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Crassostrea Oyster Fossils Show Evidence of Extreme Longevity

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Abstract

This paper presents evidence that fossil *Crassostrea* oysters experienced much greater longevity than their modern-day descendants. For extant animals, multiple studies have revealed a positive correlation between longevity and adult body size: the larger the organism's size as an adult, the longer its lifespan. Studies have also demonstrated that organisms that take longer to reach skeletal and/or sexual maturity also tend to have longer lifespans. Fossil *Crassostrea* oysters are generally larger than their modern-day counterparts, and ontogenetic growth curves suggest longer lifespans and generally longer growth intervals. This evidence should be of great interest to Biblical creationists in light of the Bible's claim that humans in the pre-Flood and immediate post-Flood worlds experienced much greater longevities than modern-day humans. Animals may also have once experienced greater past longevity, since whatever genetic or environmental factors were enabling extreme human longevity were likely also operating across the animal kingdom.

Key Words: antediluvian, bivalves, *Crassostrea*, fossils, giantism, growth bands, longevity, oyster, sclerochronology

Introduction

One of the claims in Scripture that is most ridiculed by skeptics is the Bible's matter-of-fact declaration that, in the pre-Flood world, humans routinely attained ages in excess of 900 years (Genesis 5). Even for some time after the Flood, humans were experiencing lifespans of about 400 years (Genesis 11:12–17), which eventually dropped to 200 years (Genesis 11:18–32), and then gradually decreased to the 70–80 year average lifespan at the time of Moses (Psalm 90:10). Such extraordinary centuries-long lifespans are far beyond our present-day experience. Hence, creationists should be interested in possible corroboration of the Bible's claim in this regard from historical or paleontological data. Previous creationist authors (Patten, 1982; López, 1998) have discussed possible historical and cultural confirmations of these vast ages. Others have discussed possible evidence of greater longevity in post-Flood Neanderthal fossils (Cuozzo, 1998), as well as a possible connection between greater longevity and past giantism (Patten, 1982; Beasley, 1990; Nelson, 2017).

Crassostrea virginica (Figure 1), also known as the Atlantic or East Coast Oyster, is capable of attaining ages of 20 years with adult sizes of up to 8–10 inches, or 20–25 cm (Wallace, 2022;

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Anonymous a). However, these seem to be exceptional values, with most lifespans and sizes being much less than these (Osborne, 1999). Other sources (Harzhauser et al., 2016; Kusnerik et al., 2018) list the maximum lifespan as between 5 and 10 years, and the AnAge Animal Ageing and Longevity Database (de Magalhães, 1997) lists the lifespan for wild *Crassostrea virginica* oysters as 5 years. They are prized as a seafood, but there is another reason for creationists to love *Crassostrea* oysters: *Crassostrea* fossils provide evidence that they were experiencing much greater longevity compared to modern *Crassostrea* oysters, and they provide an important link suggesting that this was also true for other animal forms. This paper expands on the brief discussion presented by Hebert (2023).

Background: Asymptotic Growth and the von Bertalanffy Growth Equation

Many animals exhibit asymptotic growth; that is, as they mature, their length L asymptotically approaches a maximum value that we designate as L_∞ (Figure 2). This asymptotic growth can be described mathematically by the von Bertalanffy (1938) growth equation:

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

Here, t is the time since birth (measured in years) and k is a parameter (with units of years^{-1}) that governs the relative speed with which an organism reaches adulthood. Although k is not a growth rate *per se*, it is a proxy for growth rate, with high k values representing faster growth and lower k values representing slower growth.

The value t_0 is the (theoretical) time at which the organism's length is zero. If the animal has zero size at birth, t_0 will be zero. If the creature has a positive, non-zero size at birth, t_0 will be a negative number, indicating that the creature had zero size at the beginning of its gestation, $-t_0$ years before birth.

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, Equation (1) is often used to model both indeterminate and determinate growth, since one can treat the age at skeletal maturity t_{mature} as the

