TAXONOMIC REVISION AND STRATIGRAPHIC PROVENANCE OF "HISTIOPHORUS ROTUNDUS" WOODWARD 1901 (TELEOSTEI, PERCIFORMES)

KENNETH A. MONSCH1, HARRY L. FIERSTINE2 and ROBERT E. WEEMS3
1Department of Vertebrate Zoology, Institute of Zoology, University of Wroclaw, ul. H. Sienkiewicza 21, 50-335 Wroclaw, Poland, kmsch@biol.uni.wroc.pl;
2Biological Sciences Department, California Polytechnic State University, San Luis Obispo, CA 93407;
3U.S. Geological Survey, MS 926A National Center, 12201 Sunrise Valley Drive, Reston, Virginia 20192

ABSTRACT—Until recently, Histiophorus rotundus Woodward 1901, was known from a single, poorly preserved rostrum from the Tertiary phosphate beds near Charleston, South Carolina, an area from which many fossils have been described. The specimen is relatively featureless externally; its internal anatomy is unknown and the documentation of its geological provenance was poor. In an earlier revision the species was transferred to the fossil billfish genus Xiphiorhynchus Van Beneden, 1871. Here we confirm this designation, supported by new morphological studies of the holotype, recently found specimens of Xiphiorhynchus rotundus (Woodward, 1901), and the stratigraphic record of Xiphiorhynchus. The systematic paleontology we present is a contribution to the taxonomic revision of billfishes world-wide. Because the holotype is heavily phosphatized and the type locality was vaguely described, we discuss the geology of the phosphate mining districts of the Charleston region. Based on our studies, we can narrow the possible age of the holotype to late Oligocene or early Miocene. We suggest X. rotundus was extinct by the Burdigalian.

INTRODUCTION

Until recently, Histiophorus rotundus Woodward, 1901 was known only from the holotype, a single rostrum from the Tertiary phosphate beds near Charleston, South Carolina. This specimen has proven enigmatic because of its unusual proportions, featureless external morphology, unknown internal canal system, and vague locality and age data. The fossil has been assigned to genus Histiophorus Cuvier, 1832 (Woodward, 1901), which is an invalid emendation of Istiophorus Lacépède, 1801, as well as to the spearfish Tetrapturus Rafinesque, 1810 (Monsch, 2000), and provisionally to the marlin Makaira Lacépède, 1802 (Fierstine, 2001). Schultz (1987) included the specimen in Xiphiorhynchus Van Beneden, 1871, because of its dimensions and Eocene (sic) age. Unfortunately Schultz (1987) did not supply data or new figures to support this assertion. We here recognize that these distal rostra of Xiphiorhynchus that are part of a collection in the Charleston Museum are similar to the holotype of H. rotundus. The aim of this paper is twofold: to present a revision of H. rotundus that assigns it to genus Xiphiorhynchus, and a determination of the type locality and age based on a recent stratigraphic study of the Charleston, South Carolina area by Weems and Lewis (2002). The systematic paleontology presented here is a part of the on-going revision of fossil billfishes of the world (e.g., Fierstine 1978, 2001; Schultz, 1987; Monsch 2000). We present extensive information on the geologic setting of the holotype. The information about the origin and age of these so-called Ashley Phosphate deposits is applicable to various other fossil taxa that have been described from that unit (e.g., Sloan, 1908; Malde, 1959; Weems and Edwards, 2001). The systematics presented herein are based on Monsch (2000).

Institutional Abbreviations—AMNH, American Museum of Natural History, New York; BMNH, Natural History Museum, London; CHM, Charleston Museum, Charleston, South Carolina; IRSNB, Institut royal des Sciences naturelles de Belgique, Brussels, Belgium; MNHN, Muséum national d'Histoire naturelle, Paris, France.

Anatomical Abbreviations—cc, central canal; D, depth of rostrum; gD, greatest depth of rostrum; gW, greatest width of rostrum; L, reconstructed length of fused portion of rostrum; ld, dorsal lateral nutrient canal; lv, ventral lateral nutrient canal; PMX, premaxilla, s, sagittal suture, W, width of rostrum.

