strong evidence to support an earlier conclusion that the American angler-fish is distinct from the European and should be named *L. americanus* Valenciennes.

Dahlgren (1928), in a popular account of the habits and life-history of the angler, mentions that he has watched numbers of this fish tethered alive in the sea close to the Mount Desert Island Laboratory. He describes how they were there attacked by starfishes and sea-urchins, which ate away patches of their skin. Dahlgren did not see his anglers feed and he definitely states (p. 22) that no one has seen a *Lophius* feed while confined in an aquarium. "He makes a poor aquarium subject since he refuses all food in captivity, and hence does not live long." Dahlgren points out the paucity of original observations on the use of the lure for fishing since Aristotle made the first statement about it.

The most important recent observations are those of Chadwick (1929), who gives a short, but very accurate account of the feeding habits of angler-fishes in the Port Erin aquarium. He repeatedly saw them use the lure to attract coal-fishes (*Gadus virens*), which they seized and swallowed head first.

Finally one gathers from a popular article (Weller, 1934) that living angler-fishes are occasionally exhibited in the Brighton Aquarium, and that they are there fed on flat-fishes attracted by the lure. The species has also been exhibited in the Zoological Society's aquarium at Regent's Park (Boulenger, 1932) but survived for only a few days, evidently not feeding.

INDIVIDUAL HISTORIES.

During the past two years about ten angler-fishes have lived, apparently in good health, in the Plymouth aquarium. Of these only five have survived longer than a few weeks: some particulars of their histories are given below.

Angler-fish No. 1.

Caught: first week in January, 1935.

Died: 8th April, 1935.

Length when caught: 6 inches.

Length at death: $7\frac{1}{4}$ inches.

During the first part of its captivity it lived in a bowl strewn with shelly gravel and placed under circulation from a sea-water jet. Later it was exhibited in a small tank in the public part of the aquarium. For the first ten days no food was taken although living *Gobius minutus* and small flat-fishes were supplied. Hand feeding was then resorted to, the mouth

being held open while a fish was inserted. While at first it was difficult to induce the angler to accept food, this later became easier, and it was no longer necessary to force open the mouth. This angler was never known to catch prey for itself. A photograph of it, taken within a fortnight of capture, is reproduced elsewhere (Wilson, 1935, Fig. 80).

Angler-fish No. 2.

Caught : 18th April, 1935. Died : 17th March, 1936.

Length when caught : $10\frac{1}{2}$ inches.

Length on 7th November, 1935 : 15 inches.

Length on 10th January, 1936 : $17\frac{1}{2}$ inches.

Length at death : $18\frac{1}{4}$ inches.

This specimen, like all subsequent ones, was placed in the tank already described (p. 478) as soon as it was brought in. For about the first month it was every two days or so placed in a bowl and removed from the tank for convenient feeding by hand. Later it was allowed to catch living fish for itself. It was often seen to fish with the lure, except during the last few months when it always waited until prey chanced to wander, or was driven, within reach. This angler, like the first, was very docile and easy to handle, never snapping at the fingers when fed by hand. It finally succumbed to disease.

Angler-fish No. 3.

Caught : 3rd September, 1935.

Died : 16th November, 1935.

Length when caught : 8 inches.

Length at death : $10\frac{1}{2}$ inches.

At first fed on dead fish given by hand or forceps, it later refused such proffered food and apparently subsisted on living *Gobius minutus*, which were put into the tank and which it must have caught for itself. It was often seen using its fishing lure and once or twice was observed to catch a goby that came too near. A post-mortem revealed two half-digested *Gobius minutus* in the stomach and unidentifiable remains in the intestine. Cause of death unknown.

This specimen was rather vicious and would snap fiercely at food presented with the forceps ; it was not safe to give food with the fingers.

Angler-fish No. 4.

Caught : 17th December, 1935.

Died : 25th March, 1936.

Length on capture : $11\frac{1}{4}$ inches.

Length at death : 13 inches.

Unlike the last this fish never snapped when hand-fed and was quite docile. It was very easy to feed, generally accepting dead fish readily when living were not available and rarely "coughing" them out again. It gave very fine displays of its angling abilities, and on it, more than on any other single specimen, my account of this habit is based. It eventually died from the disease that killed No. 2 as well as one other angler-fish not specially mentioned in this paper. This disease was evidently highly infectious; the skin and underlying tissues of the head swelling rapidly, becoming soft and gelatinous, and finally peeling away to the bone, death ensuing within a few days.

Angler-fish No. 5.

Caught : 29th January, 1936.

Died : 24th May, 1936.

Length on capture : $10\frac{1}{2}$ inches.

Length at death : $12\frac{1}{2}$ inches.

