Creation Research Society Quarterly 2025 61:172–188

Fossil Crocodilians Grew Larger and Longer, and Lived Longer than Extant Crocodilians

Jake Hebert

Abstract

Whatever factor or factors enabled extreme human longevity in the pre- and immediate post-Flood worlds likely also affected the animal kingdom. Thus, direct or indirect evidence for greater past animal longevity is also *de facto* evidence for greater past human longevity. The field of skeletochronology is making it possible to deduce information about the ontogenetic growth trajectories of giant fossil crocodilians such as *Deinosuchus riograndensis* (alternately, *D. hatcheri*) and *Sarcosuchus imperator*. Their growth curves indicate that these crocodilians grew for at least 50–60 years, a duration significantly greater than even the total typical 30-year lifespan of extant crocodilians. Moreover, a smoothed *Deinosuchus* growth curve published in the mainstream evolutionary literature suggests this age of 50 years likely significantly underestimates the true age at maturity. Given the evidence from longevity studies linking both larger adult body sizes and greater ages at maturation to greater longevity, the large adult body sizes of *Deinosuchus* and *Sarcosuchus* and their prolonged maturation intervals are indirect evidence of lifespans greater than extant crocodilians. Other giant fossil crocodilians, some of which may be direct ancestors of extant crocodilians, were also likely experiencing greater longevity. Moreover, the similarity of giant crocodilian body sizes in Cretaceous, Miocene, and Pliocene strata suggest that these crocodilians obtained their giant sizes under similar environmental conditions. This could suggest they all lived in the pre-Flood world and would be another argument for a 'high' Cenozoic Flood/post-Flood boundary.

Key Words: crocodilians, *Deinosuchus, Euthecodon brumpti,* fossils, giantism, *Gryposuchus croizati,* longevity, ontogeny, pre-Flood, *Purussaurus brasiliensis, Rhamposuchus, Sarcosuchus imperator,* von Bertalanffy growth curves

Accepted for publication March 21, 2024

Introduction

Creation researchers have long noted (e.g., Taylor, 1987; Morris, 1993, Woetzel, 2013; Nelson, 2017; and Coppedge, 2023) that extant animals are often represented by much larger and more massive fossil ancestors. This trend extends to the crocodilians, members of the order Crocodylia (or Crocodilia). The order Crocodylia is composed of three extant families, Crocodylidae, Alligatoridae, and Gavialidae. The family Crocodylidae is composed of true crocodiles, while the Alligatoridae consists of alligators and caimans. The Gavialidae consists of gharials and false gharials.

Crocodilians generally have similar body shapes (Figure 1) but vary in size and especially in the shape of their snouts. The gharial and false gharial have long, narrow snouts compared to most crocodilians. Likewise, the jaws of alligators and caimans tend to be more 'U'-shaped than the 'V'-shaped jaws of crocodiles, and a greater number of teeth are visible in the mouths of crocodiles than in alligators (Hennigan, 2008). As a matter of nomenclature, the name 'crocodilian' is used as a generic term for all crocodile/alligator/gharial-like animals, extant and extinct, whereas 'crocodile' is used to indicate only true crocodiles in the family Crocodylidae.

Of particular relevance to this study are the giant fossil crocodilians *Deinosuchus riograndensis* (or *Deinosuchus hatcheri*) and *Sarcosuchus imperator*. Their fossils are found in Cretaceous strata, stratigraphically below the K-Pg (or K-T) boundary, which means they must date from the Flood, regardless of whether one holds to a 'high' or 'low' Cenozoic boundary between Flood and post-Flood rocks.

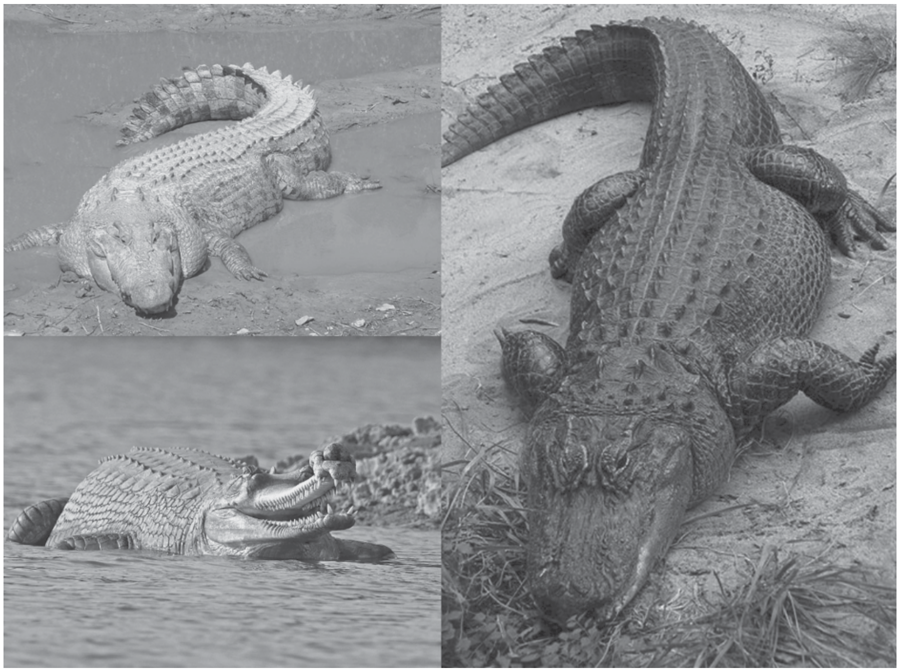

Figure 1. Representatives of the three families in the order Crocodilia: Crocodylidae, Alligatoridae, and Gavialidae. Clockwise, starting from top-left of image: the saltwater crocodile (*Crocodylus porosus*), the American alligator (*Alligator mississippiensis*), and the gharial (*Gavialis gangeticus*). Image credits: Composite Image: Little Jerry, CC BY-SA 4.0. https://creativecommons.org/licenses/by-sa/4.0/. Saltwater crocodile image credit: Molly Ebersold of the St. Augustine Alligator Farm (public domain). American alligator image credit: Postdlf, CCA-SA 3.0 Unported. https://creativecommons.org/licenses/by-sa/3.0/deed.en. Gharial image credit: Charles J. Sharp; sharpphotography.co.uk. CCA-SA 4.0 International. https://creativecommons.org/licenses/by-sa/4.0/deed.en.

Deinosuchus Background Information

The suffix *suchus* is the Latin form of the Greek word *soukhos*, which refers to a *crocodile* (Sibley 2023). Of course, *deino* is Greek for "terrible" (e.g., *dinosaur* means "terrible lizard"). Thus the name *Deinosuchus* means (Figure 2) 'terrible crocodile' or 'terror crocodile,' but it has been described as an 'alligatoroid,' more closely related to alligators than to crocodiles (Cossette and Brochu, 2020; Diaz, 2020).

Deinosuchus expert David Schwimmer (2002, p. 13) wrote that "to the casual observer, a *Deinosuchus* would appear to be a cross between a huge alligator and a huge crocodile" and stated that it would be "almost indistinguishable" from living crocodilians (Broom, 2018). Nevertheless, Schwimmer has said that he is not comfortable describing *Deinosuchus* as an alligator or crocodile *per se* (Schwimmer, 2002, p. viii). *Deinosuchus* had some noticeable anatomical differences between it and extant crocodilians, particularly its bulbous snout that is absent from extant crocodilians. Hence, it may have belonged to a different Genesis kind than the kind or kinds to which extant crocodilians belong.

Deinosuchus was enormous. Most body length estimates range from the more conservative 8–10 meters (Erickson and Brochu, 1999) to more generous estimates of 10.6 to 13.7 meters (Broom, 2018). An 8-to-10-meter-long

Figure 2. Reconstruction of *Deinosuchus hatcheri* in the Natural History Museum of Utah. Image credit: Daderot. CC0 1.0 Universal Public Domain Dedication. https://creativecommons.org/publicdomain/zero/1.0/deed.en.

Deinosuchus would have an estimated body mass of between 2500 and 5000 kilograms (Erickson and Brochu, 1999).

A well-known painting by R.D. Martin depicts a *Deinosuchus* lunging from a body of water, preparing to take a bite out of a startled *Albertosaurus*. Given the likely fearsomeness of this creature, Thomas and Biddle (2023) have suggested *Deinosuchus* as a candidate for the Biblical Leviathan described in Job 41.

By evolutionary reckoning, *Deinosuchus* lived about 83 to 74 million year ago, during the Late Cretaceous. Schwimmer (2002, pp. 48, 107) has noted that *D. hatcheri* and *D. riograndensis* specimens from the American west and southwest (e.g., Texas and Montana) tend to be larger but less numerous than the *D. schwimmeri* (formerly *D. rugosus*) specimens from the eastern United States (Mississippi, Alabama, Georgia, and North Carolina). Or to put it another way, *Deinosuchus* specimens on the western side of the so-called Late Cretaceous Western Interior Seaway are larger and less numerous than those on the eastern side. Schwimmer (2002) estimates the eastern variety to be about 8 meters long, but the west-southwestern variety to be possibly as long as 12 meters. One possible explanation for the difference in body sizes could be CET (continuous environmental tracking) adaptations to different environments (Guliuzza and Gaskill, 2018). Another possibility is that larger adults panicked during the Flood, leaving behind the more numerous but smaller and slower juveniles, so that they were physically separated during the chaos of the Flood.

There has been some controversy regarding the naming of *Deinosuchus*. The first *Deinosuchus* fossils were found in Montana by T. W. Stanton and J. B. Hatcher in 1903 and were reported by W. J. Holland six years later (Holland, 1909; Schwimmer, 2002). Holland named the species *Deinosuchus hatcheri* in Hatcher's honor. The fossils comprising this holotype (name-bearing) specimen consisted of two large vertebrae, some ribs, and about 25 bony scutes called osteoderms.

