XI.

ARE MIGRATING EELS DETERRED BY A RANGE OF LIGHTS—REPORT
ON EXPERIMENTAL TESTS.

By PROF. PHILIP COX, Ph. D., etc., *University of New Brunswick.*

Some one had ventured the opinion, on what grounds I know not, that such a device is effectual, and I was requested to test it by a series of experiments at the Biological Station, St. Andrews, in the summer of 1913. As the common eel, *Anguilla chrysopa*, is known to be a persistent and voracious spawn-eater, its exclusion by any means from the spawning grounds of lake and river food-fishes would be of vast importance to those fisheries, and give a stimulus to the restocking of new or depleted waters.

No fact is better known to the small boy who builds his fire at the water's edge after night, than that eels are attracted by the light; but will they come fully into and pass through it?

Two series of experiments were conducted: the first, in one of the tanks in the laboratory; the second on a larger scale and under more normal conditions in the outlook of Bocabec lake, 12 miles from the station.

Experiment I, July 27.—In a tray, 7 feet by 3 feet and 3 inches deep, were placed five eels which had been taken from a fresh-water lake, and gradually passed through water of increasing degrees of salinity until the average was reached. Water was admitted through a tap, provided with a jet attachment, and the stream struck the surface at a very acute angle, keeping the tray well oxygenated. Across the tank, and resting on the sides $2\frac{1}{2}$ feet from the upper end, was a broad board on which an acetylene lamp stood, screened behind so that the lower part was dark, the other brightly lighted, and the line of demarcation between the two sharp and well defined. It was remarkable how soon the fish seemed to accommodate themselves to the increasingly salt medium, which at first made them apparently very uncomfortable but at the end of two or three hours failed to have any apparent disturbing effect at all. One fish, a very large one, had been in the tray two days before the experiment began; the rest were placed there in the afternoon of the evening when the first trial was made.

July 27.

Experiment I.

At 9 p.m. the fish were screened to the lower end of the tray, the laboratory darkened and the lamp lighted.

9.26. An eel moved into the light, swam to the end of the illuminated space, turned and disappeared in darkness. This was the large one which had been imprisoned two days.

9.30. Another moved half-way into the light and rested there.

9.36. It swam out into the lighted area, turned, stopped for a minute or two, and disappeared.

10.50. One has pushed its nose to the illuminated line.

10.52. It dropped back into darkness.

11.30. Another, the large one, has drawn up close to the lighted line.

11.45. Another has moved up to the same place.

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- 12.00. The former has moved into the lighted space. raises its muzzle above the surface, and then swims back into darkness.
12.18. The same fish returns into the light, raises its nose above the water, and remains motionless.
12.23. It returns to the shadow.
12.35. A small individual has passed into the light.
12.38. It returns to darkness.
12.45. Another has gone into the light.
12.48. It returns to the shadow.

July 28.

Experiment II.

- 10.10 p.m. Lamp lighted and room darkened.
10.15. Big eel has gone into the light.
10.55. Returns to darkness when a more intense light was made.
11.00. The same fish has moved into the light.
11.15. Has returned to darkness.
11.25. The same one has returned, but only head in the light.
11.36. It passes fully into the light.
11.50. Returns into the shadow.
12.05. Extinguished light.
12.10. Turned on the light suddenly. One was in upper part of tray, and the others that had remained most of the evening in the lower part had moved far up.

Several evenings were devoted to the observation of these fish, but their actions and movements were quite similar to those recorded above, except that the longer they were kept in confinement, the less they seemed to avoid the light.

It was thought that more satisfactory results could be obtained by conducting the experiments under more natural conditions, and for this purpose the outlet of lake Bocabec was chosen. It was admirably suited for the purpose, flowing through a level little valley, had a smooth clay and sandy bottom, water from 5 to 7 inches deep, with a gentle current, and banks regular, grassy, and slightly undermined, here and there affording a cool retreat for the eels during the day.

Two wire screens about 10 rods apart were stretched over the stream, there about 12 feet wide, and sunk some inches into the bottom and banks to prevent the eels from escaping by borrowing.

Two large bullseye lanterns were arranged, one on each side at the level of the water directly opposite and facing each other. The arrangement made rendered it impossible for a fish to pass without being seen by the observer.

Seven large eels were got from a fisherman who had caught them in a herring weir that day, and were placed in the pond just before noon hour, August 15. They showed the effects of a sudden change from salt to fresh water in a more marked manner than the first lot did on being transferred from a fresh to a brackish medium. Restlessness, rapid breathing, gasping, swimming from one end of the enclosure to the other, seeking to surmount the barrier, wheeling and moving rapidly to the other end, opening the mouth widely and swelling the gill region to a marked degree; all these symptoms continued with gradually lessening intensity until about 6 p.m., when most of them were quieter and breathed more moderately and regularly. During that afternoon and next day, they showed no tendency to huddle or seek concealment, but lay out in the open stream, one here and one there, but on the third day they were active in seeking hiding places and huddled. It would seem as if the open free life is the natural one to these large fish, but it is probably otherwise with smaller ones, though young ones from 5 to 7 cm. in length will swarm up an inlet from the sea all day under direct sunlight.

