frog, the ryanodine-ATP brought about an intense rigor within a few minutes, whereas ryanodine alone ordinarily causes rigor in 3–4 hrs. Ryanodine-ATP injections caused a 9-fold increase in oxygen consumption in the roach, and in one case, where the ATP had been warmed to 45° C and then cooled to room temperature before mixing with the ryanodine, the oxygen consumption was increased to 18 times normal following injection. In the intact roach the ryanodine-ATP effect was reversible in the concentrations used. In the intact frog and the rectus preparations the rigor produced was irreversible.

These results strengthen our belief that ryanodine acts specifically on the contractile process in striated muscle and indicate that the mode of action is probably one of interference with the phosphagen-ATP-ADP-actomyosin cycle during contraction.

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The Homing Tendency of Shad

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Two of the important problems in the study of shad populations along the Atlantic coast have been to determine to what extent shad return to the stream of their origin and to determine at what age they reach maturity. Shad are anadromous fish that enter the streams of the Atlantic coast in the spring to spawn, often migrating several hundred miles into fresh water for this purpose. It is known that the resulting young spend the first several months of their existence in fresh and brackish water, feeding and growing, and in the fall leave their fluvial environment for an unknown migration into the ocean, where they stay until maturity. That shad do return to the stream of their nativity has not been demonstrated. The age at maturity has received the attention of a number of investigators. Most have based their conclusions on scale markings, which they have recognized as being difficult to interpret.

Leim (*4*), reading markings believed to be winter rings on the scales from shad taken in the Shubenacadie River, placed the age of mature shad on these spawning grounds at at least 4 years; most he believed to be 5 years old or over, the maximum age being 8 or 9 years. Marks believed to be indicative of previous spawnings were noted on some of the scales.

Borodin (*2*) worked primarily with scales obtained from shad of the Connecticut River system. Because of the lack of distinctness of the annual marks, he counted the number of transverse grooves as well as annual marks —the number of complete transverse grooves divided by two being considered the true age when annuli were unreadable. Borodin concluded that a few male shad enter the rivers as 4-year-old fish, but that most of the males which he examined from the Connecticut River in 1924 were 5–7 years old. The females were determined to be 7 or more years of age. In addition, he pointed out the distinctiveness of the first and fourth annulus, comparing the latter to the "spawn marks" of salmon.

Barney (*1*) confirmed Borodin's observations, using otoliths. In a footnote (p. 57) Barney states that a single 3-year-old buck was taken from the Salmon River, but that this was unusual.

Greeley (*3*) examined scales collected from Hudson River shad and found great variance in the relative distinctness of annuli. He concluded that, though both roes and bucks may mature at 3 years, females in this age group were in the minority, and suggested as probable that "many fish of both sexes, but particularly roe fish, remain at sea during their third year and do not mature until four years old. It is entirely possible that a small percentage of these fish might be immature at an even greater age."

The lack of agreement in the various findings may be due to inherent differences in behavior of populations of the several streams or to differences of interpretation of scale markings for which experimental evidence is lacking. Obviously, the most direct method for interpreting scale markings and for determining age at maturity is to mark the young shad of known age and obtain scale samples from them at known intervals. This marking of young shad was attempted by Robert A. Nesbit and the author on several occasions, but the marking always resulted in the death of the young shad within a few days, presumably because of the injury inflicted in tagging and handling.

In 1941 I was able to tag successfully juvenile hatchery-reared shad by holding them in Ringer's solution, after tagging, until the incisions were healed. To date, three of the tagged fish have been reported. All of these were recaptured within a radius of 10 miles from their point of release, 3, 4, and 5 years after tagging.

The shad were pond reared at the U. S. Fish and Wildlife Service's hatchery located near Edenton, North Carolina. The eggs were collected and fertilized by standard hatchery procedure on April 24, 1941, placed in McDonald jars, and hatched in running water. On April 29, 1941, about 50,000 of the newly hatched fish were placed in a pond of 0.8 acre with a maximum depth of 5′. From then until October the shad were fed with a commercial fish food. On October 10 the pond level was gradually lowered to facilitate seining. The young shad were tagged from October 11 to 15. The fish at this time averaged about 10 cm in length.

The tag used was red celluloid, 20/1,000″ thick, 9/16″ in length, and 3/16″ in width, with ends rounded.

[1] I wish to express appreciation to Robert A. Nesbit for his guidance in this experiment, to William C. Bunch, superintendent of the U. S. Fisheries Station, Edenton, North Carolina, and his staff for their assistance and interest, and to Ralph C. Hammer for his assistance in the tagging procedure.

On one side of the tag was printed a serial number and the notation "$1.00 Reward," and on the reverse, "Fish and Wildlife, Washington, D. C." The printing was done in black.