However, it was a well-known American Museum of Natural History reconstruction of a giant crocodilian jaw from the Rio Grande region of Texas that brought *Deinosuchus* to the attention of the general public. The reconstructed specimen was originally named *Phobosuchus riograndensis,* but the name was changed to *Deinosuchus riograndensis* in 1979 (Schwimmer, 2002). It is now recognized that this famous reconstruction was inaccurate in some respects.

Giant crocodilian fossil teeth were found in North Carolina in 1858. They were originally designated as *Polyptychodon rugosus*, but the name was later changed to *D. rugosus*. *Deinosuchus* species from the eastern United States were later renamed as *D. schwimmeri* in David Schwimmer's honor (Cossette and Brochu, 2020).

Because the *D. riograndensis* fossil material is more abundant than that associated with *D. hatcheri*, Cossette and Brochu (2020) proposed making *D. riograndensis* the type species, rather than *D. hatcheri*.

Sarcosuchus imperator Background Information

Sarcosuchus imperator has been described as a giant crocodile (or 'super croc') but with a snout similar to that of a gharial. As in the case of *Deinosuchus*, *suchus* refers to a *crocodile*. *Sarco-* comes from the Greek σομχος, meaning 'flesh,' and *imperator* is Latin for *commander*. Thus *Sarcosuchus imperator* is the "flesh crocodile emperor." By evolutionary reckoning, it lived in

Africa and South America in the Early Cretaceous, roughly 113 million years ago (Rigby, 2021). Sereno et al. (2001) estimated it to have a length between 11 and 12 meters, but this length estimate was later revised downward to between 9 and 9.5 meters (O'Brien et al., 2019). Booker (2005) has suggested *S. imperator* as a candidate for the Biblical Leviathan.

Like *Deinosuchus*, some aspects of the anatomy of *S. imperator* are distinct from those of extant crocodilians. For instance, *S. imperator* did not have the ball-and-socket (procoelous) vertebrae joints typical of extant crocodilians (Sereno et al., 2001). Like *Deinosuchus*, it had a somewhat bulbous snout. Hence, it is possible that *S. imperator* may, like *Deinosuchus*, represent a distinct created Genesis kind.

The Physiological Importance of Body Mass

Theodosius Dobzhansky (1973) famously wrote in an anti-creationist essay, "Nothing in biology makes sense except in the light of evolution." Many years later, C.A. Brassey and J.D. Gardiner (2015) turned this phrase to say, "Nothing in biology makes sense except in the light of [body mass]." They went on to say (p. 1), "Body mass is arguably the most fundamental property of an organism, and key evolutionary concepts within the fields of ecology, physiology, and biomechanics can only be understood within its context." Although we creationists would disagree with Brassey and Gardiner's evolutionary viewpoint, I believe they are correct when they describe the great importance of body mass in understanding physiology and biomechanics.

Creation researchers have long noted (e.g., Taylor 1987, Morris 1993, Woetzel 2013, Nelson 2017, and Coppedge 2023) that extant animals are often represented by much larger and more massive fossil ancestors. In 1982 creation researcher Donald W. Patten (1982, p. 40) suggested that the Genesis patriarchs were larger, lived longer, and took longer to mature than extant humans:

> Besides the decline in lifespans as seen in Genesis after the flood, there was also a decline in the age of the patriarchs at the time of their firstborn son, hence a decline in age of arrival at sexual maturity, and presumably skeletal maturity. Hence the smallness of contemporary animals compared to fossil ones.

Although I am not confident that the sons listed in Genesis 5 and 11 are all firstborn, I think Patten was absolutely correct that the Genesis historical data (particularly in Genesis 5) *strongly* imply delayed sexual maturation, and probably delayed skeletal maturation, as well. Creation researcher Greg Beasley (1990, p. 5) later wrote:

> The fossilised remains of both flora and fauna are, as a rule, significantly larger in the past than in their extant counterparts. One possible explanation for this 'shrinkage' over time is that the growth potential of living organisms has been impeded through *earlier maturation and declining longevity*; a consequence of changes in the prevailing biospheric conditions during the earth's recent past. It is proposed that these changes were brought about by, and as a consequence of, geophysical, atmospheric and biological changes, initiated during the Flood. The writer proposes that morphological shrinkage is **primarily a phenomenon of the post-Flood period, as was declining longevity and earlier skeletal maturation**. [italics mine, boldface his]

The deduction that ancient humans might have been larger than extant humans was fairly obvious, given the widespread giantism in the fossil record. However, Patten and Beasley's deduction that long-lived creatures in general and humans in particular should take longer to mature is particularly noteworthy, as it appears to have been deduced almost entirely, if not entirely, from the Scriptural data *alone*. Although some references published in the 1980s (Lindstedt and Calder 1981, Calder 1984, and Schmidt-Nielsen 1986) discussed the idea that biological timescales (including lifespan and maturation times) are mass-dependent, neither Patten nor Beasley appears to have been aware of these references, as they do not cite them.

Testing a Creationist Prediction

In essence, Patten and Beasley predicted that longer-lived creatures should be larger and take longer to mature than creatures with shorter lifespans (Figure 3). At the time, there were very little data available to test that hypothesis. However, that is beginning to change. Multiple studies published in the last 20 years or so show positive correlations between larger body mass and greater longevity, as well as between larger body

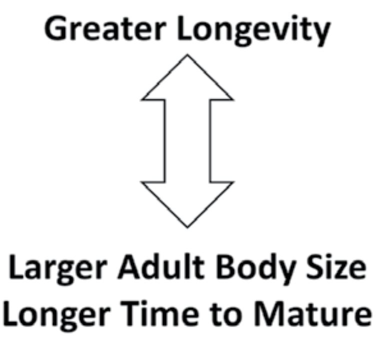

Figure 3. Studies of extant animals have shown that larger adult body sizes and longer maturation times are generally positively correlated with greater longevity.

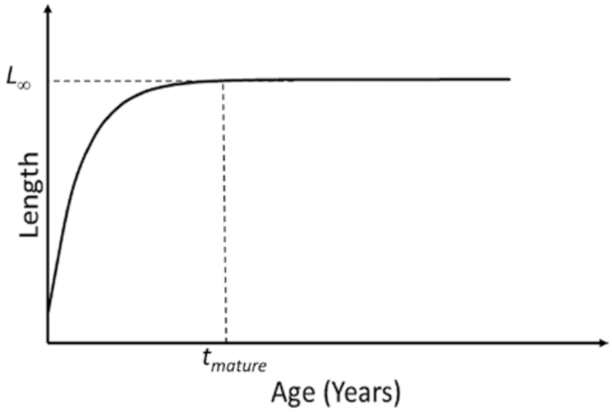

Figure 4. The von Bertalanffy growth curve, showing an organism's length or height as a function of time since birth or hatching. Growth effectively, if not completely, stops when the organism reaches skeletal maturity at time t_{mature}.

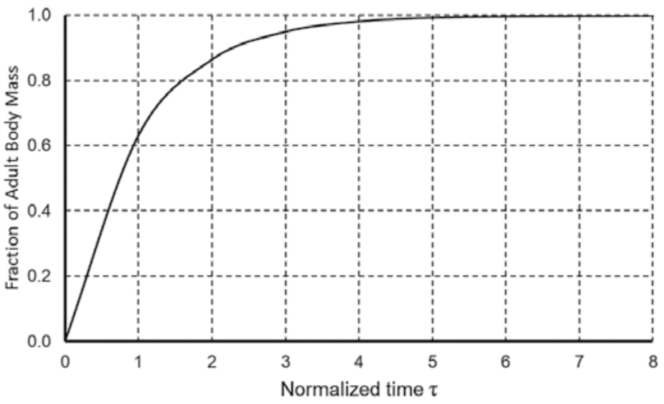

Figure 5. Theoretical mass-versus-age growth curve derived by West, Brown, and Enquist (2001), showing the manner in which fraction of adult body mass varies as a function of (normalized) time τ since birth or hatching. Reproduced from Figure 7 of Hebert (2023b). Used by permission of Cedarville University and the International Conference on Creationism.

mass and greater ages at maturation. In short, larger creatures tend to live longer and take longer to mature than smaller creatures. Admittedly, most of these studies span higher taxonomic categories (classes, orders, and families), but some show these correlations even within a single genus or species (see Sato, 1994; Genade et al., 2005; Lee et al., 2013). Overviews of these studies, including apparent contrary evidence, are provided in Hebert (2023b) and Hebert, Overman, and Sherwin (2024).

Moreover, the field of sclerochronology is now making it possible to test this 42-year-old creationist prediction by comparing the lifespans, sizes, and maturation times of fossil organisms to those of their extant, living counterparts. Sclerochronology (Moss, Ivany, and Jones, 2021) is the study and counting of periodic features in the skeletal portions of animals that grow by accretion, such as the shells of bivalves like clams and oysters. Paleontologists are using similar techniques to also count periodic growth structures in other taxa such as fishes, gastropods (Jones, Arthur, and Allard, 1989; Jambura and Kriwet, 2020; Shimada et al., 2021), and reptiles (Erickson and Brochu, 1999; Erickson, Rogers, and Yerby, 2001; Woodward, 2005). The use of growth increments in bones to determine age is called skeletochronology (Hutton, 1986).

Ontogenetic Growth Curves

The von Bertalanffy (1938) growth function (VBGF), depicted graphically in Figure 4, is often used to describe the ontogenetic growth of various organisms. The organism's length L as a function of time t is given by:

$$L(t) = L_\infty \left(1 - e^{-k(t-t_0)}\right) \qquad (1)$$

In Equation (1), time t is measured in years, as is the time t_0, the theoretical time at which the organism has a body length of zero. The parameter k (with units of years^{-1}) controls the relative speed with which the organism reaches an adult body length of L_∞. It should be noted that k is not a growth rate *per se*, although it is a proxy for growth rate. Lower and higher k values are associated with slower and faster growth, respectively.

