FUNCTIONAL ASPECTS OF THE NOTOCHORDAL APPENDAGE OF YOUNG-OF-THE-YEAR GAR (*LEPISOSTEUS*)

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Young-of-the-year gar (*Lepisosteus*) possess a unique filamentous fin-like structure arising near the base of the caudal fin and lying superior to it. This primitive notochordal appendage can be turned in any direction. It is capable of rapid oscillations, as are the small pectoral fins which have transparent outer vanes. The coordinated, almost imperceptible, fluttering movements of the notochordal appendage and the pectoral fins propel the young-of-the-year gar in any direction, the effect being a mimic of a drifting twig or willow leaf. This mechanism of motion is used by this predatory fish to stalk its food. The notochordal appendage and transparent vanes of the pectoral fins disappear when the gar reaches approximately 30 cm in length.

The gars (gar-pikes) of the genus *Lepisosteus* (Lepisosteidae, Lepisosteiformes) are among the most primitive of living fish today. Found in the larger freshwater bodies of eastern North America, they are resident in Oklahoma's larger streams, lakes, and reservoirs.

A characteristic of the young-of-the-year of this genus is the presence of a median filamentous fin-like structure arising near the base of the caudal fin and lying superior to it. This appendage is a posterior extension of the primitive notochord (Fig. 1).

This notochordal fin-like appendage is very functional in small gar providing a unique type of mobility for this predatory fish. Louis Agassiz (1) was the first to note the movements of this structure which is recorded in the minutes of a meeting of the Boston Society of Natural History where he is quoted as saying — "They were remarkable, — as still preserving certain embryological characters. The most conspicuous of these was the prolongation of the vertebral column in the form of a fleshy filament distinct from the caudal fin, which had at times a vibrating motion, involuntary, and quite distinct from the motions of the tail itself, as seen in some embryos. This singular formation shows that the caudal fin is properly an appendage of the lower surface of the dorsal column, a true second anal, and not the proper termination of the column."

Subsequent to Agassiz's brief observations nothing that I am aware of, other than Wilder (2), has appeared in printed form

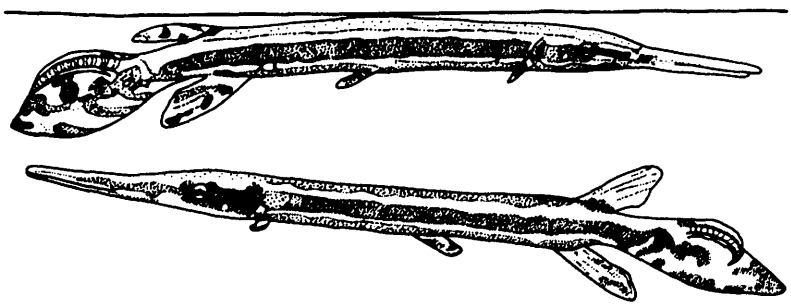

FIGURE 1. Young-of-the-year gar (*Lepisosteus* sp.) measuring approximately 10 cm in total length. Top: At rest at surface with notochordal appendange and pectoral fins immobile. Bottom: Moving backwards slowly, pectoral fins fluttering anteriorly, the notochordal appendage extending left-lateral and fluttering at its top. All figures (including following) taken from 16 mm motion picture film.

relating to the functional aspects of this notochordal appendage. Wilder, after referring to Agassiz's observations, states — "In fact, during vibration, the filament is invisible. But the motion is not involuntary as is that of cilia or unstriped muscle fibers. For at times the filament is wholly at rest; it may be elevated or depressed, curved to the one side or to the other, and more or less rapidly vibrated in any of these positions."

During mid to late summer young-of-the-year gar are available in Lake Texoma, in the vicinity of the University of Oklahoma Biological Station. Nine young-of-the-year gar measuring between 7.5 cm and 14 cm were obtained between 3 and 11 July, 1974 and placed in aquaria for observations on notochordal appendage actions. These observations have continued to date, and have been recorded on 16 mm motion picture film for detailed analysis. Most actions were observed by viewing through a magnifying glass held up to the active fish in the aquaria.