The young fish were seined from the pond in lots of about 100, placed in a tub, carried about 125′ to the site of tagging, dipped individually from the tub with a small net, and tagged. Great care was taken to avoid bruising them. They were picked from the net with wet cotton gloves, placed on a mat of soaked cotton, and held in place by the gloved hand during the operation. An incision was made into the abdominal cavity with a sharp, pointed, removable-blade scalpel just anterior to the vent and following the course of the myomeres. With fine-pointed forceps the tag was grasped by one end, the other end being inserted into the body cavity and pushed forward following the inner body wall. Each tagged fish was then placed in an adjacent tank of Ringer's solution.

The holding tanks were originally designed for the rearing of *Daphnia*. Each of these was made of concrete, measured 30′ in length and 7′ in width, and had a sloping bottom. The average depth of the filled tank was 2′. The Ringer's solution was prepared from the following formula: NaCl, 0.7%; KCl, 0.03%; $CaCl_2$, 0.025%; $NaHCO_3$, 0.003%.

The tagged fish were held in Ringer's solution until October 28, at which time they were seined from the tanks and released in Pembroke Creek, on which the hatchery is located, ½ mile above its mouth.

Over the 5-day period 2,466 fish were marked. During the holding time (13–17 days) 1,388 fish died or lost their tags (56.3% mortality). From the 1,078 fish released, three returns have been made.

Not all of the fish tagged (and presumably released) were shad. Among the tagged fish which died during the holding period a number of specimens were found which proved to be the young of river herring. These, in all probability, were introduced into the rearing pond as eggs when the pond was filled. No tags have been returned from river herring.

The particulars of the tagged shad recovered are given below.

(1) A shad bearing tag number 1057 was caught April 17, 1944, in Albemarle Sound, two miles below Chowan River bridge. The finder told me that he had caught the fish himself in a haul seine and had cleaned the fish and disposed of the offal before noticing the tag adhering to the body wall, held in place by a thin, transparent membrane. He could not recall the sex of the shad at the time I talked with him, but he stated that the shad was small and "spawned out."

(2) A roe shad bearing tag number 1412 was caught March 22, 1945. This fish was purchased by an Edenton, North Carolina, housewife from a fisherman operating at Skinner's Point on Albemarle Sound. The tag was embedded in a roe and was not noticed until the roe had been cooked and was being divided for serving.

(3) Tag number 539 was found lying free between the roes of a shad purchased from a haul seiner operating in the Chowan River near Edenton, North Carolina. This shad was caught April 3, 1946.

One other tag discovery has been reported from Skinner's Point, but this discovery is unsubstantiated by the return of the tag itself.

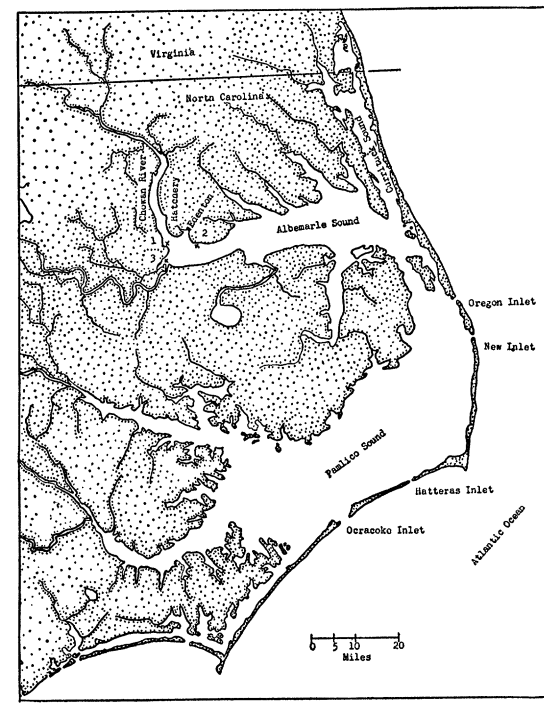

FIG. 1

Unfortunately I was unable to obtain scales from any of the three fish mentioned above and therefore was unable to determine the nature of the scale markings. Spawning marks appear to be formed by the absorption of part of the anterior periphery of the scale at the time the shad enters fresh water to spawn. This mark shows up in strong contrast to that portion of the scale deposited between spawning migrations. Had scales been available from these returned fish, it should have been possible to determine whether they were recaptured on a first or a subsequent migration.

The fact that all of the returns were made from the immediate vicinity of the place at which the young shad were released and that no returns were made from other areas in this complex system of waterways (Fig. 1) is consistent with the theory that shad do return to the stream of their nativity.

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