Contributions to Alabama Cretaceous Paleontology

Guest Editors
Jun Ebersole
&
Takehito Ikejiri
An Overview of Late Cretaceous Vertebrates from Alabama

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ABSTRACT

Presented here is an overview of fossil vertebrate specimens collected from Upper Cretaceous strata (Early Santonian–Upper Maastrichtian) in Alabama. In total, 8,275 vertebrate specimens housed in 12 institutions are summarized here by geologic age, locality, year collected, institution, and taxon, using numbers of identified specimens (NISP). A total of 76 genera and 92 species of vertebrates are identified in this study. Taxa identified include Chondrichthyes (21 gen. and 30 spp.; NISP = 2,150), Actinopterygii (23 gen. and 25 spp.; NISP = 2,607), and Reptilia (32 gen. and 37 spp.; NISP = 3,174), and 344 specimens not identifiable to a higher taxonomic level. All Cretaceous vertebrate specimens have been collected from the following five stratigraphic units in Alabama: Unit 1, the Eutaw Formation; Unit 2, the Mooreville Chalk and Blufftown Formations; Unit 3, the Demopolis Chalk and Cusseta Sand Member of the Ripley Formation; Unit 4, the Ripley Formation (excluding the Cusseta Sand Member); and Unit 5, the Prairie Bluff Chalk and Providence Sand. Of these stratigraphic units, Unit 2 has the largest NISP (6,363), and Unit 4 has the smallest NISP (139). Of the 20 counties that have produced Cretaceous specimens, nearly 70% of the vertebrate fossils are from Dallas and Greene counties. Although preservation and collecting biases have a strong influence on the data presented herein, this study does provide a new perspective of the Cretaceous vertebrate diversity as well as the geographic and stratigraphic distributions of these taxa in Alabama.

INTRODUCTION

A tremendous number of vertebrate fossils have been collected from Upper Cretaceous strata in Alabama. Beginning in the early 1830s, these fossil-rich exposures, which represent roughly 11% of the state’s surface geology, attracted many of the world’s early paleontologists and geologists including Charles Lyell, Thomas Nuttall, Timothy Abbott Conrad, Samuel Morton, and Joseph Leidy (see Ebersole and Dean, this volume). Beginning with these early researchers, the nearly 200 years of paleontological studies in Alabama has resulted in the collection of a large number of Cretaceous vertebrate taxa including numerous holotypes of new taxa (Table 1). The rich marine and terrestrial vertebrate faunas of Alabama have served as a significant addition to our overall understanding of the diversity of Late Cretaceous vertebrates in North America.

Late Cretaceous vertebrates in Alabama include fully aquatic forms (e.g., sharks, rays, bony fish, marine reptiles) from the Cretaceous Gulf of Mexico and terrestrial taxa (e.g., pterosaurs, crocodilians, non-avian dinosaurs, birds) from the southern Appalachia landmass. The Cretaceous fossils from Alabama are representative of the vertebrate fauna from the Cretaceous Gulf of Mexico, a region once physically connected to the southern Western Interior Seaway and the southern Atlantic Seaboard during the Late Cretaceous (Fig. 1). In previous studies, the Late Cretaceous taxa from Alabama have been compared with...
Ikejiri et al. Cretaceous Vertebrates from Alabama

Table 1. Type specimens of Cretaceous vertebrates from Alabama.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Status</th>
<th>Specimens</th>
<th>Remarks</th>
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<tr>
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<td>Applegate, 1970</td>
</tr>
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<td>Ptychodus mortoni</td>
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<td>NHMUK PV OR 28394</td>
<td>Agassiz, 1839; Morton, 1842; Everhart, this volume</td>
</tr>
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<td>ACTINOPTERYGII</td>
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<td>Albula dunklei*</td>
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<td>Applegate, 1970</td>
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<td>Megalocoelacanthus dobiei</td>
<td>Valid</td>
<td>CCK-88-2-1; AUMP 3854</td>
<td>Schwimmer, et al., 1994</td>
</tr>
<tr>
<td>Propenser hewletti*</td>
<td>Synonymized as Hadrodus hewletti</td>
<td>?</td>
<td>Thurmond and Jones, 1981; Bell, 1986; Applegate, 1970</td>
</tr>
<tr>
<td>Benanogmus criehy*</td>
<td>Valid</td>
<td>FMNH PF 3608</td>
<td>Applegate, 1970</td>
</tr>
<tr>
<td>Moorevillia hardi*</td>
<td>Valid</td>
<td>FMNH PF 3567</td>
<td>Applegate, 1970</td>
</tr>
<tr>
<td>Palelops eutawensis*</td>
<td>Valid</td>
<td>FMNH PF 3559</td>
<td>only scales; Applegate, 1970</td>
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<tr>
<td>REPTILIA</td>
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<td>Clidastes intermedius*</td>
<td>Nomen dubium</td>
<td>ANSP 9023, 9024, 9029 +</td>
<td>Leidy, 1870; See also Spamer et al., 1995:131</td>
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<td></td>
<td></td>
<td>9092-9094</td>
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<td>ANSP 10193</td>
<td>Cope, 1869; See also Spamer et al., 1995:149</td>
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<td>Tylosaurus perlatus*</td>
<td>Nomen dubium</td>
<td>AMNH FR 2391</td>
<td>Cope, 1870; original material lost (Carl Mehling pers. comm. 2011)</td>
</tr>
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<tr>
<td>Selmasaurus russelli*</td>
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<td>UAM PV 2005.0006.0009 (formerly GSATC 221)</td>
<td>Wright and Shannon, 1988</td>
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<td>Globidens alabamaensis</td>
<td>Valid</td>
<td>USNM 6527</td>
<td>Gilmore, 1912</td>
</tr>
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<td>Discosaurus ventutus*</td>
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<td>ANSP 9258 or 9282</td>
<td>Leidy, 1851; See also Spamer et al., 1995:156</td>
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<td>Podocnemis alabamae</td>
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<td>Zangerl, 1953b</td>
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<td>FMNH P 27314</td>
<td>Zangerl, 1953a; Thurmond and Jones, 1981, Hooks, 1998</td>
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<td>Zangerl, 1953</td>
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<td>Zangerl, 1953</td>
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<td>Zangerl, 1960</td>
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<td>Zangerl, 1953a</td>
</tr>
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<td>Ctenochelys tenuitesta</td>
<td>Valid</td>
<td>FMNH P 27361</td>
<td>Zangerl, 1953b</td>
</tr>
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<td>Prionochelys matutina*</td>
<td>Valid</td>
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<td>Zangerl, 1953b</td>
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<td>Prionochelys nauta</td>
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<td>Zangerl, 1953b</td>
</tr>
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<td>Thinochelys lapidossea*</td>
<td>Valid</td>
<td>FMNH P 27453</td>
<td>Zangerl, 1953b</td>
</tr>
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<td>Lophorhathion atopus*</td>
<td>Valid</td>
<td>FMNH P 27383</td>
<td>Langston, 1960</td>
</tr>
<tr>
<td>Appalachiosaurus montgomeriensis</td>
<td>Valid</td>
<td>RMM 6670</td>
<td>Carr et al., 2005</td>
</tr>
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<td>Halimornis thompsoni*</td>
<td>Valid</td>
<td>UAM PV 996.1.1</td>
<td>Chiappe et al., 2002</td>
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<td>Plegadornis antecessor</td>
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<td></td>
<td>See Thurmond and Jones, 1981 (p. 164); Synonymized by Padian, 2004; Clarke, 2004</td>
</tr>
</tbody>
</table>

*The asterisk (*) next to taxonomic names indicates specimens which are only known from Alabama.
vertebrate assemblages from other paleogeographic regions of North America such as the central Western Interior Seaway (e.g., the Niobrara Chalk and Pierre Shale of the central U.S.), the northern Western Interior Seaway (e.g., the Mason River Formation in northern Canada), and the Atlantic Seaboard (e.g., the Navesink Group in the northeastern U.S.) (Russell, 1988, 1993; Nicholls and Russell, 1990).

To date, the most comprehensive overview of the Cretaceous vertebrate taxa from the state was *Fossil Vertebrates of Alabama*, published in 1981 by John T. Thurmond and Douglas E. Jones. While still the only study reviewing all of the state’s vertebrate fossils, this work has shortcomings with respect to its taxonomic list of Cretaceous vertebrates. Since this book was first published, a significant number of Cretaceous vertebrate specimens have been collected by numerous institutions (most notably the Red Mountain Museum) and the systematics of many taxa have been revised. As a result, this study represents the most comprehensive overview of Alabama Cretaceous vertebrates yet undertaken.

In order to illustrate the taxonomic diversity of vertebrates from Upper Cretaceous marine and coastal strata across North America, previous studies compared and contrasted the quantity and types of genera and species based on stratigraphic units and/or paleogeographic regions (e.g., Russell, 1988, 1993; Everhart, 2005a; Shimada and Fieltz, 2006; Cumbaa et al., 2010). In this study, numbers of identified specimens (NISP) is utilized to quantify relative abundance and diversity of faunal assemblages. NISP is commonly used to quantify relative abundance of Late Cenozoic mammals from archeological sites (e.g., Grayson and Frey, 2004; Davis and Pyenson, 2007). Few studies, however, have used NISP for Cretaceous vertebrates from marine and coastal strata of North America.