GEOLOGICAL SETTING

The information archived with the type specimen of X. rotundus only states that it came from the Tertiary phosphates of the Cooper River near Charleston, South Carolina (Fig. 1). This phosphate-rich rock is a lag-concentrate derived from geologic formations that long ago lay above the late Oligocene Ashley and Chandler Bridge Formations (Sloan, 1908; Weems and Lemon, 1988).

The type specimen of X. rotundus is dense and heavy. This is because its original pore space largely has been filled with additional phosphatic minerals emplaced during one or more phosphatization episodes. Recent work by Riggs et al. (2000) indicates that in the Carolinas there were three discrete intervals of phosphatic enrichment occurred. These were at 21 to 18 Ma, 10.8 to 11.5 Ma, and 9.0 to 8.6 Ma. Analyses of phosphate clasts from basal lag gravels of units younger than 8.6 Ma show that this material accumulated through reworking of phosphate formed in one of the three episodes of phosphate enrichment. This makes it highly unlikely that the phosphate-impregnated type specimen of X. rotundus originated from any of the units from the Charleston area that are younger than 8.6 Ma (late Miocene), for example the widespread lower Pliocene Goose Creek Limestone.

Conversely, although the mid-Oligocene Ashley Formation directly underlies the phosphate district, it is a dense calcarenite that is nearly impervious to ground water flow. For this reason, fossil vertebrate specimens found within the Ashley are not secondarily phosphatized, because phosphatic-rich water could not flow through the Ashley. This groundwater reality makes it virtually certain that the secondarily phosphatized type specimen of X. rotundus originally came from a stratigraphic
horizon higher than the Ashley (i.e., no older than upper Oligocene (Chattian)). The known plausible source beds for this specimen are summarized in Fig. 2 (with locality information in Fig. 1) and described as follows.

Only one Oligocene stratigraphic unit, the Chandler Bridge Formation (Sanders et al., 1982; Weems and Sanders, 1986), is currently documented above the Ashley Formation in the old phosphate-mining district. However, at least one other upper Oligocene unit must have been present. Samples of rock phosphate from this district, processed for dinoflagellates, have yielded dinocyst assemblages indicative of two slightly different ages: an early Miocene (early Aquitanian) flora and a late Oligocene (late Chattian) flora (Lucy E. Edwards, U.S. Geological Survey, pers. comm.; Miocene data cited previously in Weems and Lemon, 1988). The late Oligocene flora is indistinguishable from the flora found in the Chandler Bridge Formation. These floral assemblages indicate that, in the past, there were at least two phosphatized calcareous units in the Charleston region, now gone, that lay above the noncalcareous quartz-phosphate sands of the Chandler Bridge Formation.

The Aquitanian rock phosphate almost certainly was derived from the Edisto Formation (Sloan, 1908). The only likely correlative unit for the other (upper Oligocene) phosphatized quartzose calcarenite is an unnamed quartzose calcarenite, here informally designated as the “Givhans Ferry beds,” that occurs at the Givhans Ferry bluff beneath the type section of the Edisto Formation. Recent auger drilling, directly across the Edisto River from this bluff, penetrated below river level a phosphate pebble bed at the base of the Givhans Ferry beds. This lag bed, lying on typical Ashley Formation calcarenite, indicates an unconformity between these two units.

A number of widespread and often thick Miocene units occur in eastern Georgia (Weems and Edwards, 2001), but only patches of some of these are known from the Charleston region (Weems and Lewis, 2002). Today, only the basal Aquitanian Edisto Formation occurs specifically in the area of the old phosphate mines (Sloan, 1908; Weems and Lemon, 1988), though some younger Miocene units presently are known to occur in outlying regions (Weems and Lewis, 2000).