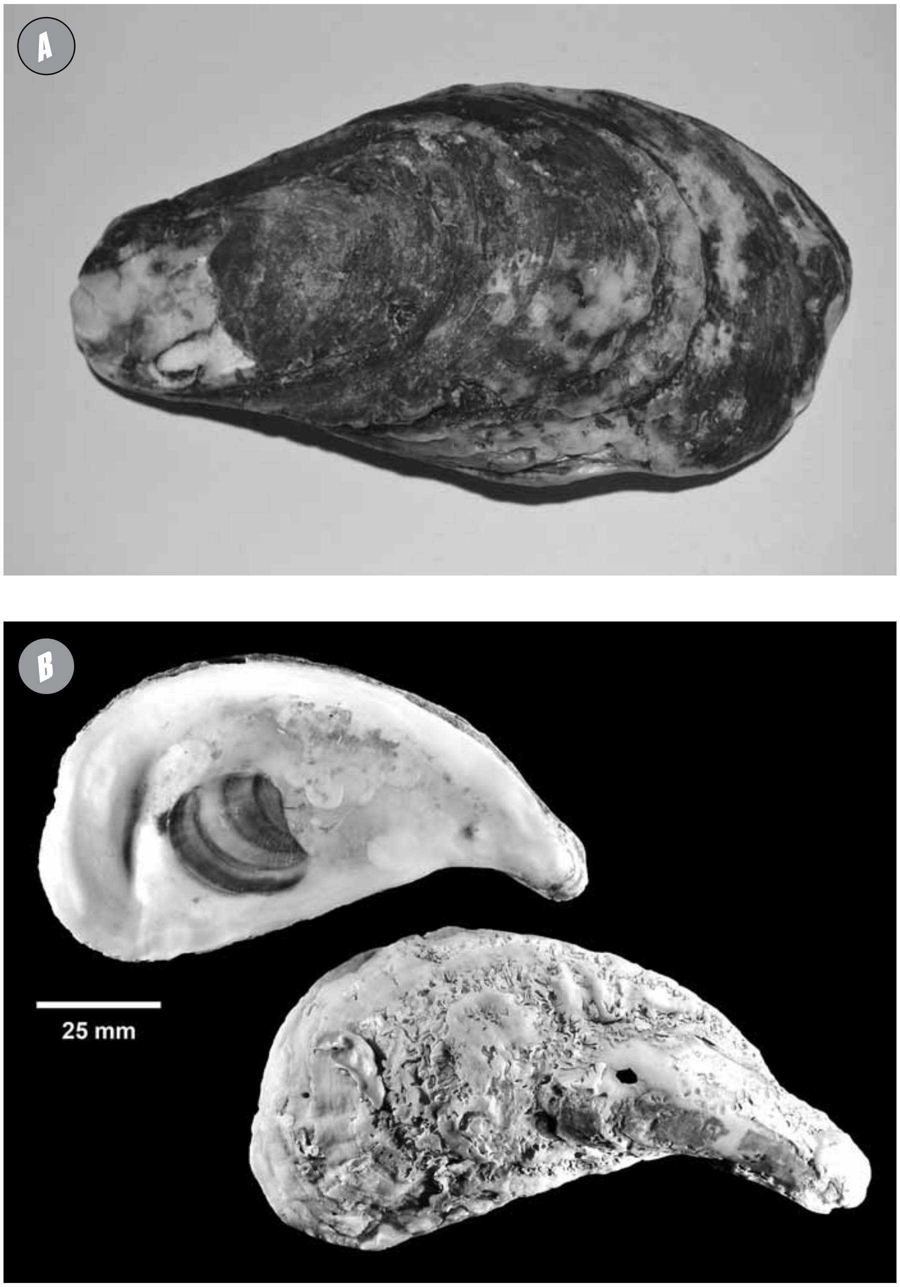

Figure 1. The oyster species *Crassostrea virginica*, or Eastern Oyster. Figure 1a by Andrew C, Creative Commons Attribution 2.0 Generic license. Figure 1b by Eric A. Lazo-Wasem, Yale University Peabody Museum. Creative Commons CC0 1.0 Universal Public Domain Dedication.

time at which the slope of the function becomes arbitrarily small.

Day and Taylor (1997) have criticized use of Equation (1), arguing that two separate equations are needed to accurately model growth, one for younger ages and a second for older ages. Nevertheless, the von Bertalanffy equation is routinely used by commercial fisheries to estimate age-size relationships for fishes, and it is the growth curve most often used for bivalves (Moss et al., 2021).

Eq. (1) is obtained from a population of organisms. L_∞ thus represents the average adult body size for the population, obtained from fitting a growth curve to the size-versus-age population data. Since this is a population average, individual specimens in the population will be characterized by L_∞ values that are both smaller and larger than this.

Given sufficient time, the growth rate of an organism exhibiting *determinate* growth will become vanishingly small when it reaches skeletal maturity at time $t \approx t_{mature}$. At this time, the slope of the growth curve approaches zero. Note that t_{mature} is not necessarily the same as the age t_{sex} at sexual maturity, as ages at sexual maturity do not necessarily coincide with ages at skeletal maturity. Indeed, *Crassostrea virginica* can reach sexual maturity soon after hatching (Anonymous a), although it continues to grow for much longer than this. Nevertheless, one might reasonably expect higher ages t_{mature} at skeletal maturity to be associated with higher ages of sexual maturity t_{sex}. These points will become important later in our discussion.

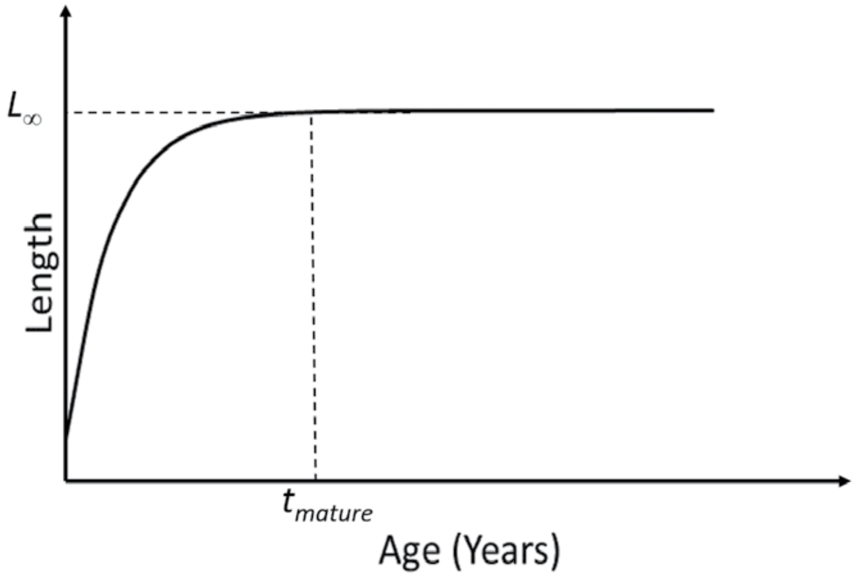

Figure 2. The von Bertalanffy growth curve, showing the increase of an organism's length or height as a function of time since birth or hatching. Note that growth effectively, if not completely, stops, when the organism reaches adulthood at time t_{mature}.

Longer Childhood, Longer Life?

Although longevity is influenced by multiple factors, greater longevity in extant creatures has repeatedly been shown to be positively correlated with greater values of t_{mature}. In a study of 124 terrestrial vertebrate taxononomic families, including birds, mammals, reptiles, and amphibians, Ricklefs (2010a) showed that the rate of aging decreased with a number of factors, two of which were increasing gestation period and age at maturity. He also showed that the rate of aging in birds decreased with increasing length of embryonic development. Naturally, one would expect a decreased rate of aging or senescence to imply greater longevity. In order to better ensure that the data met the requirements for a linear least-squares regression, Ricklefs log-transformed his data before performing his correlation, a common practice in such studies. A second study (Ricklefs, 2010b) of 36 bird species and 18 mammal species found that longer embryonic growth rates were positively correlated with decreased rates of aging for both birds and mammals.