The characteristics of my young-of-the-year gar do not fit the descriptions for similarly sized alligator gar (*Lepisosteus spatula*) described by May and Echelle (3) or the postlarval form noted by Moore, Trautman and Curd (4). The two species of gar most abundant in the region of the University of Oklahoma Biological Station are the spotted gar (*Lepisosteus oculatus*) and the longnose gar (*Lepisosteus osseus*). It is my belief that all young-of-the-year gar exhibit the notochordal appendage as a functional unit since this structure is present on the illustrations of the cited references (3, 4).

The notochordal appendage arises as a posterior longitudinal projection in line with the vertebral column dorsal to the much larger caudal fin and extends to a length equaling the caudal fin. This filament-like structure has both a dorsal (broadest) and ventral vane and thus appears and functions as an auxiliary fin, unique for this small fish's mode of operation. In life the filamentous shaft or core tapers from the base to the tip and is light reddish-brown or pink in color, while the vanes are transparent — almost invisible —

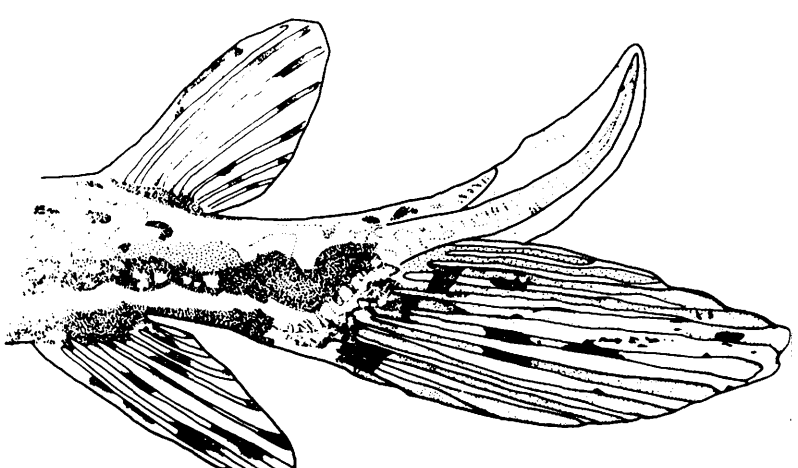

FIGURE 2. Lateral view of the notochordal appendage and caudal fin of a young-of-the-year gar. This position and that of Fig. 3 indicate how this structure can be brought forward along the central plane.

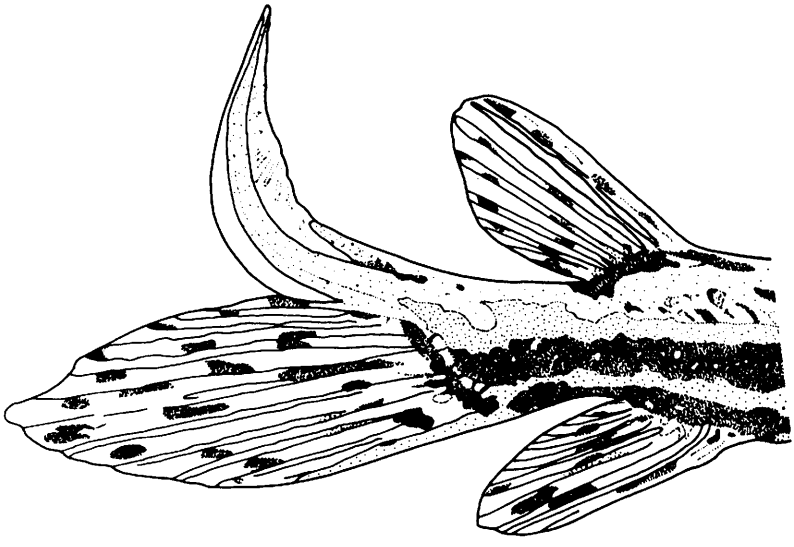

FIGURE 3. Lateral view of the notochordal appendage and caudal fin. Note that the notochordal appendage can bend forward behind the directly vertical plane. The ray-like structures of the dorsal vane of the notochordal appendage appear as the wave-like flutter moves from the proximal to the distal region along the vanes.

to the unaided eye, the dorsal vane being highest in its center and tapering only at the tip. The basal area of the dorsal vane appears to form a partial sheath which has some pigmentation. The vanes appear to be supported by almost imperceptible "rays" extending from the filament to the outer edges of the vanes (Figs. 2, 3, and 4).