Theoretically, Equation (1) describes indeterminate (never-ceasing) growth, since for any finite time t the organism's growth never quite stops. As a practical matter, however, it is often used to model both indeterminate and determinate growth, since one can treat the age at skeletal maturity as the time at which the slope of the function becomes arbitrarily small. However, Day and Taylor (1997) have criticized the use of the VBGF, particularly for modeling determinate growth, stating that the VBGF "often fails to provide an appropriate description of prematurity growth" (pp. 381–382). They argue that two separate equations, one for younger ages and a second for older ages close to maturity, are needed to accurately model ontogenetic growth. However, we are here most concerned with correctly modeling growth closer to ages at maturity, and the VBGF seems to do this reasonably well. Thus, most researchers ignore this complication, as we do here. The VBGF is used by commercial fisheries to model fish growth, and it is the growth curve most often used to model the growth of bivalves, like clams and oysters (Moss et al, 2021). Relevant to our purposes here, most studies of crocodilian ontogenetic growth use the VBGF (Viotto, Navarro, and Piña, 2020).

It should be noted that the VBGF is ideally obtained from length-versus-age data for a population. As such, L_∞ is the *average* size of organisms in the population that live long enough to reach maturity. Hence, some members of the population will have adult body sizes greater than L_∞, and some will have adult body sizes less than L_∞. When fitting a VBGF to length-versus-age data for a population, a computer program uses nonlinear least squares regression to find the values of k, t_0, and L_∞ that give the best overall fit to the data.

West, Brown and Enquist (2001) have developed a metabolic theory of ontogenetic growth, in which the organism's mass m as a function of time t is given by

$$\left(\frac{m}{M}\right)^{1/4} = 1 - \left[1 - \left(\frac{m_0}{M}\right)^{1/4}\right] e^{-\frac{1}{4} a t M^{-1/4}} \qquad (2)$$

In Equation (2), M is the adult body mass, m_0 is the mass at time $t = 0$, and a is a taxon-specific constant. A generalized form of Equation (2) is shown in Figure 5. In Figure 5, the fraction of adult body mass is plotted as a function of a dimensionless time parameter τ. Hence, Equation (2) and Figure 5 are general results that may be applied to a wide array of organisms. With some algebraic manipulation (West, Brown, and Enquist, 2001; Hebert, 2023b), it is possible to show that an organism's adult body mass M is proportional to the fourth power of its age at skeletal maturity, t_{mature} :

$$M = k \cdot t_{mature}^{4} \qquad (3)$$

The value of k is taxon-dependent. Thus, we might expect larger, more massive versions of creatures within a biblical kind to take longer to mature. However, it should be noted that k in Equation (3) may also depend on ambient conditions, which certainly have changed after the Flood. Thus one likely cannot safely assume, until demonstrated otherwise, that the proportionality 'constant' k for a particular taxon would have necessarily remained the same before and after the Flood.

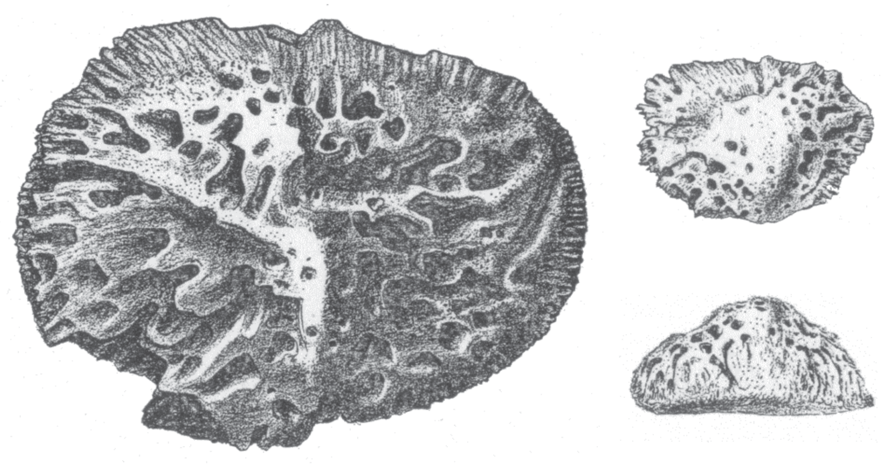
Figure 6. W. J. Holland sketches of overhead (left and upper right) and lateral (lower right) views of *Deinosuchus hatcheri* osteoderms. Public Domain. Wikimedia Commons.

Inferring Crocodilian Ages from Dorsal Osteoderms

Hutton (1986, p. 333) showed that growth in Nile crocodiles from Zimbabwe was "strictly confined" to the hot season (late October to mid-March), when water temperatures were highest. This makes sense in light of the fact that crocodilians are poikilothermic ("cold-blooded"). Hence their rates of bone growth and deposition vary with ambient temperatures (Schwimmer, 2002, p. 62). During these periods of rapid growth, broad "zones" of rapid bone deposition formed within crocodile bones. During the cool season, narrow "annuli," indicative of slow bone growth, were deposited. Hutton noticed that these seasonal laminations were most numerous and distinct within the crocodiles' long bones and within bony scutes called *osteoderms* (Figure 6).

Presumably, these seasonal laminations could be used to construct size-versus-age growth curves for living crocodilians. However, a complication is that the oldest laminations within long bones are sometimes "re-modeled." This complicates the counting process, necessitating some means of estimating the number of older laminae that have been remodeled and are no longer visible within the long bone. This re-modeling process is less of an issue in reptiles than it is in mammals. This is one of the reasons that crocodilians are considered an 'excellent' choice for the study of morphological changes throughout ontogeny (Cossette et al., 2022, p. 2905).

However, Hutton noted that the laminae within osteoderms were also numerous, distinct, and were less subject to remodeling. Although it is not readily apparent from Figure 6 how or where these growth laminations are located, Erickson and Brochu (1999) seem to imply (see the caption to their Figure 2b) that the counted growth laminations are visible on the ventral (bottom) portions of osteoderms taken from the dorsal neck region. However, Figure 6 only depicts the dorsal (overhead) and lateral (side) views of an osteoderm, This is apparently the reason that the growth laminations are not evident in Figure 6.

Hutton conducted longitudinal studies and found that he could use the growth laminations within these anterior neck osteoderms to construct age-versus-length growth curves for crocodiles. He validated his method for male and non-breeding female crocodiles with ages as high as 46 years, and found that his method could ‘predict’ lengths at a given age with no more than 9–15% error.

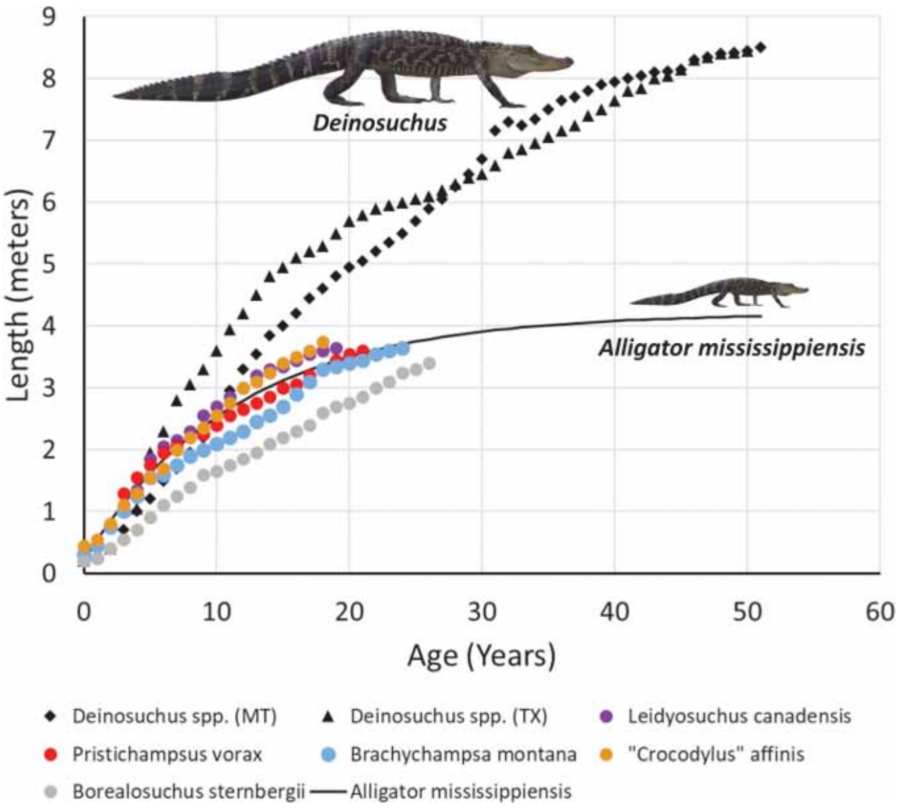

Figure 7. Length-versus-age growth curves for the American alligator (*Alligator mississippiensis*) and multiple species of fossil crocodilians, after Figure 2a in Erickson and Brochu (1999). Alligator image credit: Gareth Rasberry, CC BY-SA 3.0. https://creativecommons.org/licenses/by-sa/3.0/. Reproduced from Figure 10 of Hebert (2023b), used by permission of Cedarville University and the International Conference on Creationism.

Deinosuchus Ontogenetic Growth Curves

Erickson and Brochu (1999) used Hutton’s osteoderm method and *Deinosuchus* specimens from Texas and Montana to construct growth curves for *Deinosuchus*, five other non-gavialoid fossil crocodilians, the American alligator *Alligator mississippiensis*, and the saltwater crocodile *Crocodylus porosus*. As Erickson and Brochu were not sure whether or not the Montana and Texas specimens were the same species, they designated both the Texas and Montana specimens as *Deinosuchus* spp. I emailed Erickson and Brochu, hoping to obtain their raw data, but I did not hear back from them. I reconstructed the seven fossil growth curves from their Figure 2a to the best of my ability. I had difficulty plotting all the data points close to the origin due to the overlap of the multiple different curves in that part of the chart. I also included in my chart the inferred VBGF from an American alligator catch-tag-and-release study (Chabreck and Joanen, 1979), to provide a comparison between extinct and extant crocodilians. These eight reconstructed growth curves are shown in Figure 7.