A study of 1456 mammals, birds, amphibians, and reptiles (de Magalhães et al., 2007) showed that age at maturity is positively correlated with maximum adult lifespan. They also showed that postnatal growth rates were inversely correlated with adult lifespan: the faster an organism reached maturity, the shorter its life. Their analysis used a technique called 'phylogenetic independent contrasts' (PIC), which assumes the validity of evolutionary theory. Hence, this may have prejudiced their results by evolutionary assumptions. However, they obtained statistically significant results, both with and without the use of PICs.

Particularly relevant to this study, since we are discussing the molluscan bivalve genus *Crassostrea*, researchers have repeatedly shown that age at sexual maturity in bivalve mollusks is positively correlated with greater longevity. One particular bivalve, the ocean quahog (*Arctica islandica*), is the longest-lived molluscan species on Earth (Abele 2008), with a life-span of ~400 years, and even 500 years. Abele et al. (2009) summarize the commonalities previous researchers have observed in extremely long-lived bivalves:

> Extremely long-lived bivalves share common and characteristic life history features. The first is an *extremely slow and seemingly indeterminate growth* in Arctic and Subarctic climates, compared to sympatric species from warmer habitats….A second is the *late onset of reproduction* which then continues into old age without a post-reproductive phase. [emphases ours]

In today's world, very slow growth and increased lifespans in bivalves are associated with very cold climates and low and seasonal food availability (Palmer et al., 2021). But if slow growth and delayed reproduction were induced for some other reason or reasons, might they still be associated with extreme longevity?

Ridgway et al. (2011) showed a statistically significant positive correlation between the natural logarithm of bivalve adult life span and the natural logarithm of bivalve age at sexual maturity, as well as a statistically significant negative correlation between the natural logarithm of maximum species age and the natural logarithm of the Bertalanffy growth coefficient *k*. For eight bivalve orders, Moss et al. (2016) also found a statistically significant negative correlation between the logarithm of bivalve lifespan and the logarithm of the von Bertalanffy growth coefficient *k*.

However, because these studies often involved creatures from different genera, one might perhaps worry that these results only hold when one is comparing lifespans of creatures belonging to different Genesis baramin or 'kinds.' It is well-known that larger, more massive animals (such as elephants) tend to live much longer than smaller, less massive animals (such as shrews). In fact, biologists have long noted that biological timescales, such as lifespan, time to sexual maturity, blood circulation time, etc. are generally proportional to the organism's mass raised to the ¼ power (Lindstedt, 1981; Calder, 1984; Schmidt-Nielsen, 1986). Hence, one would expect more massive species of animals to have longer lifespans and to take longer to reach maturity than less massive species.

But is this merely an inter-species or inter-genera result? Does greater longevity also positively correlate with t_{mature} or with t_{sex} *within* a single 'Genesis kind'?

Although not as abundant as the evidence cited above, there is some evidence that it does. Most creationists would probably agree that, in general, two species belonging to the same genus are members of the same Genesis kind, even if they have been assigned different species names (Woodmorappe, 1996). A study (Genade et al. 2005) of two fish species of the genus *Nothobranchius* showed that a *Nothobranchius* species (*N. Kunthae*) taking longer to mature lived much longer than the *Nothobranchius* species (*N. furzeri*) that matured more quickly (see especially Figure 5 in Genade et al., 2005).

In a study of three-spined stickleback fish (*Gasterosteus aculeatus*), Lee et al. (2013) found statistically significant positive correlations between pulses of accelerated/slowed growth and decreased/increased longevity. The 2013 study by Lee et al. is particularly noteworthy because it was apparently the first rigorous *experimental* confirmation of an inverse relationship between growth rate and longevity, as it controlled for the effects of food supply and final adult size:

> We used brief (less than 4% of median lifespan) exposure to relatively cold or warm temperatures in early life to deflect juvenile three-spined sticklebacks *Gasterosteus aculeatus* from their normal growth trajectories; this induced catch-up or slowed-down growth when ambient temperatures were restored, and all groups attained the same average adult size. Catch-up growth led to a reduction in median lifespan of 14.5 per cent [sic], while slowed-down growth extended lifespan by 30.6 per cent [sic]. These lifespan effects were independent of eventual size attained or reproductive investment in adult life.

In this study, the fish all took the same total amount of time to reach maturity, but those experiencing the accelerated catch-up growth had shorter lifespans. It should be noted that both the three-spined stickleback and the freshwater killifish (like *Nothobranchius* fishes) are often seen as "model systems" for studying vertebrate biology due to a number of factors, including their small body size, short reproduction times, and high fecundity (Reichard and Polačik, 2019; Reid et al., 2021).

Also, Tabatabaie et al. (2011) found that long-lived Ashkenazi Jews were older at first childbirth, suggestive of delayed sexual maturation. However, this last line of evidence is less convincing, due to the many variables that can affect human lifespan.

Delayed Maturation of the Genesis Patriarchs?

In light of these observations, it is striking that the earliest age at which a Genesis 5 patriarch is listed as having a son is 65 (Genesis 5:15, 21). Granted, many of these sons may have not been firstborn, but at least some of them probably were. Given the strength of the human sex drive, it seems very unlikely that the Genesis patriarchs were all becoming sexually mature at 15 or 16 and yet were all deciding to postpone sexual relations for fifty years! It seems far more likely they were becoming sexually mature at much greater ages than do humans today, as suggested by Patten (1982) and Beasley (1990). Thus, the greater ages at sexual maturity recorded in Genesis are consistent with expectations from numerous longevity studies: one would expect very long-lived humans to have longer periods of growth than humans with much shorter lifespans. The same is true for the ages of the patriarchs listed in Genesis 11. The earliest age at which a Genesis 11 patriarch is listed as having a son is 29, and most of these listed ages cluster between 30 and 35. Chances are that at least one of these listed sons was a firstborn. By today's standards, 29 or 35 is rather late in life to have a firstborn son.

Whatever conditions in the pre- and immediate post-Flood worlds (lower genetic mutational loads, somewhat higher atmospheric oxygen content, abundant food, etc.) were allowing humans to achieve longer lifespans, those same conditions would likely have also applied to the animal kingdom. Thus we should not be surprised if the fossils themselves provide evidence of much greater animal lifespans than at present.