The pair of small pectoral fins are rounded, fleshy lobes arising just ventro-lateral to the opercular openings. From each lobe a broad, rounded, vane arises near the center of the anterior surface and nearer the end of the lobe posteriorly (Fig. 5). The fleshy lobe is well-pigmented and easily discernable to the unaided eye, while the vane extensions are transparent, being slightly pigmented at the base. Under magnification the vanes have very faint radiating lines suggesting supporting "rays".

Using only the actions of the notochordal appendage in coordination with the movements of the pectoral fins, the young-of-the-year gar is able to propel itself with almost imperceptible locomotory actions through the water - maneuvering forward, backward, laterally, pitched with head up or down.

At rest the notochordal appendage extends straight posteriorly, the shaft paralleling the caudal fin, or with the tip pointing dorsally (Fig. 1 and 2).

Forward movement is accomplished with the notochordal appendage extended straight posteriad (Fig. 1); the tip only may wave or beat laterally, or the beat may extend to various distances along the course of the entire filament, the latter producing more apparent force. The movement of the filament is rapid and appears both to the unaided eye and under magnification as a "flutter-like" movement. Movements of the pectoral fins (especially the membranous outer vane or fringe) may accompany the movements of the filament in producing forward locomotion, the lobes of the pector-

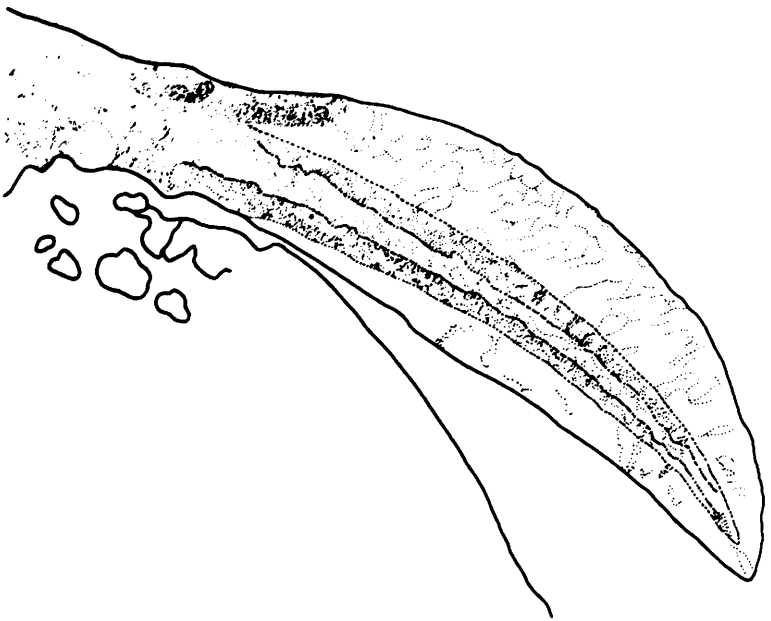

FIGURE 4. Enlarged lateral view of the notochordal appendage indicating pigmentation. The vanes are apparent against a dark background but are transparent against a light background.

al fins projecting down and slightly posterior, the vanes beating rapidly with a similar flutter-like movement. The caudal fin extends posteriad and usually does not move. A small movement in the basal lobe region of the pectoral fin produces a much greater movement in the distal fluttering vane.