At the time Erickson and Brochu did their analysis, no complete *Deinosuchus* fossils were available, so they had to use allometric relationships to estimate the total *Deinosuchus* body length. In extant crocodilians, head length is strongly correlated with total body length (Schwimmer, 2002, p. 47), and the equation

$$TBL = -4.39 + 7.49THL \qquad (4)$$

is sometimes used to estimate total body length (*TBL*) when total head length (*THL*) is known. In Eq. (4) *TBL* and *THL* are both measured in inches. Erickson and Brochu used an allometric formula similar to that of Eq. (4) to estimate total body lengths of between 8.43 and 9.10 meters for their Texas and Montana *Deinosuchus* specimens.

From Figure 7 it seems that *Deinosuchus* spp. was much larger and took much longer to mature than extant crocodilians. Although I extended my *Alligator mississippiensis* growth curve in Figure 7 out to an age of 51 years to match the lengths of the two *Deinosuchus* growth curves, Erickson and Brochu's VBGR curve for the American alligator extended only to 25 years. Likewise, a 'typical' growth curve for extant crocodiles in Figure 1 of Padian, Horner, and de Ricqlés (2004) only extends to ~27 years. The AnAge database (https://genomics.senescence.info) reports that some crocodiles have been reported to attain ages as high as 40 to 70 years, but these were animals living in captivity, not the wild. As Erickson and Brochu noted (1999, p. 205), "[e]xtant crocodilians rarely live this long [~50 years] in the wild." Thus, these growth curves show that *Deinosuchus* had a lifespan significantly longer than extant crocodilians. A popular-level account (Connor, 1999) summarizing their research said:

> Scientists have solved the mystery of a giant prehistoric crocodile which was so big that it could make a meal of a dinosaur.
>
> Deinosuchus was five times the size [in weight, J. H.] of the biggest crocodiles alive today and researchers have now discovered why—it lived far longer than its present-day cousins.
>
> Unlike the dinosaurs, which became giants by putting on weight quickly, Deinosuchus grew slowly and became gigantic simply by continuing to get bigger while living to a relatively great age….
>
> The scientists studied the growth rings of Deinosuchus bones and found that the reptiles must have lived for at least 50 years, about 20 years more than living crocodiles, and considerably longer than the dinosaurs alive at the time.

Note that this last statement implies that a longevity of ~30 years is typical of today's crocodilians. Although it is often claimed that 50 years represents *Deinosuchus* longevity, 50 years is not necessarily the full lifetime potential of *Deinosuchus*. Rather, 50 years is simply the approximate ages of these two *Deinosuchus* specimens when they died.

In passing, I do not necessarily agree that (large) dinosaurs grew rapidly. Myhrvold (2013) has criticized studies purporting to show that dinosaurs grew rapidly, citing an inability to replicate their results, as well as methodological and statistical fallacies (see Hebert, 2023b, for a brief discussion). The only two studies Myhrvold did not criticize implied much slower rates of sauropod dinosaur growth (Woodward, 2005; Lehman and Woodward, 2008).

Are the Laminations Annual?

Based on their published results, mainstream paleontologists clearly think growth bands in fossil crocodilians most likely represent yearly or seasonal variations. However, Schwimmer (2002) gives two reasons for questioning this assumption. First, mainstream paleontologists think the Cretaceous climate was quite warm with less-pronounced seasonality (and creationists would probably agree with this description of the pre-Flood climate). In such a climate, would temperature variations be sufficiently pronounced to result in annual growth bands, as in today's world? Second, the growth curve of the Texan *Deinosuchus* is very similar to that of the Montana specimen, even though the Montana specimen apparently lived farther north, with presumably more pronounced high-latitude seasonal differences.

Actually, the second objection is answered by the first. Latitudinal temperature differences would have been less-pronounced in a warmer climate with less-pronounced seasons.

As to the first objection, seasonal variations of some sort would still seem to be the most likely cause of the growth bands, even if some factor other than temperature was the true cause. Schwimmer suggests prey migrations, wet-dry seasonal differences, or changes in ocean circulation or nutrient availability as possible causes, but notes that these too, could be annual. He states (2002, p. 63), "At present, this line of reasoning [from the *Deinosuchus* growth curves] is an interesting and reasonable argument for the size of *Deinosuchus* and its growth. There are no good alternative explanations currently proposed, and the question is still wide open for study." As of this writing, most paleontologists still seem to think these growth bands are annual.

Also, in a (presumably) stable pre-Flood climate, one would expect non-seasonal variations in temperature or other variables to be mild, with the largest fluctuations resulting from seasonal variation. It is indeed possible that these seasonal variations may not have always been sufficiently large to stimulate annual growth rings in fossil crocodilians. But in that case, each growth band, on average, would represent *more* than one year, and the age estimates discussed below are too low. Hence, within a creationist framework, the ages discussed below could be minimum ages, with the true ages being even greater.

Still Growing at Time of Death?

In a 2004 discussion, Padian, Horner, and de Ricqlés (2004, p. 560, their Figure 4) *assume* that the Montana and Texas specimens used to construct the growth curves had reached 100% of their adult size, which Erickson and Brochu (1999, p. 206) estimated at 8.43 to 9.10 meters. However, there are reasons to suspect that these Montana and Texas *Deinosuchus* specimens were still growing when they died.

First, the American alligator (*Alligator mississippiensis*) has been shown to exhibit determinate growth. This means, contrary to popular misperception, American alligators stop growing before they die of natural causes. This was demonstrated by a 35-year capture-tag-and-release study (Wilkinson et al., 2016). Wilkinson et al. defined determinate growth (p. 843) as growth that continued for some time after an organism reached reproductive maturity, but which stopped before the organism became senescent. Hence, growth of the American alligator slows down and ceases, with the slope of the growth curve "leveling off" and approaching zero prior to natural death. The Wilkinson et al. study included alligators with ages as young as 14.6 years and as old as 68.6 years. The growth curves obtained by Wilkinson et al. (2016) implied that male alligators stopped growing at 43 years, and females stopped growing at 31 years.

Although not certain, it seems reasonable that other extant and fossil crocodilians would *also* exhibit determinate growth. Wilkinson et al. (2016, p. 843) stated their research "adds to a growing list of studies suggesting crocodilians as a group exhibit this growth pattern rather than indeterminate growth." They noted that indeterminate growth for crocodilians seems to have merely been assumed, partly because of a scarcity of data for the largest and oldest specimens. Yet a more recent study by Woodward, Horner, and Farlow (2011) shows that a kind of bone microstructure called an *external fundamental system* (EFS) is present in the long bones of skeletally mature American alligators, and it has also been found in the long bones of some dinosaur fossils. The presence of an EFS would be evidence that the Montana and Texas *Deinosuchus* specimens had stopped growing, but Erickson and Brochu did not mention or describe an EFS in their 1999 paper. Indeed, long bones may not have even been part of their two fossil samples.

The growth curves in Figure 7 seem to have not yet "levelled off," which would indicate that *Deinosuchus* spp. was still growing at 50 years of age.

Second, within a creationist framework, all animals, including crocodilians, must have been originally designed by God to exhibit determinate growth (Hebert, 2023b). In a pre-Fall world without any death, continuous growth without limit would have been physically untenable.

A third reason to suspect that these *Deinosuchus* specimens were still growing at time of death is that most adult length estimates for *Deinosuchus riograndensis* are considerably longer than 9 meters. Indeed, Schwimmer (2002, pp. 47–48) noted that a *Deinosuchus* skull from the Big Bend region of Texas, the same locale from which Erickson and Brochu obtained their Texas specimen, had a total head length of ~1.31 meters (51.6 inches). Inserting this total head length (*THL*) into Eq. (4) implies a total body length (*THL*) of 382 inches, or 9.7 meters. Interestingly, an online article on the website of the journal *Science* (Schilthuizen, 1999) published the same month as the 1999 Erickson and Brochu *Nature* paper, states that *Deinosuchus* measured "well over 10 meters from head to tail."

Schwimmer (2002, p. 13) states that the largest *Deinosuchus* specimens were at least 11 meters, and possibly 12 meters long. In a newspaper article, he was quoted as saying (Broom, 2018), "The most conservative [*Deinosuchus* length] estimate among my peers is 35 feet, and the most optimistic is 45 feet. Forty feet is a good round number." Converting these estimates into meters yields a lower length estimate of 10.7 meters, an upper limit of 13.7 meters, and an intermediate estimate of 12.2 meters. Although Schwimmer did not explicitly say so, this is probably a length estimate for the larger *D. riograndensis* specimens from the American West and Southwest, as he estimates the adult length of the eastern variety to be ~8 meters.

Moreover, Cossette and Brochu (2020) strongly imply in the very first sentence of their abstract that 10 meters is a minimum length estimate for *Deinosuchus*: "*Deinosuchus* is a lineage of giant (≥10 m) Late Cretaceous crocodilians from North America." Interestingly, in that same paper they cite the 1999 Erickson and Brochu paper, using it as evidence that the length of *Deinosuchus* approached 10 meters, despite the lower original reported length estimate of 8.43 to 9.10 meters in Erickson and Brochu (1999).

Teasing Out Additional *Deinosuchus* Ontogenetic Information

If determinate growth did indeed characterize fossil crocodilians, *none* of the fossil crocodilians whose growth curves are shown in Figure 7 have yet reached skeletal maturity, including *Deinosuchus* spp. Again, Erickson and Brochu (1999) did not mention the observation of an EFS in any of the long bones belonging to the fossil specimens used to construct their two *Deinosuchus* growth curves. Apparently, no long bones were present in their fossil samples. In fact, it isn't even clear what particular fossil data they used. The caption to Figure 2 in their 1999 paper states that the "specimen [catalog] numbers are available from the authors on request." I did email Erickson and Brochu, hoping to acquire this information, but I did not hear back from them.