The main purpose of this study is to review the occurrences the Cretaceous vertebrates from Alabama based on numbers of vertebrate specimens in museum collections. Using NISP, Alabama Cretaceous vertebrate fossils housed at various institutions are quantified by 1) taxon, 2) institution, 3) year collected, 4) stratigraphic unit, and 5) locality (county). Using these data as an example, the potential uses of NISP are discussed for future studies of Late Cretaceous vertebrate diversity, paleobiogeography, and evolution.

**Institutional abbreviations**—AMNH, American Museum of Natural History, New York, NY; ANSP, Academy of Natural Sciences of Philadelphia, PA; AUMP, Auburn University Museum of Paleontology, Auburn, AL; CCK, Cretaceous research collections at Columbus State University, Columbus, GA; FMNH, Field Museum of Natural History, Chicago, IL; GSA, Geological Survey of Alabama, Tuscaloosa, AL (vertebrate fossil collection currently housed at UAM); MMNS, Mississippi Museum of Natural Science, Jackson, MS; MSC, McWane Science Center, Birmingham, AL; NHMUK, Natural History Museum in London, United Kingdom; RMM, Red Mountain Museum, Birmingham, AL (fossil collection currently housed at MSC); UAM, Alabama Museum of Natural History, University of Alabama, Tuscaloosa, AL; UWA, University of West Alabama, Livingston, AL; USNM, United States National Museum, Washington D.C.; YPM, Yale Peabody Museum, New Haven, CT.

**Abbreviations for counties in Alabama**—Au, Autauga; Ba, Barbour; Bu, Bullock; Bl, Butler; Cr, Crenshaw; Da, Dallas; El, Elmore; Gr, Greene; Hl, Hale; Hr, Henry; Le, Lee; Ln, Lowndes; Ma, Marengo; Mg, Montgomery; Pe, Perry; Pk, Pike; Pn, Pickens; Ru, Russell; Su, Sumter; Wi, Wilcox.

**Abbreviations for Cretaceous geologic units in Alabama**—Kh, Blufftown Formation; Kd, Demopolis Chalk; Ke, Eutaw Formation; Km, Mooreville Chalk; Kp, Providence Sand; Kpb, Prairie Bluff Chalk; Kr, Ripley Formation; Krc, Cusseta Sand Member (of the Ripley Formation); Kt, Tuscaloosa Group.

**MATERIAL AND METHODS**

**Geologic Setting**

**Geography**—Of the Mesozoic strata in Alabama, only Upper Cretaceous units have surface exposure. Abbreviations for exposed Cretaceous units (listed above) follow the convention employed by the GSA on the Geologic Map of Alabama (Szabo et al., 1988). Cretaceous strata are exposed in 28 counties (Fig. 2) and lie within the Gulf Coastal Plain Physiographic Province. Only counties which have produced Cretaceous vertebrate specimens are recorded in this study. The abbreviations for counties (listed above) follow the system currently employed by the
UAM and MSC museum catalogues. Detailed information regarding specific fossil localities (e.g., towns, quarries, GPS coordinates) is not provided here but is available to qualified researchers by contacting the UAM or MSC.

All maps in this study were created by one of the authors (SE) using ArcGIS 9.3 software. For the geologic map of Upper Cretaceous units in Alabama, data were derived from the GSA Digital Geological Map (1:250,000 scale) of 2006, which was originally adapted from Szabo et al. (1988). The area of surface geology for each geologic unit was calculated in ArcGIS. Whether or not areas of surface geology (i.e., map area) are strongly correlated with actual exposure has been debated (e.g., Crampton et al., 2003; Dunhill, 2012) and is known to be scale-dependent. In this study, we used the calculated exposure of outcrops as approximate parameters to estimate relative fossil richness (i.e., numbers of specimens per area).

**Age**—Vertebrate fossils are known from various Upper Cretaceous units (formations and members) in Alabama (Fig. 3). Some of these units are age-equivalent, but geographically separate (Raymond et al., 1988). In this study, five representative stratigraphic units were established: Unit 1, the Eutaw Formation (including the Tombigbee Sand Member); Unit 2, the Mooreville Chalk (including the Arcola Limestone Member) and the Blufftown Formation; Unit 3, the Demopolis Chalk (including the Bluffport Marl Member) and the Cusseta Sand Member (of the Ripley Formation); Unit 4, the Ripley Formation (excluding the Cusseta Sand Member); and Unit 5, the Prairie Bluff Chalk and the Providence Sand. A few formations consist of subdivided members (e.g., the Tombigbee Sand Member in the Eutaw Formation; unnamed upper and lower members of the Mooreville Chalk), but these were not separately investigated in this study mainly due to the lack of specific stratigraphic information associated with most catalogued specimens.

![Figure 2](image-url) Distribution of Upper Cretaceous surface geology in Alabama based on the 1:250,000-scale digital state geology (GSA, 2006).

![Figure 3](image-url) The five Upper Cretaceous Alabama stratigraphic units used in this study.
The terms “Selma Chalk”, “Selma Limestone”, and “Rotten Limestone” have often appeared historical and recent literature. These informal names refer to the Selma Group, which was originally named by Smith et al. (1894), which consists of the Mooreville Chalk, Blufftown Formation, Demopolis Chalk, Ripley Formation, Prairie Bluff Chalk, and Providence Sand (Stephenson and Monroe, 1938; Monroe, 1941; Belt and Anonymous, 1945). “Selma” is not used as a separate stratigraphic name in this study.

Samples
Only body fossils were used in this study. Casts were not included, with the exception of special cases when the original material is missing and only the cast was available. Only specimens catalogued or curated before December 2011 were included. No private collections or uncatalogued museum specimens were incorporated into the dataset. Electronic databases and specimen catalogues (e.g., log books) provided by the following institutions were used in this study: AMNH, AUMP, FMNH, MSC (including the former RMM specimens), MMNS, UAM (including the transferred GSA vertebrate collection), USNM, and YPM.

Whenever possible, specimens were directly examined to verify taxonomic identifications and so additional information (e.g., elements present), which was often missing in original catalogues, could be included. When comprehensive catalogues were not available for a collection, such was the case with the ANSP, CCK, and UWA, published reports and personal communications were used.

In this study, every number in the NISP represents an individual specimen. In the event catalogued specimens contained a group of mixed fossils, the different taxa were counted separately following the methods outlined by Grayson and Frey (2004) and Lyman (2008) for the calculation of NISP. If articulated or associated elements from the same individual were present, they were counted as a single individual. On several occasions, a number of elements of the same taxon, collected from the same locality, were stored together and catalogued under one specimen number (a box of shark teeth, for example). Since there was no way to determine whether or not these teeth belonged to one or multiple individuals, these specimens were counted as a single individual when calculating the overall NISP.

Taxonomic Identification
Three levels of taxonomic identifications were recorded for the Cretaceous vertebrate specimens used in this study. The highest level included the following: Chondrichthyes (chimaeras, sharks and rays), Actinopterygii (bony fishes), and Reptilia (turtles, sauropthygians, squamates, and archosaurs). The intermediate level (30 sub-taxonomic groups) and the lowest level (genus and species) were recorded whenever possible for each individual specimen. Over the past few decades, many taxonomic names of Cretaceous vertebrates, as well as phylogenetic relationships, have been revised, synonymized, and/or newly established. Because a number of these names could be seen as questionable, controversial, or ambiguous, only taxonomic names which have appeared in peer reviewed studies were used (e.g., Russell 1993, Shimada and Flietz, 2006; Cumbaa et al., 2010). Non peer reviewed literature, such as field guides, abstracts for conferences, and dissertations and theses, were mostly excluded from this study (with the exception of a few instances which are cited herein). Furthermore, personal notes, such as identifications left with specimens by visiting researchers, were not used without verification.

During the course of this study, much of the data recorded in museum catalogues and on specimen labels were found to be outdated or unreliable. Therefore, taxonomic identifications of all specimens were confirmed by the authors whenever possible (with the exception of the specimens housed in distant collections such as the AMNH, ANSP, FMNH, and USNM collections). Specimens with questionable taxonomic assignments are noted herein and listed in Table 5. We recognize that various researchers are engaged in projects establishing new taxa and/or revising taxonomic assignments of various groups of Cretaceous vertebrates. Out of respect for these researchers and their studies, potential new taxa which have not appeared in the literature are not included.

Data Entry and Summary
For this study, a master data set was created in Microsoft Excel that includes: 1) specimen number; 2) taxon (genus, species, and higher taxonomic groups); 3) locality (county); 4) stratigraphic unit (Units 1–5); 5) institution, and 6) year collected. This information was derived from a number of sources including museum catalogs, specimen labels, field logs, and at times the matrix associated with a specimen. In the event key information was missing, the term ‘Unknown’ was entered in the field. For questionable information, a '?' was entered. Once this master data set was completed, the NISP was tabulated for each data field for comparison and analysis.