This was first fed by hand on dead fish which were occasionally accepted but more often refused, being "coughed" out repeatedly. There is little doubt that it caught and ate the *Gobius minutus* living in the same tank. It was often seen with the rod held horizontally forwards above the closed mouth as if in readiness to fish, but was never actually observed to catch anything. It died by jumping out of the tank during the night, having been saved from the disease that killed Nos. 2 and 4 by being isolated from them. A post-mortem revealed remains of food, including an otolith in the intestines.

The remaining angler-fishes need not be specially mentioned. They were very useful in checking observations made on these five, and added some details to them. One, caught early in July, 1936, and suddenly dying for no apparent cause about five weeks later, is shown in Plate I. This photograph was taken when it appeared to be in perfect health eleven days before death. At that time it was expected to live for at least several months.

Angler-fishes show strong individual characteristics, especially as regards their habits and reactions. While some are sharp tempered and snap readily at any object, such as a ruler pushed towards them, others are very quiet and docile. Some readily swallow dead fishes placed in their mouths, others do not. Some angle with the lure much more frequently and readily than do others. One or two specimens have made little or no use of the lure, at least while being watched. Certain individuals seemed much more inclined than most to sit about on the rocks at one side of their tank. In short, no two anglers behaved exactly alike.

GROWTH.

In Figure 1 are shown graphically the length increases of the five angler-fishes whose histories have just been given. Except for No. 2 only the lengths at capture and at death are plotted. Frequent measurements were not taken as they were scarcely practicable. It is extremely difficult to measure a living angler at all accurately, especially at the bottom of a tank where the ruler has to be balanced horizontally on the rounded upper

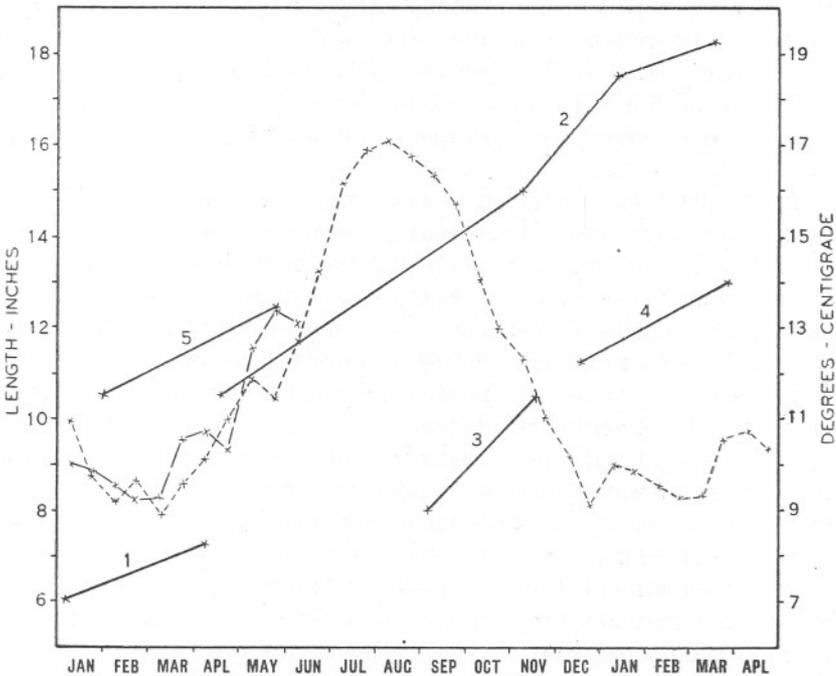


FIG. 1.—Growth of the five angler-fishes mentioned in the text shown by continuous lines. Broken lines represent tank temperatures from January, 1935, to June, 1936. Temperatures from January, 1936, to June, 1935, are plotted on the left and the points joined by longer broken lines. Each plotted point is an average fortnightly temperature calculated from daily readings taken by Mr. A. J. Smith.

surface of the angler's head. The amount of closure of the mouth may make a slight difference. The limits of error are probably an eighth of an inch or a little more either way. For this reason too much reliance should not be placed on the exact slopes of the growth lines as shown. Nevertheless the relatively rapid growth of No. 3 as compared with the others might be due to the fact that it took place when the tank temperature was higher than at the times when Nos. 1, 4, and 5 were kept. On the other hand the rapid growth of No. 2 between 7th November, 1935, and 10th January, 1936, scarcely justifies such a conclusion.

Angler-fish No. 2 increased in length by $7\frac{3}{4}$ inches in almost exactly eleven months, giving an annual increment of about $8\frac{1}{2}$ inches per year. The other four fishes lived for much shorter periods than this, but all appear to have been growing at approximately similar rates.