The growth curves of the other fossil crocodilians shown in Figure 7 are probably too short to justify attempting to fit VBGFs to them. However, in the case of *Deinosuchus*, we have a sufficient amount of ontogenetic data that we can reasonably attempt to do so. Given an estimated adult body length of ~10 meters, the Deinosuchus specimens whose growth curves are shown in Figure 7 had likely already achieved more than 80% of their total adult body length. A VBGF would give us a better idea of how long it would take *D. riograndensis* to reach skeletal maturity.

As noted earlier, Erickson and Brochu (1999) did not provide their length-versus-age data in tabular form, but I reconstructed their data to the best of my ability, as shown in Figure 7 (see also Figure 10 in Hebert 2023b). However, Padian, Horner, and de Ricqlés (2004) *did* include a smoothed version of Erickson and Brochu's *Deinosuchus* growth curve in their Figure 1. Careful examination shows that the Padian et al. growth curves for *Deinosuchus* and 'Typical crocodiles' do not extend all the way back to an age of $t = 0$ years. Their 'Typical crocodiles' curve begins at $t \sim 3.5$ years, and the *Deinosuchus* curve begins at $t \sim 2$ years. Padian et al. probably truncated their smoothed curves because of the inability of a VBGF to accurately model the inflection in the growth curves at the earliest states of ontogeny, with ages close to $t = 0$.

They did not provide VBGF equations for these two smoothed curves, but it is possible to learn them. I was able to reproduce their smoothed curves by carefully reading off their Figure 1 length and age values that were, with three exceptions, equally spaced at five-year intervals. The reason for the exceptions is that I made sure to include the 'end points' of their smoothed curves, which did not always fall on even multiples of five years. Seven data points were used to re-construct the 'Typical crocodile' growth curve, and eleven data points were used to re-construct the *Deinosuchus* growth curve (see Tables I and II). I then used the IDL function mpfitexpr.pro (Markwardt, 2009) to perform a nonlinear least squares regression to obtain best-fit VBGFs for these two curves.

I should note that here I am *not* attempting to find the best-fitting smoothed curve to the raw *Deinosuchus* data in Erickson and Brochu (1999). Rather, I am simply taking Padian et al.'s published 2004 curve at face value and trying to find the equation that describes it. Obviously, they thought their smoothed curve was reasonable, or they would not have published it. I just want to find the *equation* of this curve in order to estimate how long, based on the assumption of determinate growth, it would take an "average" *Deinosuchus* to reach skeletal maturity.

This method requires a specified functional form, trial values for the parameters to be found, and estimated errors (one standard deviation) in the dependent variable values. When finding the overall best fit, the method gives greater weight to data points with smaller uncertainties. Because I am only attempting to reproduce the two smoothed curves from Figure 1 in Padian et al., I assumed *equal uncertainty* in each data point, rather than the 15% length error estimated by Hutton (1986). This is because the error in this exercise is *not* the uncertainty in an allometric length estimate. Rather, it is the uncertainty in reading data points off an already-published plot. Since it is presumably equally difficult for me to read one data point off Padian et al.'s Figure 1 as it is any other data point, I assumed equal uncertainty in all the data points. Since I was reasonably, but not absolutely, confident that I could read data points to within a precision of 0.10 meters, I took the 2-sigma estimated uncertainty to be 0.10 meters, with the corresponding 1-sigma error of 0.05 meters.

Table I. Reconstructed age and length values from the smoothed 'Typical crocodile' growth curve shown in Figure 1 in Padian, Horner, and de Ricqlès (2004).

Age (Years)	Length (meters)
3.5	1.3
5	1.7
10	2.6
15	3.2
20	3.6
25	3.8
27	3.85

Table II. Reconstructed age and length values from the smoothed *Deinosuchus* growth curve shown in Figure 1 in Padian, Horner, and de Ricqlès (2004).

Age (Years)	Length (meters)
2	0.55
5	1.9
10	3.4
15	4.4
20	5.3
25	6.05
30	6.7
35	7.1
40	7.7
45	8.0
50	8.4

All data values and trial parameters were inputted as double-precision.

For the 'Typical crocodile' curve, I used starting values of $L_\infty = 4.0$ meters, $k = 0.1$ years^{-1}, and $t_0 = -0.5$ years. In five iterations, the code converged to values of $L_\infty = 4.183$ meters, $k = 0.0937$ years^{-1}, and $t_0 = -0.4957$ years.

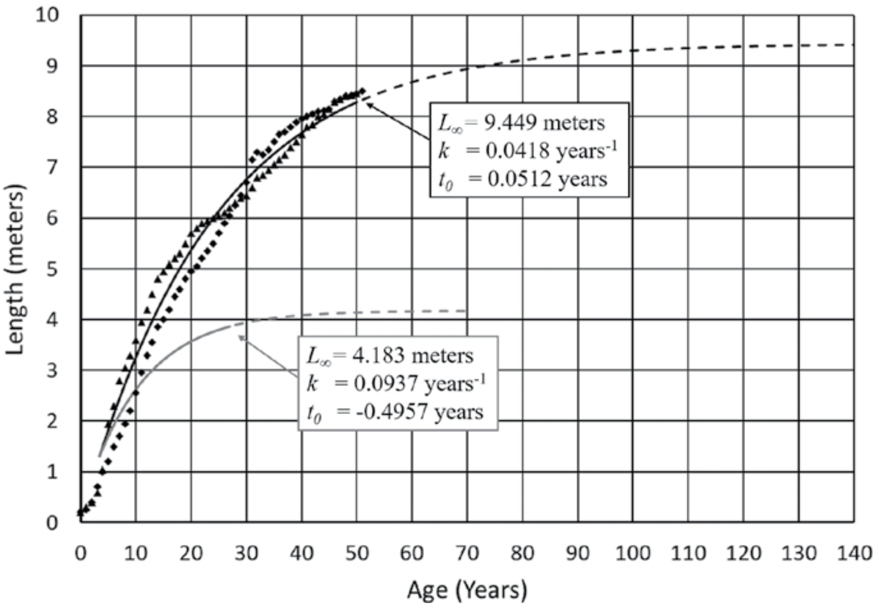

Figure 8. A smoothed von Bertalanffy growth curve for 'Typical crocodiles' (solid and dashed gray line) and for *Deinosuchus* spp. (solid and dashed black line). The smoothed *Deinosuchus* growth curve fits the reconstructed *Deinosuchus* length-versus-age data (black triangles and diamonds) quite well, despite being derived from Figure 1 in Padian, Horner, and de Ricqlés (2004), rather than Figure 2a in Erickson and Brochu (1999).

For the *Deinosuchus* growth curve, I used starting trial values of $L_\infty = 9.50$ meters, $k = 0.05$ years^{-1}, and $t_0 = -0.50$ years. Within six iterations, the code converged to best-fit VBGF values of $L_\infty = 9.449$ meters, $k = 0.0418$ years^{-1}, and $t_0 = 0.0512$ years. Given that *Deinosuchus* surely had a positive body length at hatching, t_0 should technically be a negative value. However, this issue is moot, since we used only age values of 2 years or greater in our fitting. Also, it may seem odd that the fitted values of t_0 imply that the gestation time for the giant *Deinosuchus* (0.051years) is actually less than that of an extant smaller 'Typical crocodile' (0.496 years), but this too is likely due to our exclusion of data near $t = 0$.

I also experimented with other starting values and constraints, such as minimum allowed final lengths of 10 and 11 meters. The result shown in Figure 8 is the most conservative result, having the smallest value of L_∞ and the shortest time to reach skeletal maturity.

In Figure 8, I have overlaid my reconstructed smoothed *Deinosuchus* and 'Typical crocodiles' growth curves on top of my reconstructed *Deinosuchus* data from Figure 7. Note that the *Deinosuchus* growth curve does a good job of matching the reconstructed data and 'splitting the difference' between the Montana and Texas data sets, even though they were both obtained from the smoothed curve in Figure 1 in Padian, Horner, and de Ricqlés (2004) and *not* from 'raw' data in Erickson and Brochu's Figure 2.

Implications of Their Smoothed Growth Curve

The smoothed growth curve of Padian, Horner, and de Ricqlés (2004), under the assumption of determinate growth described by a VGBF, implies that *Deinosuchus* probably took *considerably* longer than 50 years to reach skeletal maturity. As noted earlier, one could define t_{mature} as the age at which the slope of the growth curve becomes arbitrarily small. If one defines this as the age at which growth drops to less than 1 cm per year, the implied age of *Deinosuchus* skeletal maturity is 89 years. If one defines it as the age at which growth drops to less than 1 mm per year, then it is 144 years (!). Some papers in the technical literature (Taylor, 1958; Natanson et al., 2006) define "longevity" as the age at which an organism typically reaches 95% of its final adult body length. This definition doesn't really make sense to me, as longevity, as most people understand it, can greatly exceed the time to reach maturity. In any case, according to this definition, *Deinosuchus* spp. reached maturity at 72 years.

This smoothed curve gives an additional reason to suspect that growth had not yet ceased at 50 years of age. The dashed black line in Figure 8 implies a growth rate of just under 5 cm per year at age 50. Would growth then completely stop at age 51, or is it more likely that growth would continue, but at a decelerated rate, until the growth rate became negligible?

Thus, Padian et al.'s (2004) smoothed *Deinosuchus* growth curve could imply that *Deinosuchus* age at skeletal maturity was ~70 years, or greater. However, it's not possible to say too much beyond this, as the informal nature of the smoothed curve in Padian, Horner, and de Ricqlés (2004) makes a rigorous statistical analysis impossible. A more rigorous statistical analysis of the two original *Deinosuchus* spp. curves in Figures 7 and 8 might be possible. However, such an analysis is complicated by the fact that the data points in each of the two curves don't meet the requirements for a 'simple' non-linear regression. For instance, attempting to fit a VBGF to the Texas *Deinosuchus* data (triangles) in Figures 7 and 8 will result in residuals that are consistently positive for one part of the VBGF curve and consistently negative for another part of the curve. The same will be true for the Montana *Deinosuchus* data (diamonds) in Figures 7 and 8.