RESULTS
Summary of Vertebrate Fossil Collections from the Late Cretaceous of Alabama
A total of 8,275 vertebrate specimens from Upper Cretaceous strata of Alabama were recorded from 12 institutions. Of these specimens, 77.9% are housed at two Alabama institutions, UAM (NISP=3,710) and MSC (NISP=2,739) (Table 2). The size of these collections is
due in part to the UAM acquisition of the former Geological Survey of Alabama fossil vertebrate collection and the merger of the former Red Mountain Museum (RMM) with MSC (see Ebersole and Dean, this volume). The third largest collection of Alabama Cretaceous vertebrates is housed at the AUMP (NISP=1,018). This shows that 90.2% of the Cretaceous vertebrate specimens collected from Alabama are physically located within the state. The FMNH in Illinois and the USNM in Washington house the fourth and fifth largest collections of Alabama Cretaceous vertebrate material, respectively. Other institutions included in this study that are known to house Alabama Cretaceous vertebrate material are shown in Table 2.

Cretaceous vertebrate fossils were first collected in Alabama in the early 19th century (Fig. 4). In the early 1830s, Timothy Abbott Conrad of the ANSP collected a large number of fossils from various Cretaceous localities in Greene, Dallas, and Montgomery counties (Ebersole and Dean, this volume). Among the specimens collected by Conrad was the holotype of *Ptychodus mortoni* which was later figured and described by Mantell (1836), Morton (1842), and Agassiz (1833–1843). Aside from the holotype of *P. mortoni*, the oldest Cretaceous vertebrate specimen from Alabama confirmed in a museum collection (with respect to collection date) is UAM PV 2005.0006.0374 (bone fragments of an indeterminate bony fish: possibly, *Enchodus* sp.), collected in 1850 by Alabama’s first State Geologist, Michael Tuomey. Before his death in 1857, Tuomey had accumulated a rather large collection of Cretaceous vertebrate fossils (Tuomey, 1858), but most were destroyed near the end of the Civil War in 1865 when Union troops set fire to the University of Alabama campus (Howard, 1982). According to the UAM catalogue, only three of Tuomey’s specimens are recorded as being in the museum today. There is a strong possibility, however, that others exist as well (see Ebersole and Dean, this volume).

Of the Cretaceous vertebrate specimens from Alabama, the USNM (now the National Museum of Natural History) had the largest number of specimens (26 specimens) collected in Alabama during the 19th century. Nearly all of these early USNM specimens were collected by Lawrence C. Johnson, including the holotype of *Globidens*

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**Table 2. Numbers of identified specimens (NISP) of Alabama Cretaceous vertebrates from museum collections.** Data were based on specimens in museum collections cataloged before August 2011.

<table>
<thead>
<tr>
<th>Collections</th>
<th>NISP</th>
<th>per total</th>
</tr>
</thead>
<tbody>
<tr>
<td>UAM (including GSA)</td>
<td>3,710</td>
<td>44.84%</td>
</tr>
<tr>
<td>MSC (including RMM)</td>
<td>2,739</td>
<td>33.10%</td>
</tr>
<tr>
<td>AUMP</td>
<td>1,018</td>
<td>12.30%</td>
</tr>
<tr>
<td>FMNH</td>
<td>581</td>
<td>7.02%</td>
</tr>
<tr>
<td>USNM</td>
<td>132</td>
<td>1.60%</td>
</tr>
<tr>
<td>MMNS</td>
<td>60</td>
<td>0.73%</td>
</tr>
<tr>
<td>CCK*</td>
<td>18</td>
<td>0.22%</td>
</tr>
<tr>
<td>AMNH</td>
<td>8</td>
<td>0.10%</td>
</tr>
<tr>
<td>ANSP**</td>
<td>4</td>
<td>0.05%</td>
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<tr>
<td>TMM***</td>
<td>2</td>
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<td>NHMUK</td>
<td>1</td>
<td>0.01%</td>
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</tbody>
</table>

*Data from Case and Schwimmer (1988) and Ebersole and King (2011).

**Data from Spamer et al., (1995).

***Data from Wann Langston Jr. (pers. comm., 2012).

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Figure 4. Numbers of vertebrate specimens collected in Alabama since 1850. Note: only specimens catalogued in institutions are included in this figure (see further explanation in the text). Vertical scale represents number of specimens.
Alabamaensis (Gilmore, 1912) (Table 1), while employed at the United States Geological Survey (see more information on L. C. Johnson in Ebersole and Dean, this volume).

In the early 20th century, only a handful of Cretaceous vertebrate fossils were collected in Alabama (Fig. 4). Of these, most are housed at the UAM while two are in the AUMP collection. During 1940s to 1950s, the Chicago Museum of Natural History (now the FMNH) organized a number of expeditions to central Alabama for the purpose of collecting Cretaceous vertebrate fossils (Zangerl, 1948a; Applegate, 1970). Starting in 1945, these FMNH expeditions produced a total of 581 catalogued Cretaceous vertebrate specimens, which represents the fourth largest collection from Alabama. During the 1960s and 1970s, there was a noticeable increase in the number of Cretaceous vertebrates collected, a direct result of renewed collecting efforts by the UAM, GSA, and AUMP. In the early 1970s, the RMM was established and later began a series of systematic collecting efforts across the state. The 1980s to early 1990s has been the most productive period for the collection of Cretaceous vertebrate fossils in Alabama (Fig. 4), highlighted by intense collecting by the UAM, RMM, and AUMP. Beginning in the early 2000s, the UAM has conducted a series of fossil expeditions to the Harrell Station area in Dallas County, thus continuing to add large numbers of vertebrate specimens into the collection.

Late Cretaceous Vertebrate Taxa from Alabama

Higher taxonomic groups—Of the total number of vertebrate specimens recorded in this study, 95.8% are assigned to either Chondrichthyes, Actinopterygii, or Reptilia, with 4.1% (NISP = 339) not identifiable to any

![Vertebrate groups (n = 8,275)](image)

Figure 5. Numbers of Cretaceous specimens in major vertebrate groups from Alabama. ‘Indet.’ is assigned to specimens not identifiable at any particular taxonomic level.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Taxa* (#s)</th>
<th>Specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Genera</td>
<td>Specie**</td>
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<td>CHONDRICTHYES</td>
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</tr>
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<td>Chimaeriformes</td>
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<td>2</td>
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<tr>
<td>Heterodontiformes</td>
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<td>Hybodontidae</td>
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<td>Lamniformes</td>
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<tr>
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<td></td>
<td></td>
</tr>
<tr>
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<td>3</td>
<td>5</td>
</tr>
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</tr>
<tr>
<td>Pachycormiformes</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Lepisosteiformes (and Semionotiformes)</td>
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</tr>
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<td>Tsolfatiiformes</td>
<td>4</td>
<td>3</td>
</tr>
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<td>3</td>
</tr>
<tr>
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<tr>
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<td>1</td>
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<tr>
<td>Aulopiformes</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Beryciformes</td>
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<tr>
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<td>REPTILIA</td>
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<td></td>
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<tr>
<td>Pterosauria</td>
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<tr>
<td>Dinosauria</td>
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<td>2</td>
</tr>
<tr>
<td>Aves</td>
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<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>76</td>
<td>92</td>
</tr>
</tbody>
</table>

*Ambiguous taxa are not included and are listed in Table 5.
**Only identified species are counted (excluding "sp.")
higher taxonomic group due to their fragmentary state of preservation. To date, no Cretaceous mammals or amphibians have been confirmed from the state. Of all specimens, the largest NISP, 3,168 (38.3% of the total), is referred to reptiles and birds; 2,605 specimens (31.5%) to actinopterygian bony fishes; and 2,163 (26.2%) to chondrichthyan fishes (Fig. 5).

Each of the three higher taxonomic groups of vertebrates were further subgrouped. Of the 30 subgroups identified (Table 3), Mosasauridae (mosasaurs) contains the largest number of specimens (1,563). Turtles (Testudines) and lamniform sharks (Lamniformes) follow with 1,250 and 1,243 specimens, respectively. These three groups make up nearly 49.0% of the total NISP. Relatively rare taxa in Alabama consisting of fewer than 10 specimens were recorded in: Heterodontiformes (one specimen), Sclerorhynchiformes (four specimens), Squatiniformes (seven specimens), Beryciformes (four specimens), and Semionotiformes (two specimens).