In assessing the value of these growth data for young angler-fishes kept under aquarium conditions it should be remembered that all were carefully fed and probably on the whole got as much food as they wanted. The temperature curve given is based on regular readings taken in an aquarium tank in another part of the building. Although all tanks exhibit slight individual temperature variations they are on the same circulatory system, and it is known that their average temperatures do not materially differ, but all follow the same general curve. Thus this curve should represent quite closely the conditions that occurred in the angler-fish tank itself.

Fulton (1903) has attempted to assess the growth rate of *Lophius* in the northern North Sea. By measuring specimens trawled in all months of the year he has estimated, admittedly on somewhat scanty data, that the mean annual increment in length is a little over 6 inches, this for angler-fishes ranging from about 6 to 18 inches long. He considered that anglers of a mean length of $6\frac{3}{4}$ inches would be approximately six months old; a year later the mean length reaches about $12\frac{1}{2}$ inches, and at two years six months $18-18\frac{1}{2}$ inches.

It will be noted that Fulton's fishes were of the same size range as mine. Although it is always dangerous to compare growth in an aquarium with growth in the sea it is not without interest that his estimate of annual growth is of the same order as that which actually took place in captivity. If one could assume that both his anglers and mine obtained as much food as they felt naturally urged to eat, the difference between his smaller estimate and my records might conceivably be regarded as due to a difference in temperature. Bottom water in the northern North Sea is considerably colder throughout the year than that circulating in the Plymouth aquarium.

MOVEMENTS AND CAMOUFLAGE.

As has been often remarked by other writers angler-fishes are very poor swimmers. They can get along moderately fast by vigorous undulations of their stumpy bodies, but this looks and probably is an exhausting process. Once in mid-water they can plane down gracefully with outstretched pectoral fins, but on the whole they do not swim much, spending the greater part of their time resting quietly on the bottom. The paired fins are used for walking; the pelvics by virtue of their position under the widest part of the head raise the fish off the ground; they are used as legs and are assisted by the pectorals pushing against the

ground. The centre of gravity lies between the insertions of the pectorals and the pelvics. When the angler-fish settles down in sand or sandy gravel it digs for itself a small hollow to accommodate the deep rounded underparts of head and abdomen. The pelvics shovel the sand and any pebbles somewhat forwards and outwards and the pectorals push this material away to either side. The fish has remarkable control over the movements of the pectorals, they are used almost like webbed hands. In a few minutes the hollow is made and the angler then backs into it. One or both of the pectorals may flick a few grains of sand over the back. As the fish finally settles down it slightly raises the head and then lowers it rather smartly. By this action water is driven out from under the fish and, flowing away on all sides, spreads out the irregular tags of skin that fringe the lower jaw and sides of the body. The tags then settle neatly on the surface of the sand alongside. At the same time the pectorals spread themselves flat over the ground. In this position the coloured upper surface of the angler-fish is almost flush with the surrounding surface.

The angler-fish has very perfect powers of matching its colour and colour mottlings to the sand or gravel on which it is resting. I consider that once it has settled down and become fully colour-adapted it is more difficult to detect than the average flat-fish, unless the latter happens to be partially buried. Frequently I have been surprised at the time it has taken to discover the whereabouts, in a not very large tank, of an angler-fish known to be there. The disguise produced by the remarkable way in which the colour mottlings take on the tone and texture of the ground is heightened by the presence of the fringing tags, which break up the outline of the body and merge it most effectively with the surroundings (see Plate I).

When an angler-fish is really settled small bottom organisms crawling over it do not seem to cause disturbance. An *Aphrodite aculeata* has been seen to crawl rapidly across the head and eyes without the fish taking any apparent notice.

Certain individual angler-fishes would sometimes sit propped up among the rocks at one end of their tank. It may be that they were attracted by the small fishes (blennies, wrasses) that tended to congregate there, and the habit does at any rate suggest that from time to time they would naturally haunt rocky places in the sea. The suggestion made by some writers that an angler-fish simulates an irregular lump of rock with the tags resembling attached sedentary organisms should not therefore be dismissed too lightly. I am of the impression, however, that in such a position an angler is more readily perceived by other fishes, but the point is one that is difficult of proof.

RESPIRATION.

A peculiarity of the angler-fish and its relatives is the position of the gill-slit, which opens behind the pectoral fins instead of in front of them as in all other fishes. Viewed from above the slits are largely hidden by the pectoral fins, but their innermost and posterior corners open in the axils between these fins and the trunk. In the position in which the angler normally lies, the lower border of each slit is formed by a loose flap of skin, which in the above-mentioned axil is developed to form a somewhat spout-like structure, or perhaps a better comparison is to the lip of a jug