The Bigger They Are… the Longer They Live?

Studies have shown that larger adult body sizes (larger values of L_∞) are positively correlated with greater longevity (de Magalhães et al., 2007; Wasser and Sherman, 2010; Ricklefs, 2010a; Ridgway et al., 2011). However, there is conflicting evidence in the case of bivalve mollusks. In their study of 56 bivalve species, Ridgeway et al. (2011) found a weak but statistically significant ($p = 0.004$, 95% level) positive correlation between the natural logarithm of L_∞ and the natural logarithm of maximum age. However, a larger study by Moss et al. (2016) did not find such a correlation, although Moss et al. did find a positive correlation between t_{mature} and total longevity.

Holm et al. (2016) found that within the family *Geometridae*, larger moth species tended to live longer than smaller ones. However, it is not clear if this study was free of possible evolutionary assumptions, as this study too made use of phylogenetic independent contrasts (PICs).

The above size-longevity studies compared creatures across 'higher' taxonomic categories, such as classes, orders and families. Thus, the creatures compared often came from different Genesis kinds. Of much greater interest to us are results from within a particular Genesis kind, or baramin. Intra-specific studies by definition are confined to a single baramin, and intra-generic studies are almost certainly confined to a single baramin. However, such intra-specific and intra-generic studies are much less abundant, and results are conflicting. See Marchionni et al (2019) for a review of results from both inter-specific and intra-specific non-creationist longevity studies, including human studies. However, in Sato's (1994) study of six modern *Phacosoma japonicum* (since reclassified as *Dosinia japonica*) bivalve assemblages, larger body size was consistently associated with greater ages at sexual maturity and maximum observed ages (see Table I), although Sato did not perform a statistical test. Given that greater ages at sexual maturity are often linked with greater longevity and greater size in bivalves, this may be indirect evidence of an intra-species size-longevity connection. Moreover, we shall see in the following sections examples in which (apparently) long-lived fossil oysters are indeed larger than their shorter-lived fossil and modern-day counterparts.

Moreover, there are reasons to suspect a positive correlation between longevity and higher values of L_∞, even within a baramin. As noted earlier, it has long been observed that biological timescales tend to be proportional to an organism's mass raised to the ¼ power. Consistent with this general result, West et al. (2001) have presented a theoretical justification for expecting an organism's adult body mass M to be proportional to its age at maturity t_{mature} raised to the fourth power:

$$M \propto t_{mature}^4 \qquad (2)$$

Of course, higher values of L_∞ naturally imply higher adult body masses M. Since we have intra-genera experimental justification (Sato, 1994; Genade et al., 2005; and Lee et al., 2013) for expecting delayed maturation (greater ages at maturity) to positively correlate with greater longevity, Eq. (2) implies that we might also expect greater adult body mass M to be positively correlated with greater longevity, as well.

A weakness in this chain of reasoning, however, is that the result of West et al. (2001) does not explore the effect that a change in environmental conditions might have upon longevity within a taxon. In other words, adult body mass within a taxon depends upon age at maturity, but it likely also depends upon factors such as oxygen availability, nutrient availability, etc. These are factors which could conceivably have changed between the pre- and post-Flood worlds. Changes in these variables could conceivably attenuate and/or obscure the general result implied by Eq. (2).

There is another reason to suspect a positive correlation between greater longevity and larger adult body size (higher values of M and L_∞). If one considers Figure 2, t_{mature} may be increased by proportionally "scaling up" the size of the organism's growth curve without changing its general shape. Doing so forces t_{mature} to become larger as L_∞ becomes larger. Since there is some intra-genus evidence (Sato, 1994; Genade et al., 2005; Lee et al., 2013) that t_{mature} is positively correlated with greater longevity, and since one way (but admittedly not the *only* way) to increase t_{mature} is to increase the organism's adult body size L_∞, we might also expect greater longevity to be associated with greater adult body size.

Counterexamples

Of course, there are counterexamples to both trends. In a summary of other studies, Marchionni et al. (2019) noted that body masses of mice, horses, dogs, and humans are usually negatively correlated with longevity in intraspecies studies. However, at least in the cases of dogs and horses, some of this could be the result of inbreeding.

Likewise, Miller et al. (2002) found that two out of three wild-derived mice strains were smaller and experienced delayed sexual maturity compared to laboratory strains of mice, yet the wild mice strains were generally longer-lived. They also found that females of these two longer-lived wild strains were also slower to reach sexual maturity. Miller et al. speculated that these results may be due to inbreeding of laboratory strains. So in this particular case, the results were mixed.

Mueller and Mazur (2009) and Samaras (2014) found that greater body size and height were positively correlated with increased human mortality. On the other hand, Brandts and van den Brandt (2019) found a positive correlation between height and longevity for women in the Netherlands but not for men. Given that, as of June 2023, the Dutch people are the tallest in the world (Bostock and Ankel, 2023), this result is intriguing. On the other hand, a very large study (Wormser et al., 2012) found that greater height was associated with a greater risk of cancer but a decreased risk of coronary heart disease and stroke. However, given the multiple factors that can influence human longevity, these results are probably not conclusive, and even the positive results by Tabatabaie et al. (2011) discussed previously should be viewed with some skepticism. Results from experiments under carefully controlled conditions using "model" laboratory animals, like those obtained by Lee et al. (2013) are probably more reliable.

Although it might perhaps seem obvious, it should be noted that body size (specifically, body mass) does not explain *all* intraspecies and interspecies variation in longevity—it explains much of the variation, but not all of it. For instance, one might naively expect a gorilla (average adult body mass greater than 110 kg) to have a longer lifespan than a human (average adult body mass of 60–80 kg). Yet humans, with their lifespans of around 70–80 years, generally live longer than gorillas (~50 years). So although these trends are real, factors other than mass clearly also influence longevity.

A Working Hypothesis… and Predictions

Despite the existence of some contrary data, we assume as a working hypothesis that organism longevity is indeed positively correlated (Figure 3) with both age at maturation t_{mature} and adult body length or height L_∞. In the absence of a fully-developed theory of longevity, it may not be possible at this time to make an airtight argument for the validity of these assumptions. Nevertheless, they are reasonable. Note also that we are *not* at this time attempting to explain the *cause* of these correlations; we are simply accepting them as valid empirical results.

