FOSSIL TUNA VERTEBRAE PUNCTURED BY ISTIOPHORID BILLFISHES

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Extant billfishes of the family Istiophoridae (Teleostei: Perciformes: Scombridae) often use their rostra to impale or slash prey (Gudge, 1940; Nakamura, 1983; Frazier et al., 1994). Although it is generally assumed that fossil and living representatives of the same species have similar behaviors and physiology (Fierstine, 2001), there is no documentation of a fossil istiophorid billfish using its rostrum for food capture. The Yorktown Formation (early Pliocene) at Lee Creek Mine, eastern North Carolina, USA, has yielded the world's largest collection of fossils of the family Istiophoridae (Fierstine, 2001), and an abundant number of vertebrae belonging to tunas of the genus Thunnus (Purdy et al., 2001), have five extant species, all of which are prey of istiophorid billfishes (Nakamura, 1983). We offer evidence that puncture marks in five tuna vertebrae collected at Lee Creek Mine were the result of impalement by istiophorids.

MATERIALS AND METHODS

We follow Robins et al. (1991) for scientific and common names for recent species of fish, institutional abbreviations of Leviton et al. (1985), and osteological terminology of Gregory and Conrad (1937) and Potthoff (1974). All material examined (Tables 1, 2) is housed in one of the following institutions: Los Angeles County Museum (LACM), North Carolina Museum of Natural Sciences (NCSM), or National Museum of Natural History (USNM). Over 3,000 fossil Thunnus vertebrae from the Lee Creek Mine, Beaufort County, North Carolina, were examined from the collections of NCSM and USNM for evidence of punctures. Fossil vertebrae were compared with those of extant Thunnus species to substantiate identification, determine position in the vertebral column, and to estimate sizes of fish. Linear measurements of vertebrae were made to the nearest 0.5 mm (Table 1). Perch length (FL) is the straight-line measurement from tip of snout to fork of caudal fin (Thunnus and from tip of upper jaw to fork of caudal fin (Family Istiophoridae). All species of Thunnus have 15 or 19 precaudal vertebrae and 21 or 20 caudal vertebrae, for a total of 38 to 40 vertebrae (Gilbert and Collette, 1967). Rostra of various extant istiophorids were inserted into each puncture mark to determine if they fit into the hole. The rostrum with the "best" fit of the rostra tested was recorded as the approximate size of the istiophorid that made the puncture mark.

RESULTS

Five fossil tuna vertebrae (NCSM 12683, 12684, and 49441, 49442) collected at Lee Creek Mine, North Carolina, have a single puncture mark in each of their centra. Each mark is round to oval in cross-section, has its largest diameter on the lateral surface of the centrum, and terminates by a hinge of bone in the coelous intercentral space (e.g., Fig. 1B). If these weren't fossil specimens, one might consider each hole to have been made by a fishermen's gaff. None of the five punctured vertebrae showed evidence of being ingered; there is no visible etching of the bone.

NCSM 12683 (Fig. 1A, B) is a posterior caudal vertebra similar in size and shape (Table 1) to vertebrae 34 or 35 (from the anterior part of the peduncular keel) of a bluefin tuna (Thunnus thynnus) of 1,670 mm FL (USNM 269885; Table 2). The puncture mark enters the right dorso-lateral fossa of the centrum and extends into the posterior coelous space. The tip of the rostrum of an 86 kg blue marlin (Makaira nigricans; LACM 25321) fits the hole in the centrum (Table 2).

NCSM 12684 (Fig. 1C, D) is a posterior caudal vertebra similar in size and shape (Table 1) to vertebrae 33 or 35 from the anterior part of the peduncular keel of a bluefin tuna of 1,767 mm FL (USNM 269987; Table 2). The puncture mark enters the left dorso-lateral fossa of the centrum and extends into the posterior coelous space. The tip of the rostrum of a 123 kg blue marlin (Makaira nigricans; LACM 25320) fits the hole in the centrum (Table 2).

