Spectacle Development in the Pygmy Sunfish, Elassoma Zonatum, With Observations on Spawning Habits[1]

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Moore and Sisk (1963) described the spectacle of the adult *Elassoma zonatum* Jordan and set forth criteria for establishing the spectacle of *Elassoma* as a primary or secondary structure on the basis of its morphological ontogeny. Since there appears to be no physical difference between primary and secondary spectacles they concluded, "If a species develops a spectacle during embryonic life in such a manner that the spectacular space is bounded by dermis and corneal dura, rather than having an epidermal lining, that species has a primary spectacle which may persit through metamorphosis or fuse with the dura. If no larval

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spectacle is present, the epidermis and dermis may split away from the dura to produce a secondary spectacle. . . It, therefore, would appear that the only practical classification of spectacles is one based on ontological morphology."

The initial purpose of this research was to classify the spectacle of *Elassoma* by examining sections of the eyes of developing embryonic and postembryonic fish. While acquiring eggs and individuals at various stages of development, I was able to observe spawning activity.

During the summer (1963) no specimens young enough for a comprehensive study were procured. An Academic Year Extension, also financed by NSF, permitted me to continue the project through the winter and spring (1964) and to make periodic collections at Wallace Lake, southeast of Wright City, McCurtain County, Oklahoma, and in the city spring in Fort Towson at the upper end of Lake Raymond Gary, Choctaw County, Oklahoma. Fish in spawning condition, collected from both locations on March 2, subsequently produced offspring in laboratory aquaria.

Periodic examination of the developing fish indicated that the eyes of *E. zonatum* became functional at seven to nine days from the time the eggs were laid. I observed slight eye movement on the seventh day and the angle of movement increased rapidly until a range comparable to that of the adult was reached on the tenth day. Definite visual responses to bright light were not noted until the eighth day. At nine days strong responses were stimulated by the movement of any close object toward the fish. The eye rotated toward the object and the fish immediately swam away.

Specimens of embryonic, larval, and juvenile fish were fixed in formalin, dehydrated, temporarily stained in erythrosin and embedded in celloidin at daily intervals for 24 days. Sections were cut at eight microns and stained with Mallory's triple connective-tissue stain.

Examination of the prepared slides showed a direct correlation between the functional movements of the eye of *E. zonatum* and the development of the spectacle. A rudimentary temporary sulcus, consisting of a small indentation in the skin in the normal position of a sulcus, is present in young *Elassoma* (Fig. 1). Near this area the spectacle begins its separa-

LEGEND TO THE FIGURES

Figure 1. 6-day *Elassoma* eye, vertical section, showing rudimentary sulcus before spectacle formation.

Figure 2. 7-day *Elassoma* eye, vertical section, showing the beginning of spectacle formation. Note that the head skin is losing the deep indentation at the periphery of the eye.

Figure 3. 9-day *Elassoma* eye, vertical section, showing tissue separation in an advanced state. Note the change in cell structure of the epidermis.

Figure 4. Adult *Elassoma* eye, vertical section, through the optic nerve, from Moore and Sisk (1963), showing the fully developed spectacle.

Symbols.

C, choriocapillaris; CH, choroid; CF, connective tissue fibers; ES, extent of tissue separation in spectacle formation; HS, head skin; I, iris; IR, inferior rectus: L, lens; ON, optic nerve; R, retina; S, spectacle; SC, sclera; SP, substantia propria; SR, superior rectus.

tion from the substantia propria (Figs. 2, 3). Presumedly the muscular action of the turning eyeball coupled with resistance occasioned by the imperfect sulcus produces the separation that proceeds to work its way through the cornea to form the adult spectacle. The rudimentary sulcus, never fully functional, smooths out as the fish develops and becomes nonexistant in the late juvenile and adult (Figs. 3, 4).

The first split of the tissues covering the eye occurred in seven-day-old fish (3.1 mm total length). This consisted of a narrow space that developed between the dermis and the substantia propria in the peripheral margin of the eye. Sections of older fish indicated that the spectacle is nearly complete in nine-day (3.4 mm) fish and allows for free movement in individ-

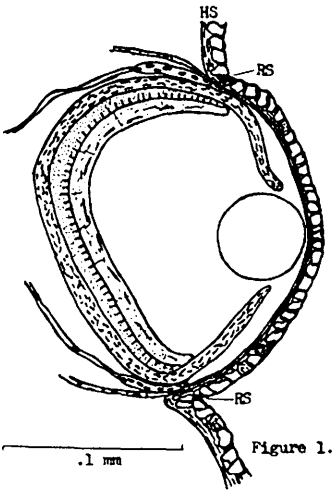
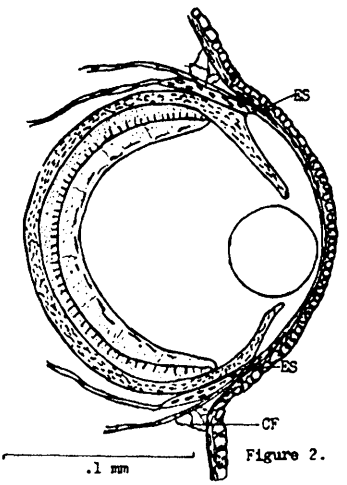


Figure 1.