We can be fairly certain that the phosphatized type specimen of *Histiophorus rotundus* came from one of these upper Oligocene or Miocene horizons, but it is impossible to be sure which one. It is
noteworthy, however, that all four specimens of tX. rotundus (including ChM GPV4864 from the Chandler Bridge Formation) have been found in the vicinity of Charleston, S.C., and nowhere else. tX. rotundus has not been found among the abundant billfish remains recovered over the years from the Miocene (Burdigalian through lower Tortonian) Calvert, Choptank, or St. Marys Formations in the Chesapeake Bay region of Virginia and Maryland. Similarly, tX. rotundus has not been found among the abundant vertebrate remains recovered from the Miocene (Burdigalian) Pungo River Formation at the Lee Creek Mine in North Carolina. If this species existed along the Atlantic coast during the Burdigalian to Tortonian portion of the Miocene, it is likely that its remains would have been found in the vicinity of Charleston, S.C., and nowhere else. Thus, the absence of any specimens of tX. rotundus from elsewhere within the Atlantic Coastal Plain strongly suggests that it was extinct by the Burdigalian, at least along the Atlantic seaboard of the United States. This in turn strongly suggests (along with the occurrence of a supplementary specimen in the Chandler Bridge Formation) that the type specimen of tX. rotundus originally came from an upper Miocene (Chattian) deposit (the Chandler Bridge Formation, or the unnamed beds at Givhans Ferry) or from the lower Miocene (Aquitian) Edisto Formation or Parachulca Formation.

SYSTEMATIC PALEONTOLOGY

Order PERCIFORMES Bleeker, 1859
Suborder SCOMBROIDEI Bleeker, 1859
Family SCOMBRIDAE Rafinesque, 1815
Subfamily XIPHIIDAE Swainson, 1839
Tribe XIPHIORHYNCHINI Regan, 1909

Genus tXIPHIORHYNCHUS van Beneden, 1871

†XIPHIORHYNCHUS ROTUNDUS (Woodward, 1901)
(Fig. 3, Table 1)

†Histiophorus rotundus Woodward, 1901:495, fig. 18/3.
†Histiophorus rotundus Woodward: Leriche, 1942:93.
†Xiphiorhynchus rotundus (Woodward): Schultz, 1987:146, fig. 5, table 2.
†Tetrapturus rotundus (Woodward): Fierstine, 2001:36.
††Makaira rotundus (Woodward): Fierstine, 2001:150, fig. 7.54.

Holotype—†Histiophorus rotundus, BMNH P8799 (Fig. 3A): distal rostrum, upper Oligocene–early Miocene “Tertiary phosphate beds,” Cooper River, South Carolina, U.S.A.

Referred Specimens—Three distal rostra: ChM GPV2026 (South Carolina, no other data); ChM PV2697 (upper Oli-
gocene—lower Miocene “Tertiary phosphate beds,” Magnolia Phosphate Mine, Charleston County, South Carolina); ChM PV4864 (Chandler Bridge Formation, late Oligocene, South Carolina).

**Emended Species Diagnosis**—Differs from other xiphiorhynchin billfish (which are characterized by two pairs of lateral nutrient canals and usually a central canal) by having a massive rostrum (distal fused portion) with its greatest depth more than one-fourth of its total length and nearly round in cross-section throughout its length, with a depth/width ratio greater than 0.70.

**Description**—The holotype (BMNH P8799) is poorly preserved proximally, but otherwise complete to its distal tip. The surface is badly worn, and rather smooth with a slight fibrous texture, except for three shallow grooves near the distal tip. We believe these grooves are on the dorsal surface and represent sutures formed by fusion of the premaxillae and a trace of the sagittal suture (Fig. 3A). From the specimen it is not clear to served proximally, but otherwise complete to its distal tip. The specimen has a greatest depth proximally (gW) of 53.7 mm and a proximal greatest width (gD) of 78.5 mm. We lack direct information on its internal anatomy because canals are not visible at the broken proximal end and the specimen has never been sectioned or CT-scanned. Nevertheless, we believe the rostrum has two pairs of lateral nutrient canals and probably a central canal, based on the internal anatomy of the referred specimens.

These new specimens are distal rostra as well, with their anterior tips missing. The actual length of the specimens varies between 190 and 225 mm, and we estimate their actual lengths to have been between 235 and 335 mm (Table 1). Where not eroded, the surface of these specimens is fibrous (“woody”). Specimens ChM PV4864 (Fig. 3B–D) and ChM GPV2026 have a very shallow, ventral, mid-line groove. None of the referred specimens possesses denticles or alveoli. In every specimen, the maximum depth is about 30% of the estimated total length (Table 1). All of the rostra in question are nearly round throughout: proximally and distally they are almost as deep as they are wide (Table 1). CT scans have been taken of ChM PV4864 and ChM GPV2026. The scan image of the first of these two (Fig. 3D) shows a central canal and two pairs of nutrient canals. A CT scan taken at 140 mm from the proximal broken end of ChM PV2026 shows both a dorsal and a ventral left lateral nutrient canal.