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Late in the evening when it begins to grow dark, they become very active, issuing from their retreats, and heading up stream, one by one.

All the eels were driven below the line of the lamps, and the latter lighted at 8.45.

Experiment III.

9.45. One ran past, but manifesting uneasiness returned to darkness a minute or two later. I should have observed that the lights were only about 6 feet below the upper screen, hence the intervening space was fairly well lighted up, but planks across just below, made a marked line of division between the two.

10.00 Another runs past, but returns almost immediately.

10.20. Another passes the light but goes back into the shadow at once.

10.30. Another acts in a similar manner.

11.10. One passes; three or four lying just below the line of light, but they soon drew back.

11.30. Another ran by.

11.40. Another ran by.

11.50. Another ran by.

All of these soon returned to darkness. During the rest of the vigil an hour or more, the fish as a whole lay in darkness, and, though restless and active, avoided the light.

In a general way they repeated the movements of those observed in the trays—approached the light cautiously, lay motionless for some time just below the lighted line, then passed into and through the lighted area. It was not until the third night that any rested more than a few minutes in the light.

Though the fish were about the same size and could not be distinguished one from another, the above record would seem to point to the majority or all of them having passed the range of lamps during the night. They were fish fresh from the sea, and their behaviour may be taken as representative of the species under similar conditions, and hence had there been no screen above the lamps they would have all passed and entered the lake. Still it must be noted that these fish had been impounded eight or nine hours before the lamps were lighted, and their experience in the meantime, as well as the painful effects of changed osmotic pressure, may have, on the first night at least, modified their otherwise natural actions. Still their movements the next two nights were very similar; for a failure to secure fresh lots of fish, so late in the summer, obliged the experimenter to use the same fish all the time.

They always evinced a desire to run upstream at nightfall, but after eleven o'clock very few attempted it, contenting themselves with remaining in the darkened area, where they were often heard splashing and moving rapidly about, sometimes trying to surmount the screen, at others twisting and turning violently in the middle of the stream. With the exception of a few fry of the minnow, *Coueslas plumbus* Ag., in the upper or lighted part of the inclosure, there was no food visible except a few weeds here and there.

Before closing the vigil one night, I looked over the lower part to see where the fish were, when one was seen to scud away from the light of my lantern, which suggested the trial of a *moving* light. Next night one was suspended over the middle of the stream, midway between the bullseyes and a little above, and kept swinging crosswise the stream by means of a cord. For two or three hours none ventured to pass, and hope ran high that the problem had been solved. They came up to the line of light beforementioned, and pushing the head just beyond, lay motionless for a half hour or so, as if watching the moving object, then they withdrew, only to repeat the action some minutes later. About midnight, however, one after another gradually drew into the lighted area, until all I had impounded were lying side by side, only a few inches apart. One after the other, curving the anterior half of the body upwards

and resting the other half on the bottom, thrust the head out of the water far enough to expose the muzzle and eyes, and there they remained ogre-like, to an extraordinary degree, and motionless, as if watching intently the moving light. In a few minutes they began to sink back slowly and almost imperceptibly, and withdrew into darkness. Next night, this singular behaviour was not observed except in one case. The eels paused at the line of light, but after a half hour or so, began to shoot rapidly past and remained in the upper part of the lighted area the rest of the night. Less and less fear of the swinging lamp was manifested night after night, until they seemed to pay little or no attention to it.

It has been remarked that when first put in, the fish showed no schooling tendency, indeed seemed to manifest distrust of one another; but as time passed, they became more social, and would often be seen during the day lying side by side under the overhanging bank. When disturbed they scudded into the stream, stirred up a cloud of mud at one point, when it settled only the head of the eel could be discerned. It was at length seen that the fish buried itself tail first. All the time the water was gradually falling and its temperature rising, and at length the eels ceased to lie by day under the bank, but their heads were to be seen here and there, though barely visible in the mud. Trial was made, and its temperature was found to be several degrees cooler than that of the water—a good reason for the fish burying themselves in it.

It will be seen that these two experiments were conducted under some objectionable conditions:—

- (1) The fish were penned, not free.
- (2) They had been taken from salt water and put into fresh water or vice versa, without in one case passing through slowly changing degrees of salinity.
- (3) The season for migration to fresh water had long passed.

Waiving the modifying influences of these conditions and summing up the results of the tests we see evidence that—

- (1) The fish were certainly afraid of the light at night. They would pause on the line of illumination; move slowly until about half the body was exposed, and then hurry past. As a rule, they soon returned to darkness, though after three or four nights experience they would linger a long time in the light.
- (2) The longer they were in the pen, the less fear they showed.
- (3) The moving light was at first fairly effective, but after a night or two they paid little attention to it.
- (4) That they failed to appear except at rare intervals in the illuminated end of the pen after the third night was probably due to a growing consciousness of their being impounded.

All things considered it seems very unlikely that their ascent could be arrested by such means.