**Genera and species**—All of the Cretaceous vertebrate genera and species confirmed in this study are listed in Table 4. Numerous miscellaneous or questionable taxa found in museum collections are listed in Table 5; these specimens include those with uncertain phylogenetic position, specimens that cannot at this time be assigned to any known taxon, and/or those with problematic taxo-

| Table 4. Late Cretaceous vertebrate taxa from Alabama. Listed references have information on taxonomy, systematics, and/or occurrences from Alabama. Key references are used to confirm phylogenetic positions, taxonomic identifications and/or occurrences in Alabama. Recorded taxa sorted by each stratigraphic unit are listed in Appendix 1. |

<table>
<thead>
<tr>
<th>CHONDRIICHTHYES</th>
<th>*Key references</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chimaeriformes</td>
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<tr>
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<td>h</td>
</tr>
<tr>
<td>Hybodontiformes</td>
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</tr>
<tr>
<td>Orectolobiformes</td>
<td>a, h, j, k, c, z</td>
</tr>
<tr>
<td>Lamniformes</td>
<td>a, b, k, l, m, n, o, p, q, r, s, u, v, w, x</td>
</tr>
<tr>
<td>Squatiniformes</td>
<td>i, j, k</td>
</tr>
<tr>
<td>Myliobatiformes</td>
<td>j, k, q, c, z</td>
</tr>
<tr>
<td>?Rajiformes</td>
<td>i, j, k</td>
</tr>
<tr>
<td>?Sclerorhynchiformes</td>
<td>j, q, y, a, a, b, c, p</td>
</tr>
<tr>
<td></td>
<td>a, i, j, k, q, a, c, c, p, c, z</td>
</tr>
<tr>
<td>ACTINOPTERYGII</td>
<td></td>
</tr>
<tr>
<td>Pycnodontiformes</td>
<td>aa</td>
</tr>
<tr>
<td>Anomoedus latidens, Anomoedus phaseolus, Coelodus sp.,</td>
<td>b, j, a, c, a, d, a, e, a, f, a, f, a, g, a, h</td>
</tr>
<tr>
<td>Hadrodus hewletti(?) , Hadrodus priscus, Phacodus punctatus</td>
<td>ah</td>
</tr>
<tr>
<td>?Aspidorhynchiformes</td>
<td>ac, c, w</td>
</tr>
<tr>
<td>Belonostomus sp.</td>
<td></td>
</tr>
<tr>
<td>Pachycormiformes</td>
<td>a, b, a, c, a, i, a, j, a, k</td>
</tr>
</tbody>
</table>
| Bonnerichthys gladius, Protosphyraena nitida | }
Table 4. continued

| Lepisosteiformes (or Semionotiformes) | al |
| Atractosteus sp, Lepisosteus sp. | ac,am,an,ao |

Tseltaliiformes

| Bannanognathus crikey(i), Moorevillia hardi, Palelops eutawensis, Pletodus sp. | a,b,ac,aj,ak |

Ichthyodectiformes

| Ichthyodectes sp, (I. ctenodon?), Saurocephalus lanciformis, Saurodon leanus, Xiphactinus audax | a,bj,ac,ao,ap,aq,as,at,cx |

Crossopterygiformes

Pachyrhizodus caninus, Pachyrhizodus kingi, Pachyrhizodus minimus | a,b,ac |

Albuliformes

| Albulida dunklei | a,b,ac |

Aulopiformes

| Cimolichthys nepaholica, Enchodus ferox, Enchodus gladiolus, Enchodus petrosus, Enchodus shumardi, Stratodus apicalis | a,b,ac,ac,ao,au,av |

Beryciformes

| Hoplopteryx sp. | b,ac |

Coelacanthiformes

| Megalocoelacanthus dohiei | av |

Dinosauria

| Coelurosauria: | |
| Dinosauria: | |
| Carcharodontosauridae | |
| Deinosauria | |
| Eusuchians; Mosasauridae | |

Mammalia

| Cetacea | |
| Pinnipedia | |
| Carnivora | |
| Primate | |
| Hominidae | |

**REPTILIA**

| Testudines | |
| Crocodylia | |
| Dinosaurs | |
| Aves | |

*References: a (Thurmond and Jones, 1981); b (Applegate, 1970); c (Leidy, 1856); d (Case and Schimmer, 1992); e (Egerton, 1843); f (Patterson, 1965); g (Case, 1978); h (Welson and Fairish, 1995); i (Cappetta and Case, 1975); j (Case and Schimmer, 1988); k (Cappetta, 1973); l (Shimada, 2005); m (Shimada, 1996); n (Shimada, 2007); o (Schimmer et al., 2002); p (Shimada, 1997); q (Cappetta, 1987); r (Shimada, 2009); s (Case, 1979); t (Kiernan, 2002); u (Hamn and Shimada, 2007); v (Shimada and Beverton, 2007); w (Shimada and Cicimurri 2002); x (Schimmer, 2007); y (Case et al., 2001); z (Schimmer et al., 1997a); aa (Kiernan, 2004); ab (Kiernan et al., 2009); ac (Schein and Lewis, 2007); ad (Bell, 1986); ae (Poyato-Ariza and Wenz, 2002); af (Becker et al., 2010); ag (Hooks et al., 2010); ah (Forey et al., 2003); ai (Friedman et al., 2010); aj (Friedman et al., 2013); ak (Stewart, 1988); al (López-Arbarello, 2012); am (Wiley, 1976); an (Peng et al., 2001); ao (Shimada and Flietlitz, 2006); ap (Cumba et al., 2010); aq (Harlan, 1824); ar (Stewart, 1989a); as (Leidy 1870); at (Schimmer et al., 1997b); au (Cope, 1872); av (Schimmer et al., 1994); aw (Zangerl, 1948a); ax (Gaffney et al., 2006); ay (Gaffney et al., 2009); az (Zangerl, 1953a); ba (Hooks, 1998b); bb (Zangerl, 1953b); bc (Zangerl, 1960); bd (Zangerl, 1948b); be (Zangerl, 1980); bf (Welles, 1962); bg (Spamer et al., 1995); bh (O’Keefe and Street, 2009); bi (Carpenter, 1996); bj (O’Keefe, 2004); bk (Russell, 1967); bl (Russell, 1970); bm (Bell, 1997); bn (Cope, 1869); bo (Michael Polcyn, pers. comm., 2012); b1 (Cladistes ‘moreovilensis’, Eonator instead of Halisaurus); bp (Bardet et al., 2005); bq (Polcyn and Lamb, 2012); br (Polcyn et al., 2012); bs (Konishi and Caldwell, 2011); bt (Wright and Shannnon, 1988); bu (Konishi, 2008); bv (Polcyn and Everhart, 2008); bw (Renger, 1953); bx (Everhart, 2005b); by (Uswin, 2003); bz (Chris Brochu, pers. comm., 2012); Borealosuchus; ca (Brochu, 1999); cb (Schimmer, 2002); cc (Wann Langston Jr., pers. comm., 2012); Deinosuchus; cd (Schimmer et al., 1993); ce (Ebersole and King, 2011); cf (Carr et al., 2005); cg (Kiernan and Schimmer, 2004); ch (Langston, 1960); ci (Horner et al., 2004); cj (Vickaryous et al., 2004); ck (Olson, 1975); cl (Padian, 2004); cm (Clarke, 2004); cn (Chippag et al., 2002); co (Shannon, 1975); cp (Suarez and Cappetta, 2004); cq (Case, 1987); cr (Hirayama, 1997); cs (Nicholls, 1988); ct (Shannon, 1974); cu (Wright, 1988); cv (Gilmore, 1912); cw (Whetstone, 1978); cx (Stewart, 1898b); cy (Bell and Sheldon, 1986); cz (Ciccimuri, pers. comm. 2012); da (Janssii, this Bulletin, Vol. 2).
Table 5. Miscellaneous and/or doubtful vertebrate taxa from Upper Cretaceous strata of Alabama.

<table>
<thead>
<tr>
<th>Higher taxonomic unit</th>
<th>Genus</th>
<th>Species</th>
<th>Geologic unit*</th>
<th>County*</th>
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<td>macrota</td>
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<td>Ba</td>
</tr>
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<td>Kb</td>
<td>Ru</td>
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<td>Ke</td>
<td>Gr</td>
</tr>
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<td>Kr</td>
<td>Ba</td>
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<td>Bu</td>
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<td>Bu</td>
</tr>
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<td>Mg</td>
</tr>
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<td>Bu</td>
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<td>Gr</td>
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<td>sp.</td>
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<td>Bu</td>
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<td>Da</td>
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<td>nepaholica</td>
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<td>Gr</td>
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<td>Mg</td>
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<td></td>
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<td>Su</td>
</tr>
<tr>
<td>Testudines</td>
<td>Peritresius</td>
<td>ornatus</td>
<td>Kr?</td>
<td>Ln</td>
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<td>Testudines</td>
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<td>dixie</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>Clidastes</td>
<td>iguanavus</td>
<td>Kd</td>
<td>Su</td>
</tr>
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<td>cf. sectorius</td>
<td>Kr</td>
<td>Wi</td>
</tr>
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<td>Mosasaurus</td>
<td>missouriensis</td>
<td>Kd</td>
<td>Ln</td>
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<td>Mosasauridae</td>
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<td>icericus</td>
<td>Unknown</td>
<td>Unknown</td>
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<td>zangerli</td>
<td>Km</td>
<td>Da</td>
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<td>Crocodylia</td>
<td>Bottosaurus</td>
<td>harlanii</td>
<td>Kb</td>
<td>Bu</td>
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<tr>
<td>Crocodylia</td>
<td>Leidyosuchus</td>
<td>sp.</td>
<td>Kb, Ke, Km</td>
<td>Bu, Da, Mg, Pe</td>
</tr>
</tbody>
</table>

*Abbreviations for geologic units and counties are listed in the text.
onomic assignments. Further study of these specimens is recommended.