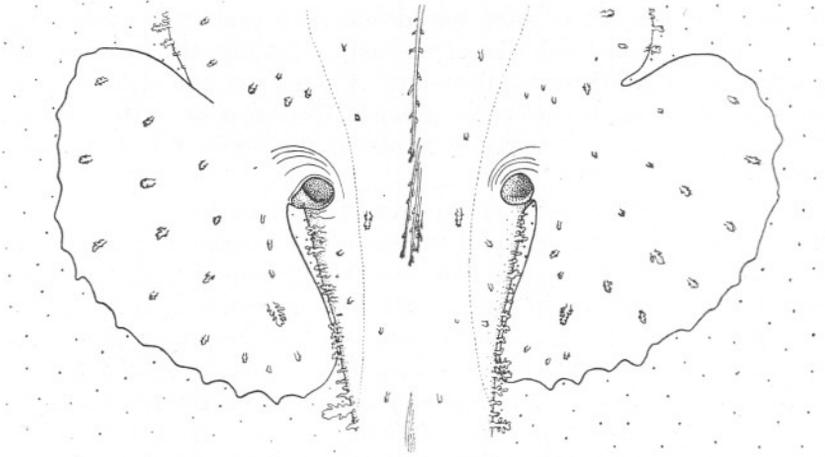


FIG. 2.—A sketch, based on a flashlight photograph, of the gill-slit apertures of an angler-fish during expiration, viewed from above.

turned upwards. The upper part of the slit is formed partly by the base of the pectoral, and partly by a loose flap of skin, lying in the axil, and stretching from the fin to the innermost posterior edge of the slit where it passes into the spout. Except during expiration the spout is covered by this loose dorsal flap of skin and is invisible from above. When expiration takes place the flap is drawn forwards to uncover the spout and with it forms a round hole (see Figure 2 and compare Plate I where the angler is not expiring). The upward curvature of the spout causes the expiratory current to be deflected vertically upwards. The expiratory currents, one from each side, were frequently so strong that the larger angler-fishes disturbed the surface of the water a foot or more above. The vertical deflection ensures that the sand around the lurking angler is undisturbed when it breathes, thus probably reducing to a minimum the chance of detection by its prey.

When a *Lophius* is quietly resting there is a long interval between the

beginning of one expiration and the next. At a temperature of 11° C. the following times were recorded.

1 minute 25 seconds.				1 minute 50 seconds.			
1	,,	56	,,	1	,,	42	,,
1	,,	44	,,	1	,,	40	,,
1	,,	38	,,				

One wonders whether these long intervals may not also assist the fishing, since they enable the angler to keep its body perfectly still while attracting its victims.

A typical respiratory cycle takes place as follows. For most of the period the angler-fish lies still with the mouth closed or nearly so. Towards the end of the period the mouth opens slightly and for some seconds inspiration takes place, the head rising slightly. The mouth is then closed, expiration follows immediately and lasts for a few seconds, the head sinking slowly down again.

While swallowing prey the respiratory rate is increased for several cycles. The resting periods are omitted, and the breathing movements are often more vigorous than usual. Perhaps the swallowing is thereby assisted, or maybe the energy expended in the capture demands an increased rate. On the other hand this increased rate has often accompanied the swallowing of dead fish placed in the mouth and accepted quietly without effort. The movements are genuine inspirations and expirations, not merely discharge of water taken in when catching prey.

USE OF THE LURE.

There is no doubt whatever that the first dorsal spine, or "rod," with its tag of skin, or "bait"—the whole being known as the "lure"—is used to attract fishes into reach of the mouth. This has not only been seen by Chadwick (1929) and others, but has been repeatedly confirmed by my own observations. An angler when hungry erects the lure immediately any suitable fishes come anywhere near and endeavours to attract one of them close enough to be caught. The lure is quickly jerked to and fro, and as the rod is almost invisible the bait (in my specimens always forked and "fly-like," not vermiform) simulates some tiny creature darting about. An attracted fish rushes up in an endeavour to catch it; the bait is skilfully flicked out of its way just in time and, with a final cast, is dashed down in front of the mouth which may open very slightly. The intended victim, still following the bait, turns slightly head downwards; it is now more or less directly head on to the angler's mouth. The jaws snap faster than the eye can follow, and the tail of the prey is next seen disappearing from sight through the firmly closed mouth.

As far as I have been able to observe the bait is not actually touched by the victim before it is caught, as has sometimes been supposed. Touching the bait with forceps does not cause a reflex snapping of the jaws.

The moving lure has a strong attraction for healthy hungry fishes of several kinds. Small pollack, whiting, pout, and bass were the species actually observed to be attracted to it, but probably most pelagic fish that capture moving prey by sight would at least swim up to investigate the darting object. Many fishes take a ready interest in moving things. A small angler crawling over the bottom of a tank into which it had just been placed aroused, as a rule, the curiosity of nearby fish, pollack and small dabs swimming towards it, keeping, however, at that time a safe distance away.