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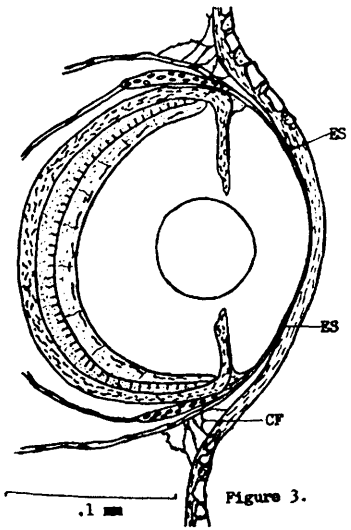

Figure 3.

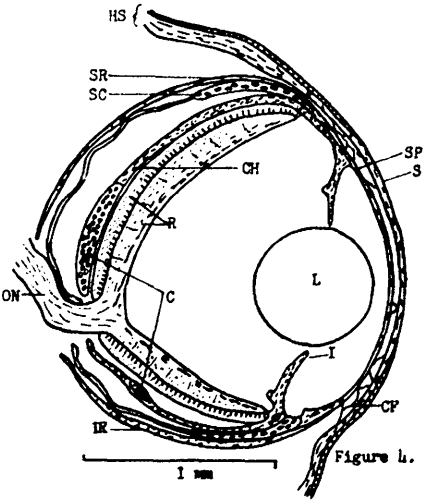

Figure 4.

uals which have reached an age of 12 to 14 days (3.9 to 4.4 mm). It is evident that the rate at which the corneal tissue separates in spectacle formation is influenced by the action of the extrinsic ocular muscles. Without their development and subsequent efforts to rotate the eye it is doubtful that the spectacle would ever develop, at least not beyond the periphery of the eye. It would be interesting to determine to what degree the spectacle would develop in *Elassoma* experimentally deprived of muscular rotation of the eye.

It is evident, then, that the spectacle of *Elassoma zonatum* is properly a secondary structure that develops entirely during the juvenile life of the fish.

The purpose, if any, of the spectacle development in *Elassoma* is not clear. It has been suggested that spectacles are developed by many species as protective structures for the eye for various environmental reasons. This does not seem to fit *Elassoma,* because its habits and habitat seem not to warrant a specialized protective structure any more than for the many fishes, of similar habit and habitats, that do not develop them.

SPAWNING

Specimens used for observations of spawning were those obtained from the Fort Towson and Wright City locations for the purpose of studying development of the spectacle. These fish were placed in aquaria containing *Myriophyllum* sp. that floated at or near the surface and extended to the bottom, covered by decaying oak leaves and twigs. The water temperature was 74F.

Male *Elassoma* became quite active in the aquaria in early January. Their breeding color developed with a general darkening; the vertical barring became jet black. The pale iridescent green spot, present between the vertical bars just behind the pectoral girdle, became more intense and the fins were banded with black. The females did not develop breeding color until the approach of spawning in late February or early March, and then did not develop dark barring, but became rather evenly dark purple-brown in color. At night when there was little or no spawning activity the color was paler in both sexes, although not as pale as in nonspawning specimens.

Breeding males swam about in the vegetation near the surface, apparently searching for suitable spawning locations. Spawning occurred immediately above vegetation that served to catch a large number of the demersal, adhesive eggs. A typical spawning site consisted of two or more branches of *Myriophyllum,* crossing to form a mat of leaves or roots close to the surface and usually at a depth of less than two inches of water. The breeding male, apparently selecting a particular site, become dominant in the surrounding locality, chasing away other males and sometimes females. This territory extended about eight to ten inches radially from where eggs were eventually deposited.

The male, having selected a territory, began to court females. Most spawning activity occurred during the early morning; it slowed during late afternoon and ceased at night. Usually many failures occurred before the male attracted a fully receptive female and spawned. The dominant male approached other *Elassoma* entering his territory with a menacing attitude of aggressiveness in which he moved toward them with his body tightly curved laterally away from the fish, moving only by rapid pectoral fin motion. Miller (1963) described a similar action for *Elassoma evergladei* that she termed the "sidling threat display". Male trespassers darted away and, if not quickly enough, were fiercely bitten by the dominant male. Females entering the territory were approached more slowly, and if they did not dart away, the male as if sensing their interest, began a maneuver

that usually led to the female following him toward the spawning location. This maneuver consisted of one to four rapid vertical undulations in a sort of dance movement that began with a downward thrust of the head as the back was arched upward, carrying the undulation through the caudal region. The fish remained in a nearly horizontal plane during the maneuver. Miller (1963) described a similar body movement with accompanying fin motions for courting males of *E. evergladei* that she termed the "wiggle waggle display". If the female did not approach the male she was driven from his territory just as were the males.