Of all vertebrate specimens in this study, 4,516 (54.6%) can be identified to at least the generic level, and from these specimens, 76 genera were confirmed (Table 3 and 4). In addition, rajiforms, elasmosaurids, dromaeosaurids, and nodosaurids were identified, but could not be assigned to the generic level. The uncertain generic assignment of these specimens is the result of one or more of the following: 1) the fragmentary condition of a specimen; 2) the current uncertainty of a specimen's phylogenetic position; 3) the lack of reliable diagnostic characteristics for determination to the generic level; and/or 4) the possibility a specimen represents a new genus or species. Based on NISP, the most common genus is that of the aulopiform bony fish, *Enchodus* (765 specimens). The abundance of this taxon is partially due to the relative ease of identification of its palatine teeth (as compared to other fishes), which are often preserved well in the Cretaceous chalks of Alabama. The second and third most abundant genera are the mosasaur *Clidastes* (495 specimens) and the lamniform shark *Scapanorhynchus* (352 specimens). The high number of identified specimens of *Scapanorhynchus*, nearly all isolated teeth, is explainable as these teeth have a distinct morphology allowing them to be easily assigned to the generic level.

Of the specimens identified to the generic level, 3,062 specimens (37% per total) can be assigned to the species level (92 species; Table 4). Single species with a large NISP appear in lamniform sharks such *Scapanorhynchus texanus* (201 specimens), *Cretalamna appendiculata* (176 specimens), *Squalicorax kaupi* (129 specimens), and the bony fish *Enchodus petersus* (210 specimens) (Table 6). In reptiles, two turtle species, *Protostega gigas* (112 specimens) and *Toxochelys moorevillensis* (105 specimens), are present in relatively large numbers. The abundance of *P. gigas* is likely a result of the size of their elements (which aid in their preservation and make them easy to identify).

### Cretaceous Vertebrates by Stratigraphic Unit

Overall, 95.1% of the specimens (NISP = 7,871) had at least some level of stratigraphic information recorded such as formation and/or member (Table 7). Cretaceous vertebrate fossils are known from the five stratigraphic units in Alabama ranging from the lower Santonian to the very upper Maastrichtian (see Appendix 1 for the distribution of vertebrate taxa within each stratigraphic unit). No definitive vertebrate remains are reported from the Tuscaloosa Group (upper Cenomanian–lower Coniacian) which underlies the Eutaw Formation (Santonian) with an unconformity.

A total of 76.9% of the vertebrate fossils are from Unit 2, the Mooreville Chalk and Bluffton Formation (Table 7, Fig. 6). In fact, the Mooreville Chalk alone produced 74.3% of vertebrate specimens recorded in museum collections (6,147 total). The second most vertebrate fossil-bearing unit was Unit 1, the Eutaw Formation, with 943 specimens (11.4%). Based on the 1:250,000 state geologic map, this unit has the largest area of surface geology among any Cretaceous formations in Alabama (Table 7). Within Unit 3, the Cusseta Sand Member of the Ripley Formation, only nine vertebrate specimens (<1%) were collected, probably a result of this unit having a relative-

<table>
<thead>
<tr>
<th>Table 6. Selected Cretaceous vertebrate genera and species with high numbers of identified specimens (NISP) from Alabama.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Genera.</strong></td>
</tr>
<tr>
<td>VERTEBRATA</td>
</tr>
<tr>
<td><em>Enchodus</em></td>
</tr>
<tr>
<td><em>Clidastes</em></td>
</tr>
<tr>
<td><em>Scapanorhynchus</em></td>
</tr>
<tr>
<td><em>Cretalamna</em></td>
</tr>
<tr>
<td><em>Ptychodus</em></td>
</tr>
<tr>
<td><em>Xiphactinus</em></td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong> (6 genera)</td>
</tr>
</tbody>
</table>

| **B. Species.** |
| **CHONDRICHTHYES** | NISP | per subtotal |
| *Scapanorhynchus texanus* | 201 | 14.58% |
| *Cretalamna appendiculata* | 176 | 12.76% |
| *Squalicorax kaupi* | 129 | 9.35% |
| *Ptychodus mortoni* | 70 | 5.08% |
| *Cretoxyrhina mantelli* | 80 | 5.80% |

| **ACTINOPTERYGII** |
| *Enchodus petrosus* | 210 | 15.23% |
| *Saurodon leanus* | 83 | 6.02% |
| *Stratodus apicalis* | 46 | 3.34% |
| *Enchodus ferox* | 24 | 1.74% |

| **REPTILIA** |
| *Protostega gigas* | 112 | 8.12% |
| *Toxochelys moorevillensis* | 105 | 7.61% |
| *Clidastes propython* | 76 | 5.51% |
| *Ctenochelys tenuitesta* | 39 | 2.83% |
| *Chegadaii barberi* | 28 | 2.03% |
| **SUBTOTAL** (14 spp.) | 1,379 |
ly restricted surface exposure. In contrast, 211 specimens (2.5%) are recorded from the Demopolis Chalk of this unit. Unit 4, the Ripley Formation, includes the smallest number of vertebrate specimens (139 specimens, 1.7%). In Unit 5, 203 specimens (2.5%) are recorded from the Prairie Bluff Chalk, while only three specimens are from the Providence Sand Formation, although fairly large outcrops are exposed (1,472 km²; Table 7).

**Table 7. Numbers of vertebrate specimens in Upper Cretaceous strata of Alabama. Ratios of numbers of specimens-to-surface geology areas (#s/km²) are shown in the far right column.**

<table>
<thead>
<tr>
<th>Stratigraphic Unit</th>
<th>Geologic unit</th>
<th>NISP</th>
<th>per total</th>
<th>surface area (km²)</th>
<th>#s/(km²)</th>
</tr>
</thead>
<tbody>
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<td>Unit 1</td>
<td>Eutaw Fm</td>
<td>943</td>
<td>11.40%</td>
<td>4,359</td>
<td>0.2179</td>
</tr>
<tr>
<td>Unit 2</td>
<td>Mooreville Chalk Fm</td>
<td>6,147</td>
<td>74.29%</td>
<td>2,642</td>
<td>2.3255</td>
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<tr>
<td></td>
<td>(Arcola Mbr)</td>
<td>(21)</td>
<td></td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>Unit 2</td>
<td>Blufftown Fm</td>
<td>216</td>
<td>2.61%</td>
<td>1,336</td>
<td>0.1624</td>
</tr>
<tr>
<td>Unit 3</td>
<td>Demopolis Chalk Fm</td>
<td>211</td>
<td>2.55%</td>
<td>2,476</td>
<td>0.0852</td>
</tr>
<tr>
<td></td>
<td>(Bluffport Marl Mbr)</td>
<td>(40)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit 3</td>
<td>Cusseta Sand Member (of Ripley Fm)</td>
<td>9</td>
<td>0.11%</td>
<td>692</td>
<td>0.0116</td>
</tr>
<tr>
<td>Unit 4</td>
<td>Ripley Fm (except for Cusseta Sand Member)</td>
<td>139</td>
<td>1.68%</td>
<td>2,045</td>
<td>0.0680</td>
</tr>
<tr>
<td>Unit 5</td>
<td>Prairie Bluff Chalk Fm</td>
<td>203</td>
<td>2.45%</td>
<td>412</td>
<td>0.4830</td>
</tr>
<tr>
<td>Unit 5</td>
<td>Providence Sand Fm</td>
<td>3</td>
<td>0.04%</td>
<td>1,472</td>
<td>0.0020</td>
</tr>
<tr>
<td>Unknown</td>
<td></td>
<td>404</td>
<td>4.87%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>8,275</td>
<td>100%</td>
<td>15,434</td>
<td></td>
</tr>
</tbody>
</table>

*Based on a 1:250,000 state map.

**Cretaceous Vertebrates by County**

Upper Cretaceous strata are exposed in 28 counties in Alabama, covering roughly 11% of the state’s surface area (Fig. 2). From our numbers, 95.8% of the specimens possess locality information at least to the county-level and show these specimens were collected from 20 counties in the state (Fig. 8). Of these 20 counties, Dallas and Greene are the most productive in terms of Cretaceous vertebrates collected. Among the 3,224 specimens from Dallas County, 3,023 were collected from the Mooreville Chalk (93.7%), 76 from the Eutaw Formation (2.3%), 62 from the Demopolis Chalk (1.9%), two from Prairie Bluff Chalk (<1%), and 61 (1.8%) had no associated stratigraphic data. Of the Dallas County specimens, 2,543 (78.9%) were collected from the Harrell Station area near Marion Junction which has sizable exposures of the Mooreville Chalk. At this location, dozens of individual fossil sites are located within a 0.5 mi² (ca 1.29 km²) area, which was purchased by the University of Alabama in 1991. This locality has turned out to be one of the most productive sites for the discovery of Cretaceous vertebrate fossils in Alabama.