Besides the quick lashing motion of the lure just described, some anglers occasionally combine with it another movement. Every now and then the rod is depressed until the bait hangs just in front of and rather below the level of the lower jaw. It is then for a few seconds given a curious vibratory movement, after which the sharp flicking is again resumed, the bait being jerked over wide arcs in various directions.

The second to sixth spines of the dorsal fin are more conspicuous when raised than the lure; they generally bear numerous short tags of skin along their whole lengths, but lack special tags at their tips. I suspect, but have not been able definitely to prove, that they are sometimes used as an accessory lure. I have once or twice seen them waved from side to side when fish, which the angler presumably might desire to eat, were too distant for the lure to be readily visible. It seemed at the time that the angler was endeavouring to seize their attention, but unfortunately on these occasions the fish were newly brought in from the sea and were too damaged to behave normally. These spines are often kept raised, although quite still, when no fish are about. In the sea water-movements might gently wave the tags; on a fish swimming up to investigate, the lure proper would be brought into play to manoeuvre it in front of the mouth, the more vigorous motion of the bait now attracting the fish more than the spines, which in any case could be folded back. As a rule they remain erect while the angler is fishing.

The lure is not invariably used when prey is captured. Very often angler-fishes simply sit quite still until a fish chances to swim near enough. They can be very patient. Individuals vary much in this respect, some using the lure much more than others. When the lure is not in use it is depressed right back between the eyes, while the other dorsal spines may or may not be raised. Some individuals were often observed to direct the lure forwards horizontally across the mouth, keeping it quite still in that position for hours on end. Whether this has indicated hunger, and the rod was in a ready position for instant action, I have not been able

to determine satisfactorily, but suspect that hunger may have been the explanation.

Angler-fishes rarely chase their prey. Very occasionally I have seen them crawl towards some newly introduced pollack or similar fishes which they had been unable to attract, only to settle themselves down again and ply the lure from a nearer vantage point. If a fish passes a little to one side an angler may turn its head slightly towards it, but never more than the merest trifle. The movement is so slight that I have never seen a fish alarmed by it. To a practised eye the presence or absence of slight movements of the head and eyes, and other almost imperceptible signs, will show whether an angler-fish is hungry and interested in prey or not.

SEIZURE OF PREY.

The actual seizure of the prey takes place too quickly for the human eye to follow. One moment the pollack is there trying to catch the bait, the next the angler-fish is sinking back with the pollack's tail protruding from its jaws. In between there is a blur of rapid movement which defies analysis by straightforward observation. Certain points, however, seem clear and can be stated.

The angler-fish nearly always strikes when the fish is just in front and a little above the level of the mouth. The latter is almost completely closed, although there may be a slight anticipatory gape. The prey should be more or less head on and approaching slowly, although this is not an invariable rule. When the moment comes to strike it seems that the angler suddenly thrusts itself a short way upwards and forwards with the aid of the pelvic fins braced against the ground. Little assistance appears to be given by the pectorals. At the same instant the mouth opens and presumably the buccal cavity is rapidly enlarged, sucking in water and fish at the same time. The jaws snap and the angler sinks back into its sandy hollow to swallow its captive in more leisurely fashion. The tail slowly disappears between the angler's lips, the fish, which always lies on its side, being drawn in and swallowed head first. The heavy breathing movements that occur during swallowing have already been described (p. 487). As the still struggling fish passes down the oesophagus and reaches the stomach its captor sometimes shivers a little as at a queer sensation.

It is well known that when the mouth of an angler-fish is closed the lower jaw projects a considerable distance in front of the upper. This leaves a well-marked gap between the two jaws. The gap is closed by a flap, pigmented on its upper surface, which is attached below the rows of lower teeth and projects freely backwards towards the upper jaw behind. This flap among other functions seems to play an important part in preventing the escape of prey, especially when a fish has to be turned in the

buccal cavity preparatory to being swallowed head first. When a fish has been caught broadside on, and has not been very firmly held between upper and lower teeth, I have watched this flap gradually and carefully worked over the fish, starting from one end or the middle.

Guitel (1891) suggests that swallowing is assisted by the very mobile superior and inferior pharyngeal teeth, which by a to and fro action drag the prey in through the jaws and pass it back into the throat. This may very well be so; the point could be investigated with an X-ray apparatus.

The angler-fish always endeavours to seize its prey head first, but is sometimes unsuccessful, especially if it strikes at a fish swimming over it from behind forwards, or one that is crossing the jaws at right angles to the body axis. In these circumstances it is quite common for the fish to be seized by the middle of the body, both head and tail projecting from the jaws. The head is usually drawn in first, not without difficulty as the angler's hold must be loosened an instant and there is a chance of the prey escaping. Occasionally the fish may be caught tail first, leaving the head projecting; this is drawn in—one or two careful gulps may be necessary—and I believe, but cannot be sure, that on such an occasion the fish is turned round within the buccal cavity so as to be swallowed head first.