Nevertheless, because longevity studies have shown a positive correlation between greater longevity and larger adult body sizes and greater ages at maturation, these *Deinosuchus* growth curves constitute both direct and indirect evidence that *Deinosuchus* longevity was considerably greater than that of today's crocodilians.

Ontogenetic Growth Inferences for *Sarcosuchus imperator*

Sereno et al. (2001) performed a similar study using Lower Cretaceous *S. imperator* fossils from the Sahara. Because no complete *S. imperator* fossil was available, they used skull lengths of the extant saltwater crocodile (*Crocodylus porosus*) and the gharial (*Gavialis gangeticus*) to estimate the total body length of *S. imperator*, since "[i]n extant crocodilians, skull and total body lengths of subadult and adult individuals are strongly correlated and show negligible sexual variation" (Sereno, 2001, p. 1517). Their plot of *C. porosus* and *G. gangeticus* total body lengths against skull lengths showed that, for a given skull length, body lengths fell within a narrow range of values. Their allometric regression (see their Figure 4B) implied that the *S. imperato*r's skull length of 1.6 meters would be accompanied by a total body length of about 11.8 meters. Their length estimate of 11–12 meters was later revised downward to between 9 and 9.5 meters by O'Brien et al. (2019).

Sereno et al. counted about 40 (presumably annual) growth rings within the trunk osteoderms of a subadult *S. imperator* specimen whose total length was estimated to be about 80% of this total adult length. A femur was present in the fossil material, but Sereno et al. did not mention an external fundamental system (EFS). He graciously responded to an email question asking about the possible presence of an EFS. He said that not many *S. imperator* femurs were even available that would enable a check for an EFS. He said that he and his team only used scutes to estimate ages for their specimens.

Although they did not include an ontogenetic growth curve, they estimated that *S. imperator* would have taken 50–60 years to reach adulthood (Sereno et al., 2001, p. 1518):

> Thin sections of trunk osteoderms from a subadult individual (80% of maximum adult size) show about 40 annual growth rings or lines of arrested growth. This count suggests that a maximum adult size was achieved only after a duration of 50 to 60 years.

Note that Sereno et al. seem to have here assumed that 20% or so of the total growth time would be needed for *S. imperator* to attain the last 20% of adult body length. But this is very likely *not* the case. We can use Figure 8, despite its somewhat tentative nature, to see why.

As noted earlier, the adult *Deinosuchus* body length estimate L_∞ in Figure 8 is 9.449 meters. 80% of this final length is 7.559 meters. Inspection of Figure 8 and insertion of the fitted parameter values into Eq. (1) reveal that a length of 7.559 meters is attained at an age of 39 years. A nearly full-grown body length that is 99% of L_∞ is 9.354 meters. Also from Figure 8 and Eq. (1) it can be shown that a length of 9.354 meters is not attained until an age of 110 years. Thus the time required for *Deinosuchus* to attain nearly the entire fraction of its remaining 20% of adult body length is 110 – 39 = 71 years, *not* 10 or 20 years! Because of the shape of the von Bertalanffy growth curve, one cannot safely assume that the time for either *Deinosuchus* or *S. imperator* to attain the last 20% of its adult body length is simply 20% of the total growth time. Doing so could *greatly* underestimate the true ages at skeletal maturity t_{mature}.

Sereno et al. (2001, p. 1518) commented:

> Because extant crocodilians do not actively grow or typically survive this long in the wild (16, 23), *S. imperator* appears to have achieved its enormous body size by extending the duration of rapid growth as has been shown to be the case in the giant crocodylian *Deinosuchus* (20), rather than accelerating the rate of bone deposition. [footnotes in original]

In summary, evolutionary paleontologists estimate that *Deinosuchus* took about 50 years, and *S. imperator* took at least 50–60 years, to reach adulthood. However, these are likely underestimates, in light of the evidence for crocodilian determinate growth and the trajectory implied by the smoothed *Deinosuchus* curve in Figure 8.

Moreover, these giant crocodilians perished in the Flood. Hence, there is no reason that creationists should naively assume that 50–60 years represents the true longevity potential of these animals. Rather, these are just their ages at time of death. Because of the positive correlations between total longevity and body mass and between total longevity and time to adulthood discussed earlier, the large body sizes and extended growth intervals of these crocodilians are indirect evidences of great longevity.

Comparison with Extant Crocodilians

Both *Deinosuchus* and *S. imperator* had noticeable anatomical differences from

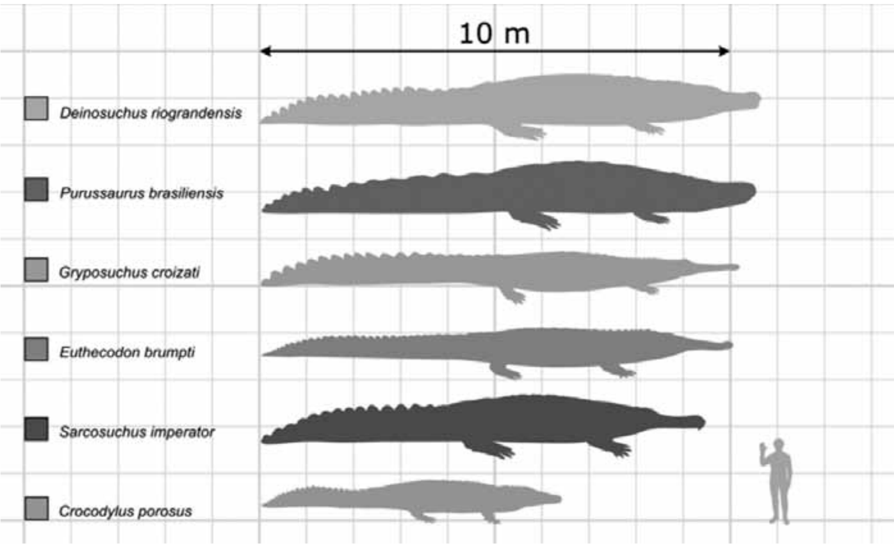

Figure 9. Length comparisons of five fossil and one extant crocodilian. Image credit: Smokeybjb. CC BY-SA 3.0. https://creativecommons.org/licenses/by-sa/3.0/.

extant crocodilians. Hence, they may not have belonged to the same Genesis kind or kinds as extant crocodilians. Indeed, creationists are still attempting to determine the number of original created crocodilian kinds (Hennigan, 2014; Cserháti, 2023).

However, their growth curves can perhaps tell us something about the ontogenies and longevities of other giant fossil crocodilians compared to extant ones. The estimated lengths of five giant fossil crocodilians, as well as the extant saltwater crocodile, are shown in Figure 9.

Purussaurus is a genus of giant caimans (Aureliano et al. 2015; Paiva et al., 2022) whose fossils have been found in Miocene deposits in Peru and Brazil. The largest specimen, *P. brasiliensis*, is thought to rival *D. riograndensis* in size and is estimated to have had the strongest bite force of any animal that ever lived.

Gryposuchus croizati is an extinct giant gavialid or gharial (Riff and Aguilera, 2008; Cidade et al., 2017). The fossils of both have been found in Miocene deposits in South America. Another giant fossil gharial (not depicted in Figure 10) is the *Rhamposuchus*, whose fossils are found in Pliocene deposits in India and Pakistan.

Euthecodon was very similar to a gharial in appearance; indeed the first remains from Ethiopia described by Joleaud (1920) were initially thought to belong to a false gharial. Its fossils are found in Miocene deposits in Africa, particularly Tunisia (Pickford, 2000; Agrasar, 2003). Evolutionists claim that the resemblance to living gharials is only superficial, and that the long snout evolved independently multiple times due to convergent evolution! The largest specimen, *E. brumpti*, was also a giant crocodilian.

Regardless of whether evolutionary scientists regard extant gharials or caimans as related to the giant gharials or caimans of the past, such ancestor-descendant relationships are very likely within a creationist framework. Indeed, even non-creationist authors have noticed that evolutionists tend to inflate the number of genera or species by failing to consider the possibility that differences in body sizes might have an environmental, rather than a genetic cause. Despite his strongly anti-Christian bias, author Vine Deloria, Jr. (1997, p. 156) astutely noted

> The problem with orthodox interpretation of the relationship of the megafauna to creatures of our present size is that most scientists have looked for *genetic* change, as the quotation by Loren Eiseley above demonstrates. They have therefore constructed a large bestiary of megafauna, and dinosaurs perhaps, which have no ancestors and no descendants. Instead of grouping animals by similarity of form and considering that they may represent a single species varying its size in accordance with the manner in which they were organically stimulated to grow, they have created all kinds of species.

Yes, it is true that in *today's* world growth trajectories and final adult body sizes for terrestrial vertebrates are strongly determined by genetics, with environmental effects playing a relatively minor role (Wilkinson et al., 2016). But evolutionists are failing to take into account the effects of truly radical environmental changes at the time of the Flood, and possibly afterward. Creationists should not be afraid to make reasonable comparisons between different-sized creatures with very similar morphologies, even if evolutionists have assigned them to different genera. In a creationist framework, *Gryposuchus croizati*, and *Rhamposuchus* likely belong to the same Genesis kind as extant gharials, and this may be true for *Euthecodon brumpti*, as well. Likewise, *Purussaurus brasiliensis* may belong to the same Genesis kind as extant caimans.

To the best of my knowledge, we don't currently have ontogenetic growth data for giant fossil gharials or caimans. However, in light of their giant crocodilian body forms, it is reasonable to assume that they had ontogenetic growth patterns similar to *D. riograndensis* and *S. imperator.* In that case, they too, would have been experiencing delayed maturation, which could be indirect evidence of greater longevity compared to their likely descendants, the extant gharials and caimans.