During backward locomotion, the pectoral fins are usually active, but they are now projecting down and slightly forward, the fluttering vanes producing a force posteriorly. The arrangement of the notochordal appendage is now greatly altered and functions with the caudal fin serving as a directional rudder, if turning is involved. If moving straight backwards, the caudal fin is little involved, while the notochordal filament is curved laterally and down (to either side), the tip often projecting below the plane of the ventral margin of the caudal fin (Fig. 6). The oscillation or fluttering of the notochordal appendage in this position, aided by the rapidly beating pectoral fins, propels the young-of-the-year gar backwards. More often when moving backwards, the fish is also turning and when this happens the caudal fin is bent laterally, along with the base of the tail, to the side of the turning motion. The fluttering notochordal appendage position with the posterior turning motion may parallel the alignment of the caudal fin or may be decurved beside the caudal fin (Figs. 6 and 7).

For rapid swimming movements, the caudal fin is waved or undulated vigorously while the dorsal and anal fins appear to serve as rudders, the pelvic fins as stabilizers. During the slow stalking actions of the young-of-the-year gar, no movements were noticed in the dorsal, anal, or pelvic fins.

The rate of oscillation or flutter of the notochordal appendage and pectoral fins have been determined from 16 mm motion pictures (taken at speeds of 16 f/s, 32 f/s, and 50 f/s) by using a Vanguard Motion

FIGURE 5. Enlarged view of the pectoral fins of a young-of-the-year gar. The left (near fin) is presented laterally, the right (far fin) presents its anterior surface showing the transparent vane with ray-like radiations.

Analyzer. It was apparent to this observer that the rate of flutter varied from very slow single waves to volleys of very rapid oscillations. Of those motion picture sequences from which these movements could be determined, the notochordal filament had a maximum beat rate of 15 to 16 beats per second, with the majority of volleys ranging between 3 and 8 beats per second (film taken at 32 f/s) and 10 to 15 beats per second (film taken at 50 f/s). This indicates that the slower speed of 32 f/s may not capture all of the motion, or that those volleys taken at 50 f/s happened to be faster volleys. A volley, as here used, was a series of 10 successive beats from one side to the other and back.

Similarly, the rate of flutter for the pectoral fins was from 5 to 7 beats per second, with a maximum of 9 to 10 (film taken at 32 f/s), while at 50 f/s the rate for most

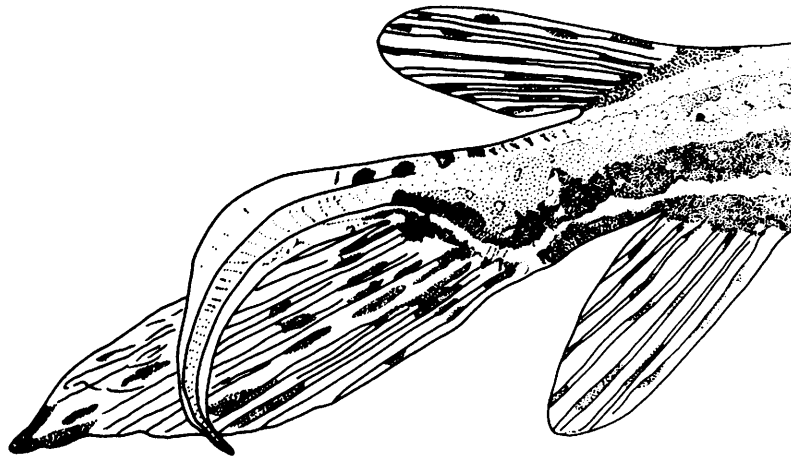

FIGURE 6. Lateral view of the notochordal appendage turned ventral to the right of the caudal fin during slow backward movement.