The few flat-fishes I have seen taken were always caught head first as they were approaching from directly in front. My impression is that greater care is taken to seize flat-fishes in this way and that they are not as much esteemed as round fishes. On one occasion when a small dab was lying across its mouth an angler-fish struck at a young whiting. The whiting was caught by the middle of the body, but in the action the dab was sucked in through the mouth. The presence of the dab obviously disconcerted the angler which seemingly tried to swallow it first while still holding the whiting. After some seconds, however, it released the latter and swallowed the dab, several pronounced gulps being required to get it down. The whiting was caught and swallowed a few minutes later, after which no further interest was shown in food.

The incident just related was the only occasion on which I have seen more than one fish caught simultaneously. I believe that an angler-fish takes care, as a rule, that not more than one shall be seized at once, especially if the fishes be of a fair size relative to itself. It seems too that a captured fish must be completely swallowed before the angler is ready to strike again.

An angler-fish rarely misses; only once or twice have I seen it happen, the intended victim dashing off in great alarm. An angler does not strike unless capture is a reasonable certainty. Once or twice an angler-fish has released a well-caught fish, probably because it was too large and struggled too violently for it to be swallowed in comfort, the angler perhaps not being extremely hungry at the time.

AMOUNT OF FOOD TAKEN AT ONE MEAL.

Lophius has long had a reputation for gluttony that seems to be based only on the size of its mouth, an occasional well-filled stomach, and on the fact that fishes are often found in its buccal cavity when the trawl is hauled. These latter, at any rate, almost certainly got there by accident, for should an angler, in its struggles amid the densely packed cod-end, happen to open its mouth an assortment of creatures will immediately fall through the gape and it will be almost impossible to eject them. Some, indeed, the angler may even be forced to swallow.

In captivity an angler is no more gluttonous than any other fish, and perhaps less so than some. The number of fishes it will take at a meal varies, of course, with their size and the hunger of the angler. Generally speaking an angler that has been feeding regularly will take one or two, occasionally even three, round fishes such as pollack when they are about equal in length to the width of its mouth. It will then refuse food for two or three days, when it is again ready for a meal. It seems to take about two days for the stomach to empty itself of one meal and prepare for the next. Quite often an angler that has been induced to take food on the day following a meal has been sick a few hours afterwards, frequently during the night. The partially digested remains of both meals have been readily distinguishable, one meal being more macerated than the other.

SIZE OF THE FISHES TAKEN.

It was quite evident from my observations that the captive angler-fishes much preferred their prey to be on the relatively small side. Out of a number of different sized pollack they would definitely try to select those shorter than the widths of their mouths, and would regularly refuse to strike at those which well exceeded these widths, even though hungry and given excellent chances of catching them. Quite often I have seen a relatively large pollack hover in perfect safety close above an angler's mouth, although a little later smaller fish of the same species would be eaten. In general it can be stated that a fish as long as an angler's mouth is wide is the maximum size normally taken. Very occasionally I have watched an angler swallow a fish larger than this, and no doubt they will take such when more than ordinarily hungry. On the other hand, it is already recorded how angler-fishes will sometimes release large and powerful fish they have seized (see p. 490). There is no question that the act of releasing was always deliberate on the part of the captor; it always had a good and powerful grip on the prey.

These observations accord with Fulton's remark that "the great majority of the fishes found in the stomachs were small even when the angler was large." Now and again relatively very large fishes are found in the stomachs of angler-fishes: perhaps a really ravenous angler will strike

at prey larger than usual, and no doubt individuals vary to some extent in their prejudices as regards size.

SPECIES EATEN.

The angler-fish shows distinct preferences for certain types of fish. There is little doubt that it will eat readily soft-finned round fishes such as pollack, whiting, pout, grey mullet, and clupeoids, while on the whole avoiding species with strong spines or of unusual shapes. A small shoal of gadoids or of clupeoids (such as a bucketful of "brit") released in its tank instantly evokes excitement and interest, whereas wrasses, sticklebacks, and flat-fishes have in my experience failed to arouse this response. As mentioned previously, flat-fishes are swallowed, but only, I think, when the angler is really hungry and other species are not available—at least this is true for the small angler-fishes I have kept. I have never seen a wrasse fished for or caught, although there is some slight evidence that occasionally they have been taken when no observer was present. On the other hand, dead wrasses, both *Ctenolabrus rupestris* (L.) and *Labrus bergyllta* Ascanius, have been repeatedly fed by hand to several young angler-fishes. The slow and hesitating manner in which these and other dead fishes were usually swallowed was in marked contrast to the quick certainty with which naturally seized living fish were dispatched.