Implications for the Location of the Flood/ Post-Flood Boundary

Deinosuchus riograndensis and *Sarcosuchus imperator* fossils are found in Cretaceous strata, which, by definition, are stratigraphically located below the K-Pg (or K-T) boundary. Virtually all creationists would accept these fossils as dating from the Genesis Flood. Hence, *Deinosuchus* and *S. imperator* fossils represent creatures that were living in the pre-Flood world. These crocodilians grew very large and apparently took a long time to reach skeletal maturity.

Extant crocodilians may not necessarily belong to the same Genesis 'kind' or 'kinds' as *S. imperator* and *Deinosuchus*. However, other giant fossil crocodilians, with body sizes comparable to those of *Deinosuchus* and *S. imperator* (Figure 9), *are* very similar to some extant crocodilians. Extant gharials could be descended from *Gryposuchus croizati, Rhamposuchus,* and possibly *Euthecodon brumpti.* Likewise, extant caimans may be descended from *Purussaurus brasiliensis.* Hence, these fossil crocodilians could be larger, longer-lived representations of these extant crocodilian kinds. In that case, they too constitute additional evidence of extreme animal longevity in the pre-Flood animal world.

It should be noted that the fossils of these other giant crocodilians, such as *P. brasiliensis*, *Rhamposuchus*, *G. croizati*, and *E. brumpti*, are found in Pliocene and Miocene strata, which are stratigraphically above the K-Pg boundary. I concur with Baumgardner (Oard, 2002), Oard (Oard, 2013), Clarey, Werner, and Tomkins (2022), and Clarey and Werner (2023) that evidence for a 'high' Flood/post-Flood boundary, generally at or above the Mid-Pleistocene (Holt, 1996) is *overwhelming*. In that case, these other fossil crocodilians *also* date from the Flood. If greater longevity was the norm in the pre-Flood animal kingdom, and if larger body masses do indeed generally correlate with greater longevity, it would make sense that these other fossil crocodilians, living in the same pre-Flood world as *Deinosuchus* and *S. imperator*, would have comparable giant body sizes, despite being found in different strata. Thus, the similar body sizes of giant fossil crocodilians, found in strata both above and below the K-Pg boundary, may suggest that they all grew under similar environmental conditions, conditions which changed drastically at the Flood. Since the Cretaceous giant fossil crocodilians are from the Flood, it seems reasonable that the Miocene and Pliocene giant fossil crocodilians would date from the Flood, as well.

Final Comments

This paper adds to a growing body of direct and indirect fossil evidence for greater animal longevity in the pre-Flood and immediate post-Flood worlds. Preliminary lines of evidence were presented in Hebert (2023b), and subsequent papers have elaborated on these arguments. Growth curves of fossil *Crassostrea* oysters provide direct evidence of greater longevity compared to extant *Crassostrea* oysters (Hebert, Overman, and Sherwin, 2024). These same growth curves show evidence of delayed maturation and larger body sizes, which have been shown to be associated with greater longevity in living creatures. Moreover, fossil bivalves from Antarctica also show evidence for very long lifespans (Hebert, 2023b), a topic I hope to discuss in more depth in a future paper. Likewise, numerous fossil sharks show evidence of giantism and delayed maturation (Hebert, 2024a). As discussed in Hebert (2023b), some fossil birds show evidence of delayed maturation, although this needs to be explored in more depth before a strong claim can be made. Also, an apparently worldwide diminution in mammal body sizes at the end of the Pleistocene could be indirect evidence of decreasing longevity at the end of the post-Flood Ice Age (Hebert, 2023a, Hebert, 2024b). Also, mainstream paleontologists have recently found evidence for "surprisingly long" (Baisas 2024) lifespans in the small Jurassic mammals *Morganucodon* and *Kuehneotherium* (Newham et al., 2020). Subsequent research has revealed long lifespans (for their body sizes) for five additional small Jurassic mammals, as well as evidence of delayed maturation in four such mammals (Panciroli et al., 2024, Newham et al., 2024, Hebert, 2024c). I strongly encourage other creation researchers to "be on the lookout" for additional possible fossil evidence of greater longevity in the pre-Flood world.

References

Agrasar, E. L. 2003. New fossil crocodilians from the Middle/Upper Miocene of Tunisia. *Annales de Paléontologie* 89(2): 103–110.

Aureliano, T., A. M. Ghilardi, E. Guilherme, J. P. Souza-Filho, M. Cavalcanti, and D. Riff. 2015. Morphometry, bite-force, and paleobiology of the Late Miocene Caiman *Purussaurus brasiliensis. PLoS ONE* 10(3): e0124188.

Baisas, L. Baby teeth reveal surprisingly long lifespans of small Jurassic mammals. *Popular Science*. https://www.popsci.com/science/jurassic-mammal-teeth/ (accessed September 17, 2024).

Beasley, G. 1990. Pre-flood giantism: a key to the interpretation of fossil hominids and hominoids. *Journal of Creation* 4(1):5–55.

Booker, P. 2005. A new candidate for Leviathan? *Journal of Creation* 19(2): 14–16.

Brassey, C. A. and J. D. Gardiner. 2015. An advanced shape-fitting algorithm applied to quadruped mammals: improving volumetric mass estimates. *Royal Society Open Science* 2(150302): 1–14.

Broom, B. This monster of an alligator once roamed Mississippi. *Mississippi Clarion Ledger*. https://www.clarionledger.com/story/magnolia/2018/07/09/mississippi-hunting-ancient-gator-species-too-big-catch/759097002 (accessed November 1, 2023).

Calder, W. A. III. 1984. *Size, Function, and Life History*. Cambridge, Massachusetts: Harvard University Press.

Chabreck, R. H. and T. Joanen. 1979. Growth rates of American alligators in Louisiana. *Herpetologica* 35(1): 51–57.

Cidade, G. M., A. Solórzano, A. D. Rincón, D. Riff, and A. S. Hsiou. 2017. A new *Mourasuchus* (Alligatoroidea, Caimaninae) from the late Miocene of Venezuela, the phylogeny of Caimaninae and considerations of the feeding habits of *Mourasuchus*. *PeerJ* 5:e3056.

Clarey, T. L. and D. J. Werner. 2023. A progressive global flood model confirmed by rock data across five continents. *Proceedings of the 9th International Conference on Creationism*: Vol. 9, Article 23.

Clarey, T.L., D.J. Werner, and J.P. Tomkins. 2022. Globally extensive Cenozoic coals indicate high post-Flood boundary. *Journal of Creation* 36(1): 13–15.

Connor, S. 1999. Solved: Mystery of crocodile that feasted on dinosaurs. *The Independent*. https://www.independent.co.uk/news/solved-mystery-of-crocodile-that-feasted-on-dinosaurs-1081362.html (accessed November 1, 2023)

Coppedge, D. F. Life is devolving from a past world of giants. *Creation Evolution Headlines*. https://crev.info/2023/03/life-is-devolving/ (accessed January 8, 2024).

Cossette, A. P., A. D. Grass, and T. DeGuzman. 2022. The contribution of ontogenetic growth trajectories on the divergent evolution of the crocodylian skull table. *The Anatomical Record* 305(10): 2904–2925.

Cossette, A. P. and C. A. Brochu. 2020. A systematic review of the giant alligatoroid *Deinosuchus* from the Campanian of North America and its implications for the relationships at the root of Crocodylia. *Journal of Vertebrate Paleontology* 40(1).

Cserháti, M. 2023. Baraminic analysis of Crocodylia based on mitochondrial DNA similarity. *Answers Research Journal* 16: 259–263.

Day, T., and P.D. Taylor. 1997. von Bertalanffy's growth equation should not be used to model age and size at maturity. *The American Naturalist* 149(2): 381–393.

Deloria, V., Jr. 1997. *Red Earth, White Lies: Native Americans and the Myth of Scientific Fact*. Golden, CO: Fulcrum Publishing.

Diaz, J. 'Terror Crocodile' the Size of a Bus Fed on Dinosaurs, Study Says. *The New York Times*. https://www.nytimes.com/2020/08/13/science/large-crocodile-deinosuchus.html (accessed January 10, 2024).

Dobzhansky, T. 1973. Nothing in biology makes sense except in the light of evolution. *The American Biology Teacher* 35(3): 125–129.

Erickson, G. M. and G. A. Brochu. 1999. How the 'terror crocodile' grew so big. *Nature* 398(6724): 205–206.

Erickson, G. M., K. C. Rogers, and S. A. Yerby. 2001. Dinosaurian growth patterns and rapid avian growth rates. *Nature* 412(6845): 429–433.

Genade, T., M . Benedetti, E. Terzibasi, P. Roncaglia, D. R. Valenzano, A. Cattaneo, and A. Cellerino. 2005. Annual fishes of the genus *Nothobranchius* as a model system for aging research. *Aging Cell* 4(5): 223–233.

Guliuzza, R. J. and P. B. Gaskill. 2018. Continuous environmental tracking: An engineering framework to understand adaptation and diversification. *Proceedings of the International Conference on Creationism*: Vol. 8, Article 11. https://digitalcommons.cedarville.edu/icc_proceedings/vol8/iss1/11/ (accessed January 25, 2024).

Hebert, J. 2023a. Rarity of long-lived post-Flood human fossils? *Journal of Creation* 37(3): 23.

Hebert, J. 2024a. Giantism in fossil sharks: Evidence for extreme longevity? *Creation Research Society Quarterly* 60(4): 267–283.

Hebert, J. 2024b. Late Pleistocene body size reduction: evidence of a post-Flood decline in longevity? *Journal of Creation* 38(1): 60–66.

Hebert, J. 2024c. Methuselah-Like Longevity in Pre-Flood Mammals. *Creation Science Update*. https://www.icr.org/article/methuselah-like-longevity-pre-flood/ (accessed October 22, 2024).

Hebert, L., III. 2023b. Allometric and metabolic scaling: Arguments for design… and clues to explaining pre-Flood longevity? *Proceedings of the International Conference on Creationism*: Vol. 9, Article 18. https://digitalcommons.cedarville.edu/icc_proceedings/vol9/iss1/18/ (accessed January 25, 2024).