According to our dataset, Greene County is the second most productive for the collection of fossil vertebrates in Alabama (Table 8). From this county, 2,885 vertebrate specimens are recorded from the Eutaw Formation, Mooreville Chalk (including the Arcola Limestone Member), Demopolis Chalk, and Ripley Formation. These fossils were collected from over 50 localities with the most productive being AGr-43, a site located along a creek which produced at least 198 specimens. Thousands of additional elements from site AGr-43 remain uncatalogued in muse-
Table 7. Percentage of Chondrichthyes, Actinopterygii, and Reptilia specimens identified from five Upper Cretaceous stratigraphic units in Alabama.
Stratigraphic Distribution of Cretaceous Vertebrate Specimens in Alabama

Comparisons of the NISP in each Cretaceous stratigraphic unit provide data for quantifying which units are more or less productive for the collecting of vertebrate fossils. Units 3, 4, and 5, for example, have a smaller NISP than Units 1 and 2 (Table 7). While this find may indicate that Units 3, 4, and 5 are more productive in terms of numbers of vertebrate specimens, this may also be influenced by area of surface exposure (e.g., the large surface exposures of Eutaw Formation as opposed to the smaller exposures of Prairie Bluff Chalk). The difference in NISP may also reflect concentrated efforts to collect more frequently within certain units.

When comparing the ratios of NISP to the surface area of formation, the most fossil-abundant (i.e., the highest value of the ratio) is the Mooreville Chalk (2.3255 NISP/km²) of Unit 2, with the least fossiliferous being the Providence Sand (0.0020 NISP/km²) of Unit 5 (Table 7). Because the Providence Sand has a relatively large area of exposure in Alabama (1,472 km²), this formation can be interpreted as not very productive for the collection of fossil vertebrates. On the other hand, the Prairie Bluff Chalk ranks second in terms of fossil abundance even though the exposed surface area is relatively small. This could indicate that a high concentration of vertebrate fossils can be found within this formation, or there has been a more concentrated effort to collect in this unit as opposed to formations with a lower ratio.

The NISP within each stratigraphic unit can likely be attributed to one or more of the following: 1) preservation bias – vertebrate remains may preserve better in some sedimentary settings than others; 2) collecting bias – some formations have been collected more frequently than others (and/or may be more accessible than others); and/or 3) some paleoenvironments being more suitable for

<table>
<thead>
<tr>
<th>County</th>
<th>Abbreviations</th>
<th>Specimen #s</th>
<th>Per total</th>
<th>Geologic unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autauga</td>
<td>Au</td>
<td>9</td>
<td>0.11%</td>
<td>Ke</td>
</tr>
<tr>
<td>Barbour</td>
<td>Ba</td>
<td>83</td>
<td>1.00%</td>
<td>Kb, Km(?) Kr</td>
</tr>
<tr>
<td>Bullock</td>
<td>Bu</td>
<td>111</td>
<td>1.34%</td>
<td>Kb, Kr</td>
</tr>
<tr>
<td>Butler</td>
<td>Bt</td>
<td>1</td>
<td>0.01%</td>
<td>Kpb</td>
</tr>
<tr>
<td>Crenshaw</td>
<td>Cr</td>
<td>1</td>
<td>0.01%</td>
<td>Km</td>
</tr>
<tr>
<td>Dallas</td>
<td>Da</td>
<td>3,224</td>
<td>38.97%</td>
<td>Kd, Ke, Km, Kpb</td>
</tr>
<tr>
<td>Elmore</td>
<td>El</td>
<td>2</td>
<td>0.02%</td>
<td>Km</td>
</tr>
<tr>
<td>Greene</td>
<td>Gr</td>
<td>2,885</td>
<td>34.87%</td>
<td>Kd, KE, Km</td>
</tr>
<tr>
<td>Hale</td>
<td>Hl</td>
<td>255</td>
<td>3.08%</td>
<td>Kd, Ke, Km</td>
</tr>
<tr>
<td>Henry</td>
<td>Hr</td>
<td>1</td>
<td>0.01%</td>
<td>Kp(?)</td>
</tr>
<tr>
<td>Lee</td>
<td>Le</td>
<td>3</td>
<td>0.04%</td>
<td>Km</td>
</tr>
<tr>
<td>Lowndes</td>
<td>Ln</td>
<td>247</td>
<td>2.99%</td>
<td>Kd, Ke, Km, Kpb, Kr</td>
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<tr>
<td>Marengo</td>
<td>Ma</td>
<td>17</td>
<td>0.21%</td>
<td>Kd, Ke, Km, Kpb, Kr</td>
</tr>
<tr>
<td>Montgomery</td>
<td>Mg</td>
<td>393</td>
<td>4.75%</td>
<td>Kd, Ke, Km, Kp</td>
</tr>
<tr>
<td>Perry</td>
<td>Pe</td>
<td>180</td>
<td>2.18%</td>
<td>Kd, Ke, Km</td>
</tr>
<tr>
<td>Pike</td>
<td>Pk</td>
<td>4</td>
<td>0.05%</td>
<td>Kr</td>
</tr>
<tr>
<td>Pickens</td>
<td>Pn</td>
<td>191</td>
<td>2.31%</td>
<td>Kd, Ke, Km</td>
</tr>
<tr>
<td>Russell</td>
<td>Ru</td>
<td>80</td>
<td>0.97%</td>
<td>Kd, Ke, Km</td>
</tr>
<tr>
<td>Sumter</td>
<td>Su</td>
<td>175</td>
<td>2.12%</td>
<td>Kd, Ke, Km, Kpb, Kr</td>
</tr>
<tr>
<td>Wilcox</td>
<td>Wi</td>
<td>67</td>
<td>0.81%</td>
<td>Kd, Ke, Kpb, Kr</td>
</tr>
<tr>
<td>Unknown</td>
<td></td>
<td>346</td>
<td>4.17%</td>
<td></td>
</tr>
</tbody>
</table>

Table 8. Counties in Alabama that have produced Late Cretaceous vertebrate fossils. Abbreviations for counties and geologic units are listed in the text.
Geographic Distribution of Cretaceous Vertebrate Specimens in Alabama

The NISP sorted by county may show unique patterns of geographic distributions for Cretaceous vertebrate specimens in Alabama. However, caution is advised when using NISP in this manner as collecting and preservation biases can strongly influence the NISP, thus skewing any paleobiogeographic reconstructions. For example, in Alabama, Dallas County has produced the largest number of specimens (Table 8). A majority of these specimens, however, were collected from a single area near the Harrell Station Paleontological Site which consists of a large number of concentrated and expansive gullies. In this case, the NISP for Dallas County is directly influenced by the amount of exposed outcrop in the area (i.e., over 0.2 square miles), the fact that a large portion of the site is not a university research site, and the ease of accessibility for collecting. We suggest that in order to reconstruct a better paleobiogeographic distribution of vertebrates in Alabama, further data collection is needed such as the NISP from individual fossil sites and additional collecting within counties where the NISP appears low. A comparison of these data to the amount of surface geology of each formation in each county will provide further insights to reconstruct paleobiogeographic occurrences of certain taxa. Gathering additional data from cataloged specimens, such as the relative completeness of specimens (isolated vertebrates than others. To further investigate this matter, systematic collecting would need to be undertaken at regular intervals at Units 1–5 and more detailed studies would need to be conducted of the sedimentology and taphonomy of specific fossil sites. Because the validity of correlations between fossil richness and surface geology area has been debated (e.g., Crampton et al., 2003; Dunhill, 2012), further studies are needed that combine the types of landscapes (e.g., creek sites vs. gullies) and actual areas of outcrops with the use of detailed aerial photography, GPS, and field observations.

Figure 8. Counties in Alabama producing vertebrate fossils within the five Cretaceous stratigraphic units used in this study. Abbreviations of counties are listed in the text.
bones vs. partial or complete skeletons), and the type of collection site (i.e., gully vs. creek), can be useful as well.

**Overview of Vertebrate Taxa**

When compared to other Cretaceous paleogeographic regions in North America (such as the Western Interior Seaway), the NISP of vertebrate taxa in Alabama can be useful to highlight some patterns of taxonomic diversity in the Cretaceous Gulf of Mexico and the Mississippi Embayment. Previous studies of taxonomic diversity of Cretaceous marine vertebrates from marine and coastal strata focused on the number of vertebrate taxa (species, genus, and higher taxonomic groups) from the northern, central, and southern regions of the Western Interior Seaway, as well as the Gulf of Mexico, the Atlantic Seaboard, and the Pacific Coast (Russell, 1988; Nicholls and Russell, 1990; Everhart, 2005a; Cumbaa et al., 2010). In addition to comparing the types and numbers of vertebrate taxa, the use of NISP can provide additional insights into the taxonomic diversity. For example, Nicholls and Russell (1990) suggested the Cretaceous Gulf of Mexico region near Alabama produced a relatively high number of turtle taxa (10 genera) when compared to other regions of North America such as the Anderson River in northern Canada (0 genera), Pembina (one genus), Sharon Springs (one genus), and Niobrara (nine genera). Similarly, our data shows a higher concentration of turtles (NISP=1,250; Table 3) along the Cretaceous coast lines of the southern-most Appalachia landmass, as opposed to the central Western Interior Seaway (210 specimens: Russell, 1988 and Nicholls and Russell, 1990).