Some species have been repeatedly refused; these were *Agonus cataphractus* (L.), *Trigla hirundo* Bloch, *Spinachia vulgaris* Flem., and *Syngnathus acus* L. Several times a suitably sized gurnard has given more than one angler-fish several excellent opportunities to catch it. Once or twice as it was passing within easy reach an angler has made to strike and then hesitated. It was reported to me by witnesses that one angler-fish did seize a gurnard swimming over it amid a shoal of pollack, but that it released it immediately. I once saw a fifteen-spined stickleback caught twice in succession and each time released, the angler-fish taking no further interest in it. The stickleback continued to live in the angler's tank for seven weeks afterwards; it showed no signs of damage, and doubtless owed its life to its hard protective coverings and the stiffness of its body. The same angler regularly swallowed considerably larger pollack.

In addition to the species already mentioned as being readily eaten by my angler-fishes some others were taken from time to time. Chief among these were gobies, *Gobius minutus* Pallas certainly, and possibly also *G. paganellus* L. The shanny, *Blennius pholis* L., was caught once or twice, and on one occasion a Lesser Weever, *Trachinus vipera* Cuv. & Val., was swallowed without ill effect. It happened by accident; the angler in question was lying in wait for a small shoal of pollack and whiting living in the tank into which it had just been put for feeding purposes. These fish were passing close by, but just out of reach, when a net,

accidentally dropped into the tank, hit a buried weever some distance away. The weever dashed off in a direction heading for the angler's mouth, approaching from in front; it was seized with amazing speed and immediately swallowed head first, its struggling tail protruding for a few seconds. The angler-fish seemed to suffer no inconvenience from the weever's poison spines and duly digested it before taking further food.

Bass occupy an anomalous position in the dietary of my angler-fishes. There was a shoal of small ones in the feeding tank at a time (January, 1936) when I had two angler-fishes in perfect health. One (No. 2) was about $17\frac{1}{2}$ inches long; the other (No. 4) was about $11\frac{1}{2}$ inches long. The bass were roughly half the length of the maximum sized pollack No. 4 was taking and were therefore suitably sized prey for both. The larger angler would catch and swallow them readily whenever it was given the chance, but the smaller persistently refused to strike at them. On several occasions when the bass were attracted to its bait, and hovered around its mouth in easy position for capture, this angler-fish deliberately folded back the lure into the position of rest and would not resume fishing until they had wandered away. It was quite evident that this angler preferred the pollack also present in the tank, and that it did not want the bass. Had the spiny fins of the bass anything to do with this, and would this angler have eaten the bass had they been still smaller? We can only guess. Guitel, however, records that his angler-fish ate a bass half its own length: was his desperately hungry?

Fulton (1903) has examined and analysed the stomach contents of five hundred and forty-one angler-fishes caught mainly in the Moray Firth, Aberdeen Bay, and off the Shetlands. Nearly half the stomachs were empty and were "shrunk and collapsed, with thick walls, probably showing that a considerable interval had elapsed since a meal had been obtained." The remaining half contained mostly the remains of fishes with a small admixture of cephalopods and crustaceans. Of the fishes about seventy per cent were round fishes, mainly whittings, haddocks, codlings, sand-eels, and herrings with an occasional *Agonus*, gurnard, lesser weever, Norway pout, and *Lumpenus*. Flat-fishes comprised roughly thirty per cent of the fish food and of these common dabs were by far the most numerous, solenettes, long rough dabs, plaice and flounders being also eaten. It will be seen that these observations on the stomach contents of anglers caught in the sea agree closely with the conclusions arrived at from the study of living anglers in captivity.

There are fairly frequent records in the literature of sea-birds having been swallowed by angler-fishes. The indications are that the birds are seized on the surface, the anglers coming up below them. Whilst it does not seem usual for angler-fishes to go after their prey in this way they may so behave when very hungry.

SOME REACTIONS OF FISHES TO THE PRESENCE OF AN ANGLER.

When living fishes are put into a tank containing an angler-fish they do not immediately become aware of its presence, and the same remark applies when an angler-fish has been induced to settle down in a tank containing fishes fully acclimatized to that tank. Bottom fishes such as dabs and gurnards have several times been seen resting on an angler-fish large enough to swallow them, sometimes even lying across the mouth without showing awareness of danger. Small pollack have accidentally touched an angler's soft body and not shown signs that they were aware of its nature. In the ordinary way fish rarely or never perceive the angler once it has merged itself with the bottom as already described (p. 485). Even when one of the members of a small shoal of pollack had been attracted away and caught close-by, its companions gave no indications of alarm.