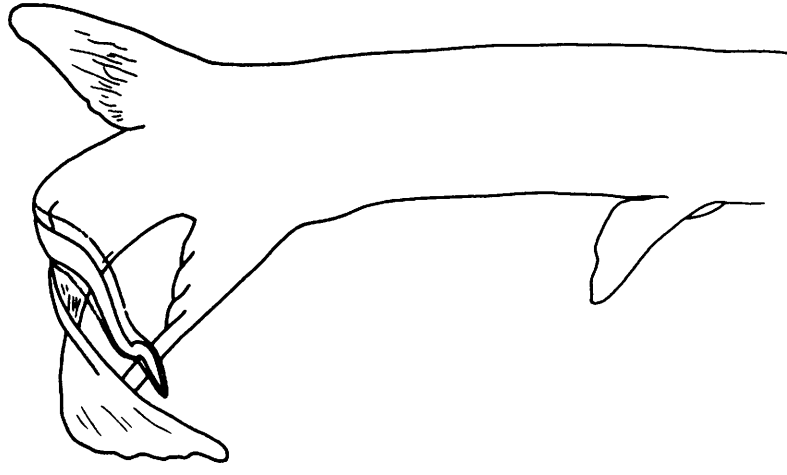

FIGURE 7. Lateral view of the notochordal appendage and caudal fin during rapid backward movement and turning right, the caudal fin acting as a rudder and also waving for propulsion.

fell between 10 and 15 beats per second, with one volley reaching 18 beats per second.

These data indicate that both the notochordal appendage and pectoral fins are capable of very rapid actions which produce the flutter-like movements by the nature of their rapid short spatial movement, and, because of the transparency of their vanes, are not readily visible.

Under magnification during fluttering of the notochordal appendage, the vanes appear to ripple, that is, the movement of the vanes begins near the base and "undulates laterally" toward the tip, reminiscent of this type of movement along the dorsal fin of the bowfin (*Amia calva*) and the bichirs (*Polypterus*).

The young-of-the-year gar often assume postures with their longitudinal axes pitched head up or down and are capable of moving up or down (maintaining this pitch) by use of only the notochordal appendage and pectoral fins. The notochordal appendage may also be used to brake forward movement by curving laterally.

They can change direction, very slowly, by bending the notochordal appendage to one side or the other, only the tip fluttering, the pectoral fins fluttering at different rates, or one fin immobile, the other fluttering, the gar turning on its dorso-ventral axis, while moving slowly forward or rotating around one point. Thus, the slow versatile movements of this fish are controlled by particular actions of the notochordal appendage, or this structure in coordination with the pectoral fins.

Young-of-the-year gar spend much time resting just below the surface of the water. In this stance the fish is immobile, all fins inactive, the notochordal appendage lying dorsal to and parallel to the caudal fin. When resting on the bottom, the young gar usually pitches with the head up at from 10 to 30 degrees, the posterior ventral area of the caudal fin slightly folded and resting on the bottom, the ventral tip of the anal fin also in contact with the bottom.

These movements in themselves may not seem to be unique, for most fishes are capable of these directional movements, however, the almost imperceptible flutter of the notochordal appendage (especially the tip) and the transparency of the membranous vanes of the pectoral fins move the gar in a manner such that locomotory movements are very difficult to discern — the effect being a mimic of a slowly drifting twig or willow leaf. In the area of the University of Oklahoma Biological Station where these young-of-the-year gar were observed in backwater locations, willow leaves are commonly drifting on the surface and mimic similarity of these small gar to such leaves is striking. In an aquarium, small gar stalk a small fish (*Gambusia affinis*) using the above described mechanism, approaching as if drifting slowly towards its prey, no readily apparent motion visible, then when its snout is within a few mm of the prey, it snaps laterally, very rapidly, catching the prey perpendicularly in its jaws, which are provided with numerous sharp teeth.

The notochordal appendage disappears with growth in length, as do the transparent vanes or fringes of the pectoral fins, though sufficient data are not available to state at what length this happens. The notochordal appendage and pectoral vanes appear to grow proportionate to the rest of the young gar, at least until 15 cm or more in length. Wilder (2) states that for a specimen 30 cm in length the notochordal appendage had almost completely disappeared, appearing as a degenerating filament lying dorsally along the basal portion of the much larger caudal fin. Wilder also referred to Agassiz (5) as stating — "That conformation persists until the fish is about 2 decimeters, or 8 inches in length." Gar larger than approximately 30 cm show no signs of the notochordal appendage or the transparent pectoral vanes — the pectoral fins in these larger individuals are totally pigmented. The final word on the size at which the notochordal appendage ceases its fluttering function, disappears, is completely incorporated into the caudal fin, or degenerates, must await further study.

ACKNOWLEDGMENT

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