Lyman (2008) argued that NISP was perhaps the most powerful parameter (and perhaps the only parameter) to quantify taxonomic abundances among vertebrate fauna. It is possible for NISP to be used to reconstruct populations of predator and prey taxa among Late Cretaceous vertebrates in North America (e.g., smaller fishes being more common than larger top-level predatory fishes and marine reptiles in the food chain; see Table 6). The comparison of NISP of terrestrial vertebrates may demonstrate other unique taxonomic compositions near paleo-shoreline environments. In addition, NISP of various aquatic and terrestrial tetrapods exhibiting ectothermic or endothermic metabolisms may reflect a restriction to lower-latitudinal warm climates. However, various types of preservation and collecting biases can limit the effectiveness of using NISP in this manner (Nicholls and Russell, 1990).

Within our dataset of 8,275 vertebrate specimens, various types of biases are clearly involved. For example, the presence of the higher number of the marine reptiles, mosasaurs, in museum collections (Table 3; Fig. 5), as opposed to cartilaginous and bony fishes which would be much more abundant in a natural setting. This may reflect a collection, sampling, or preservation bias. Our personal observations suggest that reptilian specimens, even those with small or fragmentary remains, tend to be collected and added to museum collections more often than the remains of fish. Larger, and more dense, reptilian bones also tend to preserve better than small fish elements, presenting a possible preservation bias. Moreover, the collection of microscopic-size remains has largely been neglected in Alabama, representing a sampling bias (see Ciampaglio et al., this volume).

To reduce the risk of misinterpretation, comparisons of intra-taxonomic groups (e.g., reptiles vs. birds) are used here instead of those of inter-taxonomic groups (e.g., Actinopterygii vs. Chondrichthyes). This approach can offer at least a small view of the relative taxonomic abundances of Cretaceous vertebrates from Alabama. In a comparison between 1,234 lamniform sharks and 1,563 mosasaurs (Table 9), for example, most sharks (i.e., 94.9%) were identified at least to the generic level, in contrast to only 47.5% for mosasaurs. This contrast is even more noticeable when viewed at the specific level (72.0% for sharks; only 11.3% for mosasaurs). This is a result of an identification bias as, for most lamniform sharks, even a single, isolated tooth can often be assigned to species (e.g., Welton and Farish, 1993). A better understanding of key elements, diagnostic characteristics, and alpha taxonomy will certainly aid in future studies utilizing NISP in this manner.

**CONCLUSIONS**

The Cretaceous exposures in Alabama represent one of the southern-most regions of Upper Cretaceous marine and coastal strata in North America. Many of the Cretaceous units in Alabama are fossiliferous and have produced a diverse range of marine and terrestrial vertebrate taxa. Through the use of NISP, this preliminary investigation provides the following data and insights:

1. At least 8,275 vertebrate specimens from Upper Cretaceous marine and coastal strata of Alabama are currently housed at 12 different institutions (Table 2). These vertebrates include Chondrichthyes (25 gen. and 30 spp.; NISP = 2,150), Actinopterygii (23 gen. and 25 spp.; NISP = 2,607), Reptilia (32 gen. and 37 spp.; NISP = 3,174), and 339 specimens of uncertain taxonomic identification (Tables 3 and 4). Vertebrate taxa recorded from each stratigraphic unit are listed in Appendix 1.

2. Among the five units defined in this study (Table 7; Fig. 3), the most abundant in terms of fossil vertebrates collected is Unit 2 (the Mooreville Chalk and Blufftown Formation: lower to mid-Campanian) with 6,563 specimens (Table 7). The Eutaw Formation (Unit 1: Cenomanian–Santonian), which is the largest surface geology area, is represented by the second largest number of Cretaceous vertebrate specimens. Relative to surface exposures, Units 3 and 4 (the Demopolis Chalk and Ripley Formation) are the least fossiliferous in terms of vertebrates.
3. Reptilians (reptiles and birds) are the most abundant among the vertebrates (38.4% of all specimens) (Fig. 5). This number probably indicates a strong collecting, sampling, and/or preservation biases towards reptilian material. However, among 76 identified vertebrate genera found in this study (and 92 species), the small aulopiform bony fish, *Enchodus*, has the largest value of NISP (n = 770). This is likely the result of the ease of identifying the often well preserved palatine teeth of this taxon.

4. The phylogenetic relationships and taxonomic assignments of some species are ambiguous (Table 5) and many need to be clarified. New taxa are also being described and hundreds of specimens are still waiting to be prepared and catalogued at many of the institutions reviewed in this study. Better understanding of alpha taxonomy of Cretaceous vertebrates can increase the total number of recognized genera and species from Alabama (e.g., Ciampaglio et al., Hamm and Harrell, Jasinski, Schein et al., and Shimada in this *Bulletin*, Vol. 1 and 2).

### ACKNOWLEDGEMENTS

We thank the following curators and/or collection managers who greatly aided in the collection of data throughout the course of this study: Carl Mehling (AMNH), Ted Daeschler (ANSP), Ray Wilhite (AUMP), David Schwimmer (CCK), Bill Simpson (FMNH), George Phillips (MMNS), Mary Bade (UAM), Mike Brett-Surman (USNM), and Dan Brinkman (YPM). Review comments from Steve Cumbaa and James Parham were also greatly appreciated.

### LITERATURE CITED


Hamm, S. A., and K. Shimada. 2007. The Late Cretaceous anacoracid shark, *Pseudocorax laevis* (Leriche), from the


Leidy, J. 1851. [Dr. Leidy exhibited a number of fossil reptilian and mammalian remains which he characterized verbally as follows]. Proceedings of the Academy of Natural Sciences of Philadelphia 5:325–328.


Polcyn, M. J., and J. Lindgren, N. Bardet, D. Cornelissen, L. Verding,


Stewart, A. 1898a. Some notes on the genus *Saurodon* and allied species: Kansas University Quarterly 7:177–186.


Appendix 1. Occurrences of vertebrates in Upper Cretaceous strata from Alabama. References used to confirm taxonomic identifications and stratigraphic occurrences are listed in Table 4. Ambiguous taxa listed in Table 5 are not included.

<table>
<thead>
<tr>
<th>UNIT 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eutaw Formation</strong></td>
</tr>
<tr>
<td><strong>CHONDRICTHYES</strong></td>
</tr>
<tr>
<td>Chimaeriformes</td>
</tr>
<tr>
<td>Heterodontiformes</td>
</tr>
<tr>
<td>Hybodontidae</td>
</tr>
<tr>
<td>Orectolobiformes</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Lamniformes</td>
</tr>
<tr>
<td>Myliobatiformes</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Rajiformes</td>
</tr>
<tr>
<td>Sclerorhynchiformes</td>
</tr>
<tr>
<td><strong>ACTINOPTERYGII</strong></td>
</tr>
<tr>
<td>Pycnodontiformes</td>
</tr>
<tr>
<td>Aspidorhynchiformes</td>
</tr>
<tr>
<td>Pachycormiformes</td>
</tr>
<tr>
<td>Semionotiformes (or Lepisosteiformes?)</td>
</tr>
<tr>
<td>Tseltafiiformes</td>
</tr>
<tr>
<td>Ichthyodectiformes</td>
</tr>
<tr>
<td>Crossognathiformes</td>
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<td>Coelacanthiformes</td>
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<tr>
<td><strong>REPTILIA</strong></td>
</tr>
<tr>
<td>Testudines</td>
</tr>
<tr>
<td>Plesiosauria</td>
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<tr>
<td>Mosasauridae</td>
</tr>
</tbody>
</table>
Appendix 1. continued.

Crocodylia  
Borealosuchus sp., Deinosuchus rugosus (?)

Dinosauria  
Lophorhothon atopus, hadrosaur (gen. indet.), nodosaur (gen. indet.)

UNIT 2

Blufftown Formation

CHONDRIICHYES

Chimaeriformes        gen. indet.
Hybodontiformes       Hybodus sp., Lissodus (=Lonchidion?) babulski
Orectolobiformes      Cantioscyllium sp., Chiloscyllium greeni
Lamniformes           Creotalamna appendiculata, Cretoxyrhina mantelli,
                       Scapanorhynchus raphiodon, Scapanorhynchus texanus, Squalicorax texanus, Squalicorax
                       kaupe, Squalicorax pristodontus
Squatiniformes        Squatina hassei
Myliobatiformes       Brachyrhizodus mcnultyi, Brachyrhizodus wichitaensis
Rajiformes            gen. indet.
Sclerorhynchiformes    Borodinoprists schwimmeri, Ischyricha mira, Ptychotrygon vermiculata

ACTINOPTERYGII

Pycnodontiformes      Anomaeodus latidens
Pycnodontiformes      Hadrodus priscus
Pachycormiformes      Protosphyrana nitida
Semionotiformes (or Lepisosteiformes?) Lepisosteus sp.
Ichthyodectiformes    Xiphactinus audax
Albuliformes          Albula sp.
Aulopiformes          Enchodus petrosus
Coelacanthiformes     Megalecoatancanthus dobie

REPTILIA

Testudines            Chedighaii barberi
Testudines            trionychid (gen. indet.)
Plesiosauria          elasmosaurid (gen. indet.)
Mosasauridae          Clidastes propython, Globidens alabamaensis, Halisaurus sternbergi, Platecarpus sp.,
                       Tylosaurus sp.
Crocodylia            Borealosuchus sp., Deinosuchus rugosus
Dinosauria            Appalachiosaurus montomeriensis, hadrosaur (gen. indet.)