Hebert, J., R. Overman, and F. J. Sherwin. 2024. Fossil *Crassostrea* oysters show evidence of extreme longevity. *Creation Research Society Quarterly* 60(3): 171–190.

Hennigan, T. 2008. A fearsome reptile. *Creation* 30(3): 20–22.

Hennigan, T. 2014. An initial estimate toward identifying and numbering the Ark turtle and crocodile kinds. *Answers Research Journal* 7: 1–10.

Holland, W. J. 1909. *Deinosuchus hatcheri*, a new genus and species of crocodile from the Judith River Beds of Montana. *Annals of the Carnegie Museum* 6: 281–294.

Holt, R. D. 1996. Evidence of a Late Cainozoic Flood/post-Flood boundary. *Journal of Creation* 10(1): 128–167.

Hutton, J. M. 1986. Age determination of living Nile crocodiles from the cortical stratification of bone. *Copeia* 1986(2): 332–341.

Jambura, P. L. and J. Kriwet. 2020. Articulated remains of the extinct shark *Ptychodus* (Elasmobranchii, Ptychodontidae) from the upper Cretaceous of Spain provide insights into gigantism, growth rate and life history of ptychodontid sharks. *PLoS ONE* 15(4): 1–16.

Joleaud, M. L. 1920. Sur la presence d'un Gavialide du genre *Tomistoma* dans le Pliocène d'eau douce de l'Ethiopie. *Comptes Rendus de l'Académie des Sciences* 170: 816–818.

Jones, D. S., M. A. Arthur, and D. J. Allard. 1989. Sclerochronological records of temperature and growth from shells of *Mercenaria mercenaria* from Narragansett Bay, Rhode Island. *Marine Biology* 102(2): 225–234.

Lee, W.-S., P. Monaghan, and N. B. Metcalfe. 2013, Experimental demonstration of the growth rate-lifespan trade-off. *Proceedings of the Royal Society B* 280(1752): 1–8.

Lehman, T. M. and H. N. Woodward. 2008. Modeling growth rates for sauropod dinosaurs. *Paleobiology* 34(2): 264–281.

Lindstedt, S. and W. A. Calder, III. 1981. Body size, physiological time, and longevity of homeothermic animals. *The Quarterly Review of Biology* 56(1): 1–16.

Line, P. 2013. Explaining robust humans. *Journal of Creation* 27(3): 64–71.

Markwardt, C. B. 2009. Non-Linear Least Squares Fitting in IDL with MPFIT. In D. Bohlender, P. Dowler, and D. Durand (editors), *Proceedings of Astronomical Data Analysis Software and Systems XVIII* (Quebec, CA), pp. 251–254. San Francisco: Astronomical Society of the Pacific Series, Volume 411.

Morris, H. M. 1993. *The Genesis Record: A Scientific and Devotional Commentary on the Book of Beginnings* (23rd printing). Grand Rapids, Michigan: Baker Book House.

Moss, D. K., L. C. Ivany, and D. S. Jones. 2021. Fossil bivalves and the sclerochronological reawakening. *Paleobiology* 47(4): 551–573.

Myhrvold, N. P. 2013. Revisiting the estimation of dinosaur growth rates. *PLoS ONE* 8(12): 1–24.

Natanson, L. J., N. E. Kohler, D. Ardizzone, G. M. Cailliet, S. P. Wintner, and H. F. Mollet. 2006. Validated age and growth estimates for the shortfin mako, *Isurus oxyrinchus*, in the North Atlantic Ocean. *Environmental Biology of Fishes* 77(3): 367–383.

Nelson, V. 2017. *Monumental Monsters*. Red Deer, Alberta, Canada: Untold Secrets of Planet Earth Publishing Company, Inc.

Newham, E., I. J. Corfe, P. Brewer, J. A. Bright, V. Fernandez, N. J. Gostling, S. Hoffmann et al. 2024. The origins of mammal growth patterns during the Jurassic mammalian radiation. *Science Advances* 10(32): eado4555.

Newham, E., P. G. Gill, P. Brewer, M. J. Benton, V. Fernandez, N. J. Gostling, D. Haberthür et al. 2020. Reptile-like physiology in Early Jurassic stem-mammals. *Nature Communications* 11(1): 5121.

Oard, M.J. 2002. Dealing carefully with the data. *Journal of Creation* 16(1): 68–72.

Oard, M.J. 2013. Geology indicates the terrestrial Flood/post-Flood boundary is mostly in the Late Cenozoic. *Journal of Creation* 27(1): 119–127.

O'Brien, H. D. L. M. Lynch, K. A. Vliet, J. Brueggen, G. M. Erickson, and P. M. Gignac. 2019. Crocodylian head width allometry and phylogenetic prediction of body size in extinct crocodyliforms. *Integrative Organismal Biology* 1(1), obz006.

Padian, K., J. R. Horner, and A. de Ricqlés. 2004. Growth in small dinosaurs and pterosaurs: The evolution of Archosaurian growth strategies. *Journal of Vertebrate Paleontology* 24(3): 555–571.

Paiva, A. L. S., P. L. Godoy, R. B. B. Souza, W. Klein, and A. S. Hsiou. 2022. Body size estimation of Caimaninae specimens from the Miocene of South America. *Journal of South American Earth Sciences* 118, 103970.

Panciroli, E., R. B. J. Benson, V. Fernandez, N. C. Fraser, M. Humphage, Z.-X. Luo, E. Newham, and S. Walsh. 2024. Jurassic fossil juvenile reveals prolonged life history in early mammals. *Nature* 632(8026): 815–822.

Patten, D. 1982. The longevity accounts in ancient history. *Creation Research Society Quarterly* 19(1): 40–52.

Paul, M.-J. 2010. Behemoth and leviathan in the book of Job. *Journal of Creation* 24(3): 94–100.

Pickford, M. 2000. Crocodiles from the Beglia Formation, Middle/Late Miocene boundary, Tunisia, and their significance for Saharan palaeoclimatology. *Annales de Paléontologie* 86(1): 59–67.

Riff, D. and O. A. Aguilera. 2008. The world's largest gharials *Gryposuchus*: description of *G. croizati* n. sp. (Crocodylia, Gavialidae) from the Upper Miocene Urumaco Formation, Venezuela. *Paläontologische Zeitschrift* 82: 178–195.

Rigby, S. 2021. *Sarcosuchus imperator*: The 'super croc' that could have hunted dinosaurs. *BBC Science Focus*. https://www.sciencefocus.com/nature/sarcosuchus-imperator (accessed January 11, 2024).

Sato, S. 1994. Analysis of the relationship between growth and sexual maturation in *Phacosoma japonicum* (Bivalvia: Veneridae). *Marine Biology* 118: 663–672.

Schilthuizen, M. 1999. A greater alligator. *Science.org*. https://www.science.org/content/article/greater-alligator (accessed January 25, 2024).

Schmidt-Nielsen, K. 1986. *Scaling: Why Is Animal Size So Important?* (3rd printing). Cambridge: Cambridge University Press.

Schwimmer, D. R. 2002. *King of the Crocodylians: The Paleobiology of Deinosuchus*. Bloomington and Indianapolis: Indiana University Press.

Sereno, P. C., H. C. E. Larsson, C. A Sidor, and B. Gado. 2001. The giant crocodyliform *Sarcosuchus* from the Cretaceous of Africa. *Science* 294 (5546):1516–1519.

Shimada, K., M. F. Bonnan, M. A. Becker, and M. L. Griffiths. 2021. Ontogenetic growth pattern of the extinct megatooth shark *Otodus megalodon*—implications for its reproductive biology, development, and life expectancy. *Historical Biology* 33(12): 3254–3259.

Sibley, A. 2023. A new 'marine crocodile' discovered on the Jurassic coast of England. *Journal of Creation* 37 (3): 9–10.

Taylor, C. C. 1958. Cod growth and temperature. *ICES Journal of Marine Science* 23(3): 366–370.

Taylor, P. S. 1987. *The Great Dinosaur Mystery and the Bible*. Master Books, El Cajon, California.

Thomas, B. and D. Biddle. 2023. Insight into Job's Theology from a new identification for Leviathan. *Creation Research Society Quarterly* 60(2): 72–83.

Viotto, E. V., J. L. Navarro, and C. I. Piña. 2020. Growth curves of wild and reintroduced broad-snouted Caimans (*Caiman latirostris*) and their management implications. *South American Journal of Herpetology* 16(1): 34–41.

von Bertalanffy, L. 1938. A quantitative theory of organic growth (inquiries on growth laws II). *Human Biology* 10:181–213.

West, G. B., J. H. Brown, and B. J. Enquist. 2001. A general model for ontogenetic growth. *Nature* 413(6856): 628–631.

Whitcomb, J. C. and H. M. Morris. 1991. *The Genesis Flood: The Biblical Record and Its Scientific Implications* (35th printing). Presbyterian & Reformed Publishing Company, Phillipsburg, New Jersey.

Wilkinson, P. M., T. R. Rainwater, A. R. Woodward, E. H. Leone, and C. Carter. 2016. Determinate growth and reproductive lifespan in the American Alligator (*Alligator mississippiensis*): Evidence from long-term recaptures. *Copeia* 104(4): 843–852.

Woetzel, D. *Chronicles of Dinosauria*. 2013. Illustrated by R. Dobbs. Master Books, Green Forest, Arkansas (USA).

Wood, T. The current status of baraminology. *Creation Research Society Quarterly* 43(3): 149–158.

Woodward, H. 2005. *Bone histology of the sauropod dinosaur Alamosaurus sanjuanensis from the Javelina Formation, Big Bend National Park, Texas* [masters thesis]. Lubbock, Texas: Texas Tech University.

Woodward, H. N., J. R. Horner, and J. A. Farlow. 2011. Osteohistological evidence for determinate growth in the American alligator. *Journal of Herpetology* 45(3): 339–342.