**Discussion**—Species identification of billfish based solely on the morphology of a partial, isolated rostrum is a risky activity. Fierstine and Voigt (1996) showed that there is considerable intraspecific and interspecific variability in the states of taxonomic characters of xiphin bills. Since we lack information on intraspecific variability of the rostrum of the nine recognized species of †Xiphiorhynchus, it is possible that these are variants of one, two, or three species. On what basis, then, do we recognize †X. rotundus as a distinct species?

First, there is a difference in morphology. Only four species, †Xyphiorhynchus elegans van Beneden, 1871 (upper Eocene, Gent, Belgium), †Xyphiorhynchus eocaenicus (Woodward, 1901) (middle Eocene, England), †Xyphiorhynchus homalorhamphus (Cope, 1869) (?Eocene, New Jersey, U.S.A.), and †Xyphiorhynchus priscus (Agassiz, 1844) (lower Eocene, London Clay, England) need to be considered on the basis of taxonomic priority, because X. rotundus would become a junior synonym if it was found to be similar morphologically to any one of them. Of these four, the holotype of †X. homalorhamphus has been lost and we may never know its true morphology. Five specimens identified as †X. homalorhamphus (in two lots: AMNH 8430, 8431) are relatively slender with a gW less than 40 mm. The holotype of †X. elegans (IRSNB P642) is also very slender with a gW less than 25 mm. The holotype of †X. priscus (MNHN PTE474) is a skull without a rostrum. Fierstine and Pfeil

![FIGURE 3. Distal rostra of †Xiphiorhynchus rotundus (Woodward, 1901). A, holotype, BMNH P8799, dorsal view, scale equals 50 mm; B–D, distal rostrum of †Xiphiorhynchus rotundus (Woodward, 1901) (ChM PV4864, referred specimen, late Oligocene, Chandler Bridge Formation, South Carolina). B, lateral view, scale equals 20 mm; C, proximal view, scale equals 10 mm; D, computer aided tomography image taken 107 mm from proximal end of specimen (indicated by arrow in B). See text for definition of abbreviations.](image-url)

<table>
<thead>
<tr>
<th>Measurements or ratios</th>
<th>BMNH P8799</th>
<th>ChM GPV2026</th>
<th>ChM PV2967</th>
<th>ChM PV4864</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Length</td>
<td>315</td>
<td>225</td>
<td>190</td>
<td>210</td>
</tr>
<tr>
<td>Estimated Length with</td>
<td>313</td>
<td>335</td>
<td>235</td>
<td>295</td>
</tr>
<tr>
<td>Reconstructed tip (L)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greatest width proximally (gW)</td>
<td>111.8</td>
<td>78.5</td>
<td>-53.7</td>
<td>78.0</td>
</tr>
<tr>
<td>Estimated gW/L</td>
<td>0.36</td>
<td>0.23</td>
<td>0.23</td>
<td>0.26</td>
</tr>
<tr>
<td>Greatest depth proximally (gD)</td>
<td>-106</td>
<td>-66.0</td>
<td>51.2</td>
<td>62.5</td>
</tr>
<tr>
<td>Estimated gD/L</td>
<td>0.34</td>
<td>0.29</td>
<td>0.27</td>
<td>0.31</td>
</tr>
<tr>
<td>D/W proximally</td>
<td>0.84&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.73&lt;sup&gt;3&lt;/sup&gt;</td>
<td>0.89&lt;sup&gt;3&lt;/sup&gt;</td>
<td>0.87&lt;sup&gt;4&lt;/sup&gt;</td>
</tr>
<tr>
<td>D/W distally</td>
<td>—</td>
<td>0.73&lt;sup&gt;3&lt;/sup&gt;</td>
<td>0.97&lt;sup&gt;6&lt;/sup&gt;</td>
<td>0.73&lt;sup&gt;7&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>1</sup>Measured 97 mm from broken proximal end.<br> <sup>2</sup>Measured 65 mm from broken proximal end.<br> <sup>3</sup>Measured 78 mm from broken proximal end.<br> <sup>4</sup>Measured 50 mm from broken proximal end.<br> <sup>5</sup>Measured 30 mm from broken distal end.<br> <sup>6</sup>Measured 50 mm from broken distal end.<br> <sup>7</sup>Measured 28 mm from broken distal end.