Mooreville Chalk

CHONDRIICHYES

Chimaeriformes        Edaphodon barberi, Edaphodon mirificus, Ischyodus sp.
Hybodontiformes       Ptychodus mortoni, Ptychodus polygyrus,
                       Ptychodus rugosus
Appendix 1. continued.

Lamniformes

*Cretalamna appendiculata, Cretoxyrhina mantelli, Cretoxyrhina sp., Paranomotodon angustidens, Pseudocorax affinis, Pseudocorax laevis, Scapanorhynchus rapax, Scapanorhynchus raphiodon, Scapanorhynchus texanus, Serratolamna serrata, Squalicorax falcatus, Squalicorax kaupi, Squalicorax pristodontus*

Myliobatiformes

*Brachyrhizodus wichitaensis, Brachyrhizodus menulti*

Sclerorhynchiformes

*Ischyria mira, Sclerorhynchus sp.*

ACTINOPTERYGII

Pycnodontiformes

*Anomoedus phaseolus, Hadrodus priscus, Phacodus punctatus*

Pachycormiformes

*Bonnerichthys gladius, Protosphyraena nitida*

Semionotiformes (or Lepisosteiformes?)

*Lepisosteus sp.*

Tselfatiiformes

*Bananogmius crieyli, Moorevillia hardi, Palelops eutawensis, Plethodus sp.*

Ichthyodectiformes

*Ichthyodectes sp., Saurocephalus sp., Saurodon leanus, Xiphactinus audax*

Crossopterygii

*Pachyrhizodus caninus, Pachyrhizodus kingi, Pachyrhizodus minimus*

Pleuracanthiformes

*Albula dunklei*

Aulopiformes

*Cimolichthys nepaholica, Enchodus ferox, Enchodus gladiolus, Enchodus petrosus, Enchodus shumardi, Stratodus apicalis*

Beryciformes

*Hoplopteryx sp.*

Coelacanthiformes

*Megalocoelacanthus dobiei*

REPTILIA

Testudines

*Chedighaii barberi, Calcarichelys gemma, Chedighaii sp., Chelospatharis advena, Corsochelys halinches, Ctenochelys acris, Ctenochelys tenuistea, Ctenochelys sp., Lophochelys venatrix, Prionochelys matutina, Prionochelys natua, Protostega gigas, Thinochelys lapisossea, Toxochelys moorevillensis*

Plesiosauria

*elasmosaurid (gen. indet), polycotylid (gen. indet.)*

Mosasauridae

*Clidastes liodontus, Clidastes moorevillensis, Clidastes propython, Eonatator sternbergi, Globidens alabamaensis, Halisaurus sternbergi, Mosasaurus(?) sp., Platecarpus tyneiticus, Pliopleistestus sp., Prognathodon sp., Selmasaurus russelli, Tylosaurus proriger, Tylosaurus nepaeolicus(?)*

Pteranodon sp.

Pterosauria

*Crocodylia*

*Deinosuchus rugosus*

Borealosuchus sp.

Crocodylia

*Lophorhothon atopus, hadrosaur (gen. indet.), nodosaur (gen. indet.), tyrannosaurid (gen. indet.), dromaeosaurid (gen. indet.)*

*Aves*

*Ichthyornis sp., Halimornis thompsoni*
Appendix 1. continued.

UNIT 3

Demopolis Chalk (including the Bluffport Marl Member)

CHONDRICHTHYES

Chimaeriformes

Lamniformes  *Cretalamna appendiculata, Scapanorhynchus texanus,*  
*Serratolamna serrata(?), Squalicorax knupi, Squalicorax pristodontus, Squalicorax sp.*

Sclerorhynchiformes  *Ischyrhiza mira*

ACTINOPTERYGII

Pachycormiformes  *Protosphyraena* sp.

Ichthyodectiformes  *Saurodon* sp., *Xiphactinus* sp.

Aulopiformes  *Enchodus ferox, Enchodus gladiolus, Enchodus petrosus, Stratodus* sp.

REPTILIA

Testudines  *Chedighai barberi, Cienochelys cf. tenuitesta,*  
*Prionochelys matutina(?), Protostega gigas*

Mosasauridae  *Clidastes propython, Halisaurus sp., Mosasaurus conodon,*  
*Mosasaurus cf. missouriensis, Platecarpus cf. somenensis, Plioplatecarpus sp., Tylosaurus sp.*

Crocodilia  *Boreosuchus* sp.

Dinosauria  *Appalachiosaurus(?)* sp., *hadrosaur (gen. indet.)*

Cusseta Sand Member (of the Ripley Formation)

CHONDRICHTHYES

Hybodontiformes  *Ptychodus mortoni*

Lamniformes  *Cretalamna* sp., *Scapanorhynchus texanus*

REPTILIA

Dinosauria  gen. indet.

UNIT 4

Ripley Formation (excluding the Cusseta Sand Member)

CHONDRICHTHYES

Rajiformes  gen. indet.

Orectolobiformes  *Ginglymostoma*

Lamniformes  *Cretalamna appendiculata, Pseudocorax laevis,*  
*Scapanorhynchus raphiodon, Scapanorhynchus texanus,*  
*Squalicorax pristodontus*

Myliobatiformes  *Brachyrhizodus cf. witchitaensis*

Sclerorhynchiformes  *Ischyrhiza mira*

ACTINOPTERYGII

Pycnodontiformes  *Anomoedodus phaseolus*

Ichthyodectiformes  *Xiphactinus* sp.
Appendix 1. continued.

| Aulopiformes | Enchodus ferox, Enchodus petrosus |

**REPTILIA**

| Testudines | Ctenochelys sp., Protostega gigas |
| Mosasauridae | Mosasaurus maximus, Pliopleuracanthus sp., Tylosaurus (?) sp. |
| Crocodylia | Deinosuchus rugosus |
| Dinosauria | nodosaur (gen. indet.), hadrosaur (gen. indet.) |

**UNIT 5**

Prairie Bluff Chalk

**CHONDRICHTHYES**

| Hybodontidae | Hybodus sp., Ptychodus mortoni |
| Lamniformes | Cretalamna appendiculata, Cretodus sp., Paranomotodon angustidens, Scapanorhynchus texanus, Serratolamna serrata, Squalicorax kaupi, Squalicorax pristodontus |
| Myliobatiformes | Pseudohypolophus (=Brachyrhizodus) mcnultyi |
| Orectolobiformes | Ginglymostoma sp. |
| Rajiformes | gen. indet. |
| Sclerorhynchiformes | Ischyrida mimm, Sclerorhynchus sp. |

**ACTINOPTERYGII**

| Pycnodontiformes | Anomoeodus phaseolus |
| Aulopiformes | Enchodus ferox |

**REPTILIA**

| Plesiosauria | elasmosaurid (gen. indet.; Cimoliopsis) |
| Testudines | gen. indet. |
| Mosasauridae | Mosasaurus conodon, Mosasaurus maximus, Pliopleuracanthus sp. |
| Aves | gen. indet. |

Providence Sand

**CHONDRICHTHYES**

| Lamniformes | gen. indet. |

**OSTEICHTHYES**

| indet. | gen. indet. |

**REPTILIA**

| Mosasauridae | gen. indet. |
Figure 3 (revised).
The five Upper Cretaceous Alabama stratigraphic stratigraphic units used in this study.
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CHONDRICHTHYAN ORIGIN FOR THE FOSSIL RECORD OF THE TSELFATIIFORM OSTEICHTHYAN FISH, THRYPOTODUS ZITTELI LOOMIS, FROM THE UPPER CRETACEOUS MOOREVILLE CHALK OF ALABAMA by KENSHU SHIMADA Page 72.

A NEARLY COMPLETE SKULL OF ENCHODUS FEROX (ACTINOPTERYGII, AULOPIFORMES) FROM THE UPPER CRETACEOUS RIPLEY FORMATION OF LOWNDES COUNTY, ALABAMA by JASON P. SCHEIN, DAVID C. PARRIS, JASON C. POOLE and KENNETH J. LACOVARA PAGE 78.

A NOTE ON LATE CRETACEOUS FISH TAXA RECOVERED FROM STREAM GRAVELS AT SITE AGr-43 IN GREENE COUNTY, ALABAMA by CHARLES N. CIAMPAGALIO, DAVID J. CICIMURRI, JUN A. EBERSOLE and KATELYN E. RUNYON Page 84.

“THE PALATE BONES OF A FISH?” – THE FIRST SPECIMEN OF PTYCHODUS MORTONI (CHONDRICHTHYES; ELASMOBRANCHII) FROM ALABAMA by MICHAEL J. EVERHART Page 98.