This enables us to make predictions about trends we should see in *Crassostrea* fossils. We expect fossil *Crassostrea* oysters to generally show either indirect or direct evidence of greater longevity than modern *Crassostrea* oysters: larger body sizes and indications of delayed maturation (Figure 2), as well as greater estimated ages at time of death, based on sclerochronological data, discussed in more depth below.

Two of us (Hebert and Sherwin) think evidence for a "high" Cenozoic Flood/post-Flood boundary is overwhelming (Holt, 1996; Oard, 2002a, 2013; Clarey, 2019; and Clarey, Werner and Tomkins, 2022), while the third (Overman) does not have a strong opinion. However, the results of this analysis do not necessarily depend upon the precise location of the Flood/post-Flood boundary. From Scripture, we know that human lifespans decreased dramatically after the Flood and continued to decrease in the following centuries. Hence, we should not be surprised if animal lifespans in general, and *Crassostrea* lifespans in particular, experienced a similar decline. For instance, suppose some *Crassostrea* fossils are found within Pliocene rocks. Regardless of whether one dates Pliocene rocks as Flood or post-Flood, if Pliocene rocks date from no more than several hundred years after the Flood, we should expect Pliocene *Crassostrea* lifespans at a particular location to be greater than those of extant oysters, also from that same location, within the same Genesis kind. This is because *both* pre-Flood and post-Flood human lifespans in the centuries immediately after the Flood were much greater than they are today, and the same would likely be true for animal lifespans.

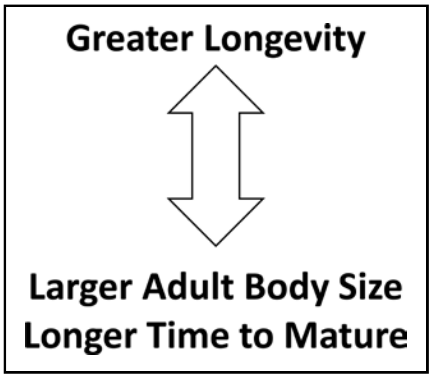

Figure 3. Longevity studies have shown that greater longevity is associated with larger adult body sizes and longer maturation times.

Complications to Consider

There are complications that should be taken into consideration before doing such a study on bivalves. Bivalve longevity is greatly influenced by factors such as water temperature, with bivalves living in very cold high-latitude waters demonstrating extreme longevity compared to those in warmer, lower-latitude waters. Growth in living *Crassostrea* specimens is influenced by temperature, salinity, water current velocity, and availability of phytoplanktonic food supply (Kirby and Jackson, 2004). Oysters often colonize together in beds, and crowding is also apparently a factor. According to some online sources, (Osborne, 1999; Wallace, 2022), uncrowded *C. virginica* oysters can live as long as 20 years. However, other sources list the lifespan for extant *C. virginica* as much closer to 5–10 years (Harzhauser, 2016; Kusnerik et al., 2018).

It is not possible to completely eliminate the influence of such factors, be we need to minimize their influence as much as possible. Hence, any comparison of modern and fossil bivalve longevity should preferably be restricted to a single location, or to locations very close to one another geographically. At an absolute minimum, the comparison should be restricted to modern and fossil assemblages found within a relatively narrow latitude band. Since we will be comparing late Cenozoic fossil assemblages to modern ones, both creationists and evolutionists would agree that the latitudes of late Cenozoic fossil assemblages would have changed only a little since the time the fossils were formed, regardless of whether one holds to traditional or catastrophic plate tectonics. However, even restricting the analysis to a narrow latitude band does not necessarily eliminate the effects of different water temperatures, for reasons explained later.

Taxonomists have assigned multiple species to *Crassostrea*, but taxonomists have a well-known tendency to 'over-split' when classifying organisms, and creationists have long pointed out that creatures within the same genus probably belong to the same Genesis kind (Woodmorappe, 1996), even if they have been classified as different species. Hence, comparisons of different *Crassostrea* species within the genus are still likely to represent valid comparisons within a single Genesis kind. In fact, as we discuss later, even some evolutionists have suggested that modern *Crassostrea* oysters are direct descendants of much larger (and apparently much longer-lived) fossil *Crassostrea* forms.

This paper presents evidence that *Crassostrea* longevity was once much greater in the past. However, in order to understand the results, a brief introduction to the field of sclerochronology is in order.

Sclerochronology: An Introduction

Sclerochronology is the study of features such as chemical and periodic structures in the skeletal portions of animals that grow by accretion (layering), such as bivalves (Killam 2018, p. vi):

> Bivalve shells contain growth lines which are formed as a result of periodic environmental or physiological stress, analogous to tree rings. The study of these regular growth increments in the hard parts of bivalves and other calcifying organisms is called Sclerochronology

The field has been widened to include the study of periodic bands in numerous aquatic and terrestrial taxa, including coralline algae, fish and gastropods (Jones et al. 1989).

Evolutionary scientists think (Trofimova et al. 2020, p. 2) "the full potential of sclerochronology has yet to be realized." Moss et al. (2021, p. 1) stated:

> Not only can sclerochronological data help to address long-standing questions in paleobiology, but they can also bring to light new questions that would otherwise have been impossible to address. For example, growth rate and life-span data, the very data afforded by chronological growth increments, are essential to answer questions related not only to heterochrony and hence evolutionary mechanisms, but also to body size and organism energetics across the Phanerozoic.

We agree with evolutionary scientists that sclerochronology has untapped potential, but for different reasons. We think it can assist in determining the effects of the Flood thousands of years ago and up to recent times. We see this field as helping to determine faunal periodic structures—and lifespans—in the pre-Flood and post-Flood worlds. As noted in the above statement by Killam, sclerochronology is much like dendrochronology, and, like dendrochronology, caution should be employed when evaluating data.