After some time in the tank of the angler, a fish that has not been caught will gradually become aware of the danger to which it is exposed and will then keep well out of reach. Small pout and pollack have survived thus for several weeks until one day, while less wary than usual, or when upset by a sudden fright, they have swum too near and been eaten. Fish aware of an angler are not attracted by its lure. Small pout, wrasses and blennies would circle round food dropped on an angler's back, always keeping at a respectful distance. Food dropped well away from the angler would be rushed for at once, but only once or twice has a rather large wrasse been so bold as to sneak up behind and take food from the back of the angler, and then only from a part some distance from the mouth.

Fish therefore can learn to avoid an angler-fish, but whether they do so in the sea is a matter for speculation. Fulton (1903, p. 199) seems to think that they may: his opinion is that "the rarity of the large fishes in the stomach of the angler probably points to their greater caution than when younger. Experience, no doubt, teaches them more readily to detect and to avoid the formidable lurking trap which forms part of their natural environment." While this may be true it may also be due partly, perhaps mainly, to the angler's habit of avoiding, as a rule, the capture of relatively large prey.

REGENERATION OF THE LURE.

The lure is of such prime importance to an angler-fish that its loss might be attended with serious consequences. Aristotle has remarked on the thin state of anglers that had lost their baits. It is a delicate organ and easily damaged. No doubt it is not essential and an angler-fish might still be able to capture stray fish that chanced to wander near, but in a sparsely populated region this might not occur sufficiently often to keep it well fed. If it is lost, can it be replaced?

I have good reason to believe that this is so. When, a month after its arrival, my first angler-fish was carefully compared side by side with another of exactly the same size freshly caught but dead, it seemed evident that the former's lure was missing. The organ was present and easily seen in the dead specimen, but could not be found in the living fish, although the knob on which it should articulate was clearly present in front of the true second spine. Thereafter, watch was kept for any sign of regeneration. For about the next four weeks, when the fish was kept in a shallow bowl, a careful and almost daily examination was made in a good light, but nothing rod-like was seen. At the end of this period the angler was placed in a small glass-fronted tank in the public part of the aquarium and it was there difficult to observe fine anatomical details with certainty. During the last fortnight before it died close observation was not made, but two days before death attention was attracted by what appeared to be a tuft of fine skin or mucus which seemed to be attached to the skin on the inner side of the right eye; this had not previously been seen. On removing the fish from the tank after death it was at once obvious that this tuft was none other than a well-formed bait on the top of a fishing rod normal in appearance. The conclusion reached was that the lure had been regenerated—assuming that previously it had had one and lost it in the sea or in the trawl—while the angler-fish had been living in the aquarium tank.

SUMMARY.

1. Young angler-fishes have been kept alive and in health for periods varying from a few weeks to eleven months. They were sometimes hand-fed on dead fishes and sometimes allowed to catch living prey. They grew at an average rate of about eight and a half inches per annum. All had strongly marked individual characters.

2. With pelvic and pectoral fins a slight hollow is made in the sand into which the angler settles itself. Its upper surface is now flush with the ground, and the colour and colour mottlings are closely matched to the surroundings. The bordering tags of skin break up the outline.

3. Breathing movements occur at relatively long intervals. The expiratory currents are discharged in the axils between the pectoral fins and the trunk, and are deflected vertically upwards.

4. When fishing the lure is jerked smartly in all directions. Small fishes are snapped up, one at a time, as they try to catch the bait. They are generally seized and swallowed head first. The second to sixth dorsal spines and their tags possibly function as secondary lures when attracting fish from a distance.

5. The angler-fishes usually fed every two or three days. The largest sized fish taken was, as a rule, as long as the angler's mouth was wide. One or two such fishes would form a meal.

6. Angler-fishes appear to prefer gadoids, clupeoids, and similar soft-finned round fishes to any others. They will eat flat-fishes, but not so eagerly.

7. A lurking angler is not readily detected by other fish. In time, if they are not caught, they become aware of its presence in their tank and keep away.

8. If the lure is lost there is evidence that it is regenerated.

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EXPLANATION OF PLATE I.

Photograph of an Angler-fish (*Lophius piscatorius* L.), 7 $\frac{3}{4}$ inches long, resting on the bottom of its tank and fully colour-adapted to its surroundings. It had dug for itself a slight hollow in the sandy gravel and was known to stay in this place for at least six hours. The lure is held forwards, the rod crossing the mouth horizontally. The divided bait, dark in tone, is clearly visible at the middle point of the lower jaw, between it and the light-toned piece of gravel to the right of the umbo of the *Nassa* shell. The lure is being held perfectly still; no fish are in sight. The second to sixth dorsal spines are depressed.

Technical data: One magnesium flash on the right side. Ilford Soft Gradation Panchromatic plate. No filter. f/44. Taken through the surface of the water: depth about fourteen inches.



Photo. D.P. Wilson.

John Bale Sore & Danielsen, 11th London.

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