NCSM 16990 (Fig. 1E, F) is a middle caudal vertebra similar in size and shape (Table 1) to vertebrae 27 or 28 (located just anterior to the peduncular keel) of a bluefin tuna of approximately 1,360 mm FL (USNM 269980; Table 2). The puncture mark enters the right ventro-lateral fossa of the centrum and extends into the anterior coelous space. The tip of the rostrum of a 23 kg white marlin (Tetrapterus albidus; LACM 25504) fits the hole in the centrum (Table 2).

USNM 49441 (unfigured) is an anterior caudal vertebra similar in size and shape (Table 1) to vertebrae 22 or 23 (located in the middle of the body) of a bluefin tuna of approximately 1,380 mm FL (USNM 268980; Table 2). The puncture mark enters the left dorso-lateral fossa of the centrum and extends into the anterior coelous space. The tip of the rostrum of a 52 kg blue marlin (Makaira nigricans; LACM 25409) fits the hole in the centrum (Table 2).

USNM 49442 (unfigured) is an anterior caudal vertebra similar in size and shape (Table 1) to vertebrae 19 or 20 (located in the middle of the body) of a bluefin tuna of approximately 1,350 mm FL (USNM 268980; Table 2). The puncture mark enters the right dorso-lateral fossa of the centrum and extends into the posterior coelous space. The tip of the rostrum of a 27 kg white marlin (Tetrapterus albidus; NCSM 31294) fits the hole in the centrum (Table 2).

DISCUSSION AND CONCLUSIONS

Various factors limited the scope of our study. Because each fossil vertebra was incomplete and missing many of its diagnostic features (e.g., spines, articular processes), we were unable to identify any of them beyond the generic level, and only able to estimate the size of the fish and the position of the vertebra in the vertebral column. We never made an exhaustive search for the perfect fit between istiophorid rostrum and puncture hole, because most species of istiophorid billfish of similar size have a similar-shaped rostral tip. Our curiosity was satisfied when we determined that an istiophorid billfish of similar size has a similar-shaped rostral tip. Our curiosity was satisfied when we determined that an istiophorid billfish of similar size has a similar-shaped rostral tip. Our curiosity was satisfied when we determined that an istiophorid billfish of similar size has a similar-shaped rostral tip. Our curiosity was satisfied when we determined that an istiophorid billfish of similar size has a similar-shaped rostral tip. Our curiosity was satisfied when we determined that an istiophorid billfish of similar size has a similar-shaped rostral tip.
TABLE 1. Measurements (mm) of vertebrae of the genus *Thunnus* from Lee Creek Mine, Yorktown Formation (Early Pliocene), North Carolina, U.S.A.

<table>
<thead>
<tr>
<th>Museum Number</th>
<th>Centrum Length (measured ventrally)</th>
<th>Anterior Surface Height</th>
<th>Anterior Surface Width</th>
<th>Posterior Surface Height</th>
<th>Posterior Surface Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCSM 12683</td>
<td>43.4</td>
<td>33.9</td>
<td>42.6</td>
<td>28.3</td>
<td>38.3</td>
</tr>
<tr>
<td>NCSM 12684</td>
<td>51.1</td>
<td>37.7</td>
<td>53.0</td>
<td>37.0</td>
<td>51.0</td>
</tr>
<tr>
<td>NCSM 16990</td>
<td>31.7</td>
<td>30.0</td>
<td>36.0</td>
<td>30.0</td>
<td>37.3</td>
</tr>
<tr>
<td>USNM 494441</td>
<td>29.9</td>
<td>27.5</td>
<td>31.7</td>
<td>27.3</td>
<td>32.3</td>
</tr>
<tr>
<td>USNM 494442</td>
<td>30.4</td>
<td>30.7</td>
<td>36.3</td>
<td>30.1</td>
<td>—</td>
</tr>
</tbody>
</table>

TABLE 2. Fork lengths and weights from five extant species used as comparative skeletal material.