Wide bands in mollusk bivalve shells are produced during times of rapid growth, and narrow bands are produced during times of reduced growth. These times of growth reduction or cessation are thought to coincide with physiological stress (Buick and Ivany, 2004). These bands may occur at different times of the years for the same mollusks in different settings (Moss et al., 2021; Jones and Quitmyer, 1996).

It has long been known (Jones, 1981) that not all bands in a mollusk shell are annual. Moss et al. (2021) note that periodic lines in shells have been shown to be tidal, daily, fortnightly, monthly, and annual. Some bands, called *disturbance lines*, can result from storms or attack by predators (Moss et al., 2017).

External bands on the outside of a bivalve shell (or valve) are often disturbance bands, and counting them can lead to erroneous age estimates (Moss et al., 2017). Internal growth bands are thought to be more accurate proxies for age, and these are observed by cutting open the valve in cross-section (Moss et al., 2017).

Can We Trust the Band Counts?

This raises an extremely important question: can bivalve annual band counts be trusted? Creationists are generally distrustful of claims that dendrochronology can provide accurate timelines going back thousands of years (Woodmorappe, 2003; Hebert, Snelling, and Clarey, 2016; Woodmorappe, 2018). If creationists accept these oyster band counts as being reasonably accurate, are we being inconsistent?

Due to uncertainties about the past, it would be a mistake to put unqualified trust in this or any other such counting method. However, for the following reasons, we can be reasonably confident that these band counts are legitimate, albeit imperfect, proxies for age.

Due to its importance to the seafood industry, modern *Crassostrea virginica* lifespans are likely well-established by direct observation. This gives us additional confidence that, in the analysis below, the ages inferred from sclerochronological analysis of modern *Crassostrea virginica* specimens are reasonably accurate. And in the case of *Crassostrea* oysters, we are not attempting to count thousands, or even hundreds, of presumed annual bands, as is the case for ice core and tree ring dating. Rather, we are attempting to count, at most, a few dozen such bands. Moreover, our analysis does not depend upon the problematic process of 'cross-matching' banding patterns in one oyster assemblage to those in another (Woodmorappe, 2003, 2009, 2018).

Also, disturbance bands are not likely to be mistaken for periodic bands, due to their random nature (Moss et al., 2017). Moreover, in the case of *Crassostrea* oysters, Zimmt et al. (2019) identified subtleties in band appearance that can be used to distinguish annual bands from non-annual bands. Moss et al. (2021) noted that annual growth bands are found in almost all extant bivalves outside the tropics, forming in response to seasonal extremes in variables such as temperature, salinity, and food availability. Moss et al. (2017, p. 367) state that annual bands are "unambiguous" if formed in a highly-seasonal environment.

Geochemical Variations Can Aid In Counting

Moreover, geochemical variations may help identify seasonal patterns, even when those seasonal variation is not as pronounced, as they can serve as a "check" on annual band counts (Moss et al., 2021, p. 3):

> Without independent temporal calibration, the assumption that growth bands are annual is not always a safe one—in some cases, visible growth increments bear no clear relation to intra-annual environmental variation. *Geochemical variation along the axis of growth, however, often provides a means by which to confirm the timing of visible growth bands and reveal the annual cycle*, thereby allowing calculation of growth rates and/or determination of ontogenetic age. [emphasis ours]

Geochemical variation refers to changes in a quantity like the oxygen isotope and carbon isotope ratios (δ^{18}O and δ^{13}C, respectively). Although creationists have been skeptical of the level of climate detail that mainstream paleoceanographers claim to be able to infer from ancient oxygen isotope (δ^{18}O) values (see Oard 1984, Vardiman 2001, Oard 2003, and Hebert 2021for a discussion), we acknowledge that δ^{18}O values are rough proxies for temperature, provided that the shell from which the δ^{18}O values are obtained was formed in isotopic equilibrium. This assumption would likely break down during the Flood itself, potentially invalidating the interpretation of the very last band or bands that might have formed during the Flood. However, this assumption would likely have been valid in the pre-Flood and post-Flood worlds. Therefore, if seasonal variation was present in the pre-Flood world, even if less pronounced than today, variations in δ^{18}O values within bivalve shells could help identify annual bands within those pre-Flood bivalves. The same would likely be true for the post-Flood world.

Moreover, the use of δ^{18}O variations as a "check" on annual counts within a shell does *not* require a precise climatic interpretation of those variations. Since only observation of repeating maximum and minimum δ^{18}O or δ^{13}C values is required for this purpose, this avoids the potential perils of attempting to deduce precise climate information (Moss et al., 2021), which requires unprovable assumptions about the past (Oard, 1984; Hebert, 2021).

Indeed, Kirby (2000) demonstrated that annual *Crassostrea* bands can likely still be resolved, even when seasonal isotopic variation is less pronounced:

> δ^{18}O and δ^{13}C profiles across skeletal growth increments in two well-preserved [North Carolina Late Oligocene] *C. gigantissima* shells show significant differences with profiles from Pleistocene and Recent *C. virginica* [from Chesapeake Bay and the Mississippi Delta]. Significantly higher δ^{18}O and δ^{13}C values and smaller seasonal isotopic ranges with less variability show that *C. gigantissima* lived in a more fully marine environment than *C. virginica*.

In passing, it should be noted that this is not the only possible interpretation of the data. It may be that *C. gigantissima* simply lived in an environment with less-pronounced seasonal differences than *C. virginica*, an intriguing possibility in light of creationist suggestions that seasonal extremes were less-pronounced in the pre-Flood world (Whitcomb and Morris, 1991), and that even the post-Flood Ice Age climate was relatively equable (Oard 1990, 2005). Kirby found that over eight apparent growth cycles, δ^{18}O and δ^{13}C minima coincided, but the maxima were slightly offset.