When the female followed, the male led her toward the selected spawning site. Usually the female would stop short of the location, as if not knowing exactly where to go, and the male would repeat his "spawning dance" as many times as it was effective in getting the female to continue following. Often the female got very close to the selected location before darting away. When this happened she was usually chased and bitten by the male. If the female was ready to lay her eggs she followed the male to the chosen area after one or two of his enticement maneuvers. The male swam into the chosen locality and stopped briefly, possibly to indicate the site to the female. He then moved out to a position just beneath this spawning site and the female swam into his vacated position.

As soon as the female was in the spawning locality the male swam up to her and began vibrating his snout on her abdominal region. Soon the female began vibrating her whole body, and the eggs were issued rapidly. As the first eggs were emitted, the male moved to a position beside the female and deposited his milt.

After the completion of spawning the male swam away first; then the female left the spawning site and showed no further interest in the eggs. The total time for the action, after the female was in position, was less than ten seconds. The male soon returned to guard the eggs, which except for a few that fell to the bottom or clung to the lower branches, formed a cluster in the vegetation. Poyser (1919) indicated that *Elassoma* spawned in open water and allowed the eggs to fall indiscriminately to the bottom from seven to eleven inches above. Barney and Anson (1920) indicated that they found no eggs near the surface in the natural habitat, but found many from 6 to 24 inches beneath the surface scattered among *Ceratophyllum* strands which they supposed had accidently obstructed the fall of the eggs to the bottom. The differences between these observations of spawning and mine may be due to differences in the behavior patterns of geographically isolated populations, or possibly to the differences in the available environment. My observations of the spawning of *Elassoma* clearly indicated that males actually sought out spawning sites in dense vegetation near the surface in aquaria with vegetation equally distributed from top to bottom. The vegetation served as an unprepared nest for the eggs.

The aggressiveness of the male within his territory increased with the presence of eggs, although he continued efforts to attract any female that approached to spawn. Eggs of additional spawns were sometimes placed in another location in the immediate vicinity, or upon the existing egg mass. The male always guarded the newest eggs more closely than the older ones, and it was easy to locate a new spawn in the aquarium by the position and behavior of the male, which swam around beneath the eggs, closely watching them. Occasionally, he would swim over and through the clinging mass of eggs, apparently fanning them with his pectoral fins. Only the pectorals were used for locomotion necessary for these slow passes over the eggs and the male remained over the eggs only as long as it took to make passes. Male *Elassoma* retained their particular territoriality throughout their spawning period. Hatching of eggs, which took 48 to 60 hours at 74F, did not influence the activity of the males which

often spawned again in the same location. Barney and Anson (1920) found that the incubation period for *Elassoma* eggs at 65F was seven days.

Female *Elassoma* heavy with eggs could be found slowly swimming near the bottom or resting on the bottom of the aquarium. They avoided the territories being guarded by the active males. During this time the females fed readily on amphipods and white worms whereas ripe males rarely fed actively, and did not leave their territory for this purpose. On at least four occasions males which had tried unsuccessfully to spawn early in the season took a stationary position in the aquarium, refused to eat, and died within a few days.

A given female spawned several times, and the number of eggs decreased during successive spawnings. The first spawn contained as many as 40 to 50 eggs, but near the end of the spawning period eggs were not as numerous, appearing singly or in small groups of 2 to 5, more or less scattered through the vegetation. The first spawning in the aquarium was on March 9, and involved fish collected a week before. Some fish collected later (April 19) were still spawning in the aquarium on May 11, when my observations ceased.

Toward the end of the spawning period both sexes began to lose color and males lost their aggressive attitudes although they remained near the region in which they had been active earlier as long as eggs were present.

Females had become quite ragged by the end of spawning, their median fins torn by numerous bites of the chasing males, and they became more active after spawning was completed. Males which had completed spawning attempted to leave the spawning site, but were often chased by other males that were still spawning. These males then moved into the upper vegetation where they lay motionless, away from the breeding males. Those that did get out of the spawning area resumed nonspawning behavior.

Barney and Anson (1920) found that 67.5 per cent of 404 specimens collected during the spawning season were females; they reported that late in the spawning season all adults became more scarce. This information corresponds with my limited observations.

Literature Cited

Barney, R. L. and B. J. Anson. 1920. Life history and ecology of the pygmy sunfish, *Elassoma zonatum*. Ecol. 1(4):241-256.

Miller, Helen Carter. 1963. The behavior of the pumpkinseed sunfish, *Lepomis gibbosus* (Linnaeus), with notes on the behavior of other species of *Lepomis* and the pigmy sunfish, *Elassoma evergladei*. Behaviour 22(2):88-151.

Moore, G. A. and M. E. Sisk. 1963. The spectacle of *Elassoma zonatum*. Copeia 1963 (2):347-350.

Poyser, W. A. 1919. Notes on the breeding habits of pigmy sunfish. Aquatic Life 4(5):65-69.