<table>
<thead>
<tr>
<th>Species</th>
<th>Museum Number</th>
<th>Fork Length (mm)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Thunnus atlanticus</em></td>
<td>LACM 37930-2</td>
<td>614</td>
<td>—</td>
</tr>
<tr>
<td><em>T. thynnus</em></td>
<td>USNM 268980</td>
<td>1257–1314*</td>
<td>38–43*</td>
</tr>
<tr>
<td><em>T. thynnus</em></td>
<td>USNM 268982</td>
<td>1793</td>
<td>est. 112</td>
</tr>
<tr>
<td><em>T. thynnus</em></td>
<td>USNM 268985</td>
<td>1670</td>
<td>est. 92</td>
</tr>
<tr>
<td><em>Istiophorus platypterus</em></td>
<td>LACM 25341</td>
<td>1460</td>
<td>14</td>
</tr>
<tr>
<td><em>Makaira nigricans</em></td>
<td>LACM 25320</td>
<td>2362</td>
<td>123</td>
</tr>
<tr>
<td><em>M. nigricans</em></td>
<td>LACM 25321</td>
<td>2210</td>
<td>89</td>
</tr>
<tr>
<td><em>M. nigricans</em></td>
<td>LACM 25330</td>
<td>2223</td>
<td>85</td>
</tr>
<tr>
<td><em>M. nigricans</em></td>
<td>LACM 25409</td>
<td>2120</td>
<td>82</td>
</tr>
<tr>
<td><em>Tetrapterus albidas</em></td>
<td>LACM 25504</td>
<td>1643</td>
<td>23</td>
</tr>
<tr>
<td><em>T. albidas</em></td>
<td>NCSM 31294</td>
<td>1854</td>
<td>27</td>
</tr>
</tbody>
</table>

*Specimen was part of a lot and only length and weight ranges were provided.

FIGURE 1. Three fossil caudal vertebrae of the genus *Thunnus* with puncture marks attributed to the rostrum of an istiophorid billfish, from the Yorktown Formation, early Pliocene, at Lee Creek Mine, North Carolina. NCSM 12683, right lateral view (AI), posterior view (A2), close-up of puncture from posterior view (A3); NCSM 12684, left lateral view (B1), posterior view (B2), close-up of puncture from left lateral view (B3); NCSM 16990, right lateral view (C1), anterior view (C2), close-up of puncture from right lateral view (C3). Arrows indicate puncture marks. Scale equals 10 mm.
vertebrae. We do not believe that marine mammals were responsible for the wounds because they have numerous teeth, one of which probably would have made an additional wound in at least one of the vertebrae examined. Also, the teeth of Orya and Physeter, which are spaced apart to puncture a vertebrae only once, are much more robust than an istiophorid rostrum and would thus not make the narrow piercing hole found in the Thunnus vertebrae.

When marlin impale their food they usually pierce it once or twice in the region of the body, then return to swallow the stunned prey (Wisner, 1958; Talbot and Pearsea, 1962; Strasburg, 1969; Nakamura, 1983). Until now, stabbings have not been reported in the region of the caudal peduncle, from which our five vertebral samples originated, or to have pierced bone. There are, however, less than a dozen cited occurrences of extant istiophorids impaling Thunnus. The fact that none of these have occurred in the caudal peduncle, or have pierced the vertebral column, is not surprising. Most of the profile of a Thunnus is not over the vertebral column, but in the abdominal cavity. The caudal peduncle region of Thunnus is where the vertebral column is nearest to the surface in the fish and thus most vulnerable to piercing. We assume the attacks associated with these wounds in all five fish were fatal because none of the vertebrae show osteogenesis (healing). However, it appears that at least these vertebrae were not ingested.

Frazier et al. (1994) reviewed the literature regarding the impaling of animate and inanimate objects by billfish and noted the capture of healthy billfish with shortened bills. They assumed that damage occurred when the fish failed to withdraw its bill successfully after impaling its target. Foreshortened bills found at Lee Creek Mine are evidence that spearing behavior was established during Yorktown times or earlier (Fierstine, 2001) and this evidence further supports our hypothesis that istiophorid billfish made the puncture marks in the fossil tuna vertebrae.

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LITERATURE CITED


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