Other studies have demonstrated the usefulness of geochemistry in identifying annual bands. Buick and Ivany (2004) found that for *Cucullaea raea* bivalves from Antarctica, troughs in δ^{18}O values consistently coincided with narrow bands corresponding to times of growth reduction or cessation, and this pattern held for 17 such growth cycles. These growth cessation bands were visible to the naked eye, with widths on the order of 0.25 mm thickness. The intervening bands corresponding to times of growth were usually about a millimeter wide. The reverse pattern held for $\delta^{13}C$ variations, with peak $\delta^{13}C$ values coinciding with the narrow bands times of growth reduction. Ivany and Runnegar (2010) showed that oxygen isotope values varied seasonally over six years of growth within an early Permian bivalve. Zimmt et al. (2019) showed a strong correlation between $\delta^{18}O$ and seasonal variations in Pleistocene *Crassostrea virginica* oysters from the mid-Atlantic United States. In a study of Recent *Crassostrea* oysters from Altamaha Sound, Georgia, Andrus and Crowe (2000) showed that dark zones (representing times of faster growth during cooler months) consistently had higher $\delta^{18}O$ and $\delta^{13}C$ values. They concluded that banding patterns were generally seasonal, but dark bands could form at any time due to extreme heat or floods.

Band Counts Likely Underestimate True Age

Both creation and evolutionary scientists would agree that band counts likely underestimate true bivalve age for a number of reasons. First, biological ages are often assigned to *Crassostrea* oysters by counting periodic increments in the ligament area. In both fossil and modern oysters, the earliest part of the ligament area, representing the first two years of growth, is often missing (Kirby, 2001), but because this is true in both the fossil and modern specimens, this will probably not affect the comparison much.

Second, in very-long lived bivalves, bands become exponentially thinner over time, making them harder to see, which means the true age can be underestimated. Moss et al. (2017, p. 373) give an example in which the last 5 millimeters of growth in one species represented 20 out of 39 years of its lifespan.

In the following sections, we will be comparing data from Miocene, Pliocene, and Eocene *Crassostrea* oysters to data from Pleistocene and Modern *Crassostrea* oysters. If the Flood/post-Flood boundary is 'high' in the Cenozoic, then the Miocene, Pliocene, Eocene, and perhaps some of the Mid- or Lower Pleistocene (Holt, 1996) fossil oysters were killed during the Genesis Flood. This means they did *not* die natural deaths. In this case, sclerochronological band-counting can only approximate their ages at death, but this does not necessarily tell us anything about their true lifespan potential, at least not directly. Hence, these age estimates are likely underestimating true lifespan potential, perhaps significantly.

Even if one attributes upper Cenozoic fossilization to post-Flood catastrophic flooding, the catastrophic nature of that record is still consistent with this conclusion. Some fossil bivalves have their valves clamped shut, a strong indication that they were still alive when they were buried, consistent with catastrophic death and burial (Good, 2004; Hoesch and Austin, 2004). Hence, inferences from fossil *Crassostrea* data will likely underestimate true lifespan potential, regardless of whether those fossils are attributed to Flood or post-Flood catastrophism. Also, unless one wishes to assume that oysters were dying promptly upon reaching maturity, there is no good reason to assume that the ages at maturity necessarily represent the total potential lifespan. It seems more likely that the total potential lifespan would be greater.

Error Probably Insufficient to Affect Analysis

Clearly, there will be some error in bivalve band counts. Neither creationists nor evolutionists expect these counts to be perfect. But any such error will only invalidate the results if disturbance bands are both very numerous and very hard to identify. For the reasons given above, we do not think this will be the case.

Also, there does not seem to be any reason evolutionary paleontologists would want to favor greater oyster band counts over smaller ones, or *vice versa*. Thus, the problem of bias, due to preconceived expectations, that affects ice core and seafloor sediment age assignments (Oard, 2005; Hebert, 2021), is minimized.

Some paleontologists seem very confident that band counts can be reliable age indicators for bivalves in general and for *Crassostrea* oysters in particular (Kirby, 2001; Moss et al., 2021), regardless of location, provided that the analysis is done with appropriate caution. Zimmt et al. (2019) are more cautious, arguing that this has only been demonstrated to be true for Pleistocene *Crassostrea* oysters from the mid-Atlantic plain (USA). Nevertheless, there seems to be general agreement among sclerochronologists that, despite possible uncertainties, these banding counts are sufficiently accurate to conclude that mid-Atlantic Pleistocene *Crassostrea* oysters were indeed longer-lived than their modern-day counterparts living in the same area (Zimmt et al., 2019; see also the studies by Norton, 2021, and Falb, 2022).

Finally, evidence that *Crassostrea* oysters experienced much greater longevity than extant *Crassostrea* oysters does not depend entirely upon the band counts. We have already listed some reasons to suspect that larger adult body sizes are *also* indicators of great longevity, and we present examples below in which the fossil *Crassostrea* forms are *much* larger than the modern forms.

Fossil vs. Modern *Crassostrea:* Virginia, Maryland, and North Carolina (USA)

Kusnerik et al. (2018) performed a study using more than a thousand Pleistocene *Crassostrea* oyster fossils obtained from five assemblages in southern Maryland, Virginia, and North Carolina (Chesa-

Table I. Approximate maximum observed body masses and lifespans, as well as ages at first and full sexual maturity, for six Modern assemblages of the Japanese venerid bivalve *Phacosoma japonicum* (since reclassified as *Dosinia japonica*) compiled from data and figures in Sato (1994).

Locality	Max. Observed Mass (g)	1^{st} t_{sex} (years)	Full t_{sex} (years)	Max. Lifespan (years)
Ishikari Bay	63	>5	7	12
Hakodate Bay	53	4	5	11
Ariake Bay	45	4	5	9
Tokyo Bay	27	3	4	8
Seto Inland Sea	21	3	4	7
Kagoshima	16	2	3	7

peake Bay region, USA). This geographical area spanned ~2.7° in latitude. These specimens were supplemented by specimens from the Virginia Museum of Natural History. These were then compared with both modern specimens and specimens from the American colonial period. They excluded specimens with shell heights less than 35 mm, in order to avoid inclusion of immature oysters (spat) in the study, and they took care to ensure that all oysters came from environments with similar salinities (15–30 ppt).

Because the shell data were, in most cases, non-normally distributed, they used the Mann-Whitney *U* test to check for differences in shell height across Maryland, Virginia, and North Carolina. They found statistically significant size differences, shown in Table II. They also found statistically significant differences in growth rates between the modern, colonial, and Pleistocene specimens, with the colonial and modern oysters growing considerably faster than the Pleistocene specimens.