**TABLE 1.** Selected morphometric measurements (mm) and ratios of the holotype (BMNH P8799) and three referred specimens (ChM GPV2026, PV2697, PV4864) of †Xiphiorhynchus rotundus (Woodward, 1901). See text for definition of abbreviations.
(2002) are studying the only known complete head (skull and rostrum) of a \textit{\textit{Xiphiorhynchus}} (lower Oligocene, Austrian Alps). According to this study, the holotype of \textit{X. priscus}, as well as similar skulls identified by Woodward (1901) and Casier (1966), are morphologically different from the Austrian specimen and may not belong to \textit{Xiphiorhynchus} at all, but to a new xiphiorhynchin genus. Thus, \textit{\textit{X. ecaecanus}} is the only remaining species with which \textit{\textit{X. rotundus}} could be synonymized. \textit{\textit{Xiphiorhynchus ecaecanus}} is known from two distal rostra (holotype BMNH 25744 and BMNH P12204, both from the middle Eocene of England). Similar to \textit{\textit{X. rotundus}}, the holotype is long (351 mm) and wide (101 mm) at its proximal end, and its dorsal, ventral, and lateral surfaces are smooth, without alveoli or denticles. Unlike \textit{\textit{X. rotundus}}, the holotype (at 150 mm from the distal end) is more depressed in cross-section (D/W = 0.62) and there are numerous small foramina, representing two pairs of lateral nutrient canals, a central canal, and possibly other canals as well.

Second, there is an argument based on the chronostratigraphic age of the specimens. All four of the comparative species were found in lower or middle Eocene deposits (Schultz, 1987), whereas we now believe that the holotype of \textit{\textit{X. rotundus}} was found in strata no older than late Oligocene, a difference in age possibly as large as 28, but certainly no less than 11 my. It is not unreasonable to hypothesize that an Eocene species of \textit{\textit{Xiphiorhynchus}} could have evolved into one or more sister species over this length of time.

CONCLUSIONS

Morphological comparisons of the holotype of \textit{\textit{Histiorhynchos rotundus}} with new specimens of this species and with specimens of other \textit{\textit{Xiphiorhynchus}} species support the recognition of a separate species \textit{\textit{Xiphiorhynchus rotundus}}. Earlier, Schultz (1987) transferred the species to \textit{\textit{Xiphiorhynchus}}, but his assignment was poorly considered, without new data to support it. The stratigraphic provenance of the holotype has been narrowed down to the upper Oligocene or lower Miocene horizons of the “Tertiary phosphate beds” in the Charleston, South Carolina region. A provenance from the upper Oligocene beds is more likely, based on the discovery of referred specimen ChM PV4864 in the Chandler Bridge Formation. We suggest that \textit{\textit{X. rotundus}} was extinct by the Burdigalian.

ACKNOWLEDGMENTS

We thank P. Forey (BMNH), D. Goujet (MNHN), J. Maisey (AMNH), D. Nolf (IRSNB), and A. Sanders (ChM) for access to specimens in their custody. The Photography Department (BMNH) provided the photo of the holotype. F. Vernaccia (San Luis Diagnostic Center) generously provided CT images at minimal cost. A. Elżanowski (Wrocław) and J. Maisey reviewed different versions of the manuscript. KAM acknowledges M. J. Bernot (University of Bristol) and P. Forey for co-supervising the PhD project (University of Bristol) that included work presented here, a LSf grant of the European Union and a ‘Badania Wlasne’ grant (2020/W/IZ/2001) of the University of Wrocław for financial assistance.REW acknowledges L. Edwards (USGS) and J. Self-Trail (USGS) for their helpful reviews of the geologic portion of the manuscript. We acknowledge two anonymous reviewers whose comments and criticisms helped us to improve this paper.

LITERATURE CITED


Submitted 2 April 2004; accepted 1 September 2004.