Of particular interest to this study, they found that Maryland Late Pleistocene (LP) oysters were significantly larger than both colonial and modern oysters (Figure 4). Virginia Middle Pleistocene (MP) oysters were also significantly larger than both colonial and modern oysters (Figure 5). North Carolina MP oysters were significantly larger than LP oysters, but not modern ones (Figure 6). The difference between LP and Modern North Carolina specimens was also statistically significant.

The Pleistocene oysters were also longer-lived than the Modern and Colonial oysters. Age estimates were obtained by counting gray bands in the cross-sections of bisected hinges. In Maryland, Pleistocene oysters attained to ages of 12 years, whereas the modern and colonial oysters rarely lived beyond 5 years. In Virginia, Pleistocene oysters lived beyond 20 years, with colonial and modern oysters rarely living beyond 5 years. For the North Carolina specimens, Pleistocene oysters did not live beyond 4 years of age, and moderns did not attain to 3 years of age (there were no colonial North Carolina specimens).

Generally, Pleistocene *Crassostrea* oysters were larger, took longer to mature, and were longer-lived than more recent oysters. This supports our working hypothesis that, within a biblical kind (and not merely across kinds), larger body size does indeed seem to correlate with greater longevity. As warm Late Pleistocene (LP) oceans cooled at the end of the post-Flood Ice Age (Oard, 1990), one might naively expect *Crassostrea* longevity and body size to have increased, due to cooling ocean temperatures. Yet the opposite occurred. This suggests that the factor causing greater longevity was strong enough to negate the competing counter-effect of warmer post-Flood and Ice Age oceans.

The results in Figure 6 partially contradict this expectation, however, as one would expect longer-lived Late Pleistocene (LP) oysters to be larger than shorter-lived Modern oysters. However, it should be noted that Pleistocene and Modern longevities in North Carolina were much more similar (no greater than 4 and 3 years, respectively) than they were in Virginia and Maryland. Hence, one might expect their body sizes to be more similar, as well.

In the next example we see additional evidence that Pleistocene *Crassostrea* oysters were longer-lived than recent specimens, and that fossils pre-dating the Pleistocene were both bigger and longer-lived than both Pleistocene and recent specimens.

Fossil vs. Modern *Crassostrea:* North Carolina and Virginia (USA)

Kirby (2001) counted internal growth ligaments to construct growth curves for Tertiary (Upper Miocene) and

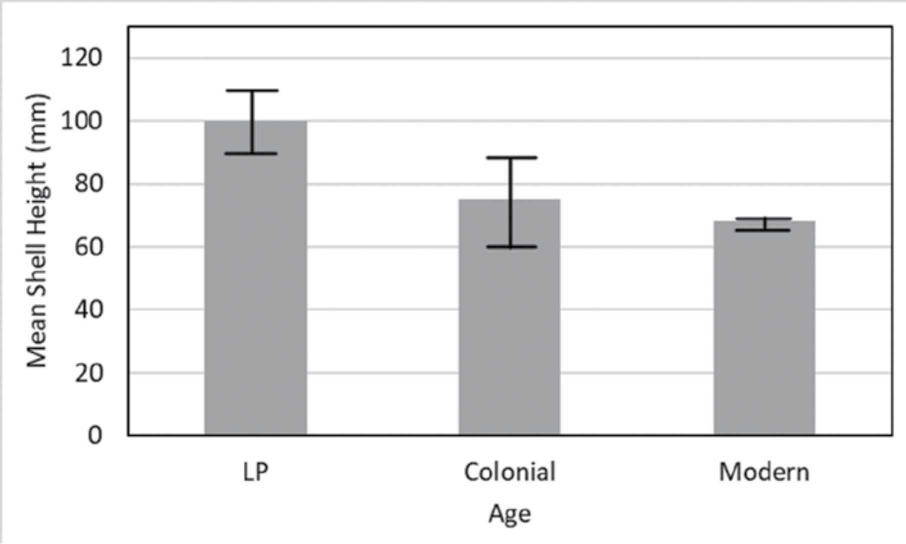

Figure 4. *(left)* **Average shell heights for Late Pleistocene, colonial, and modern *Crassostrea virginica* specimens from Maryland. Error bars represent the standard error. Image credit: Richard Overman. After Figure 6a in Kusnerik et al. (2018).**

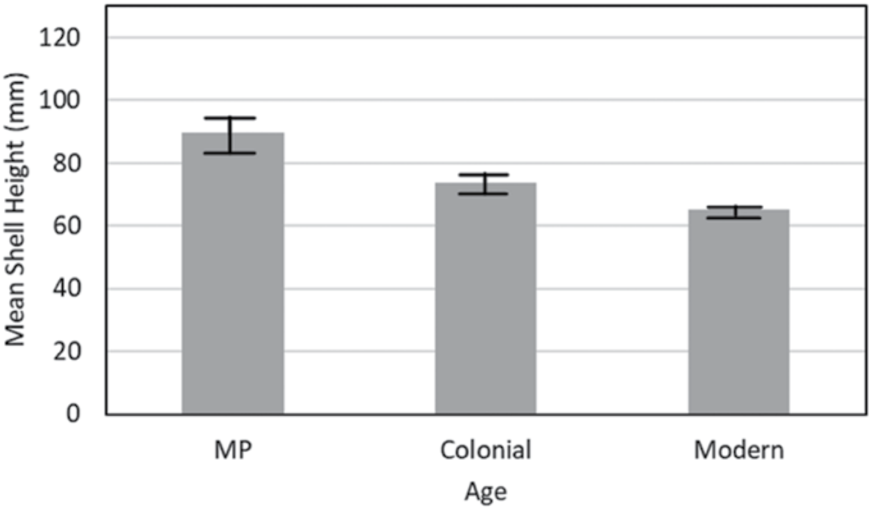

Figure 5 *(left)*. **Average shell heights for Middle Pleistocene, colonial, and modern *Crassostrea virginica* specimens from Virginia. Error bars represent the standard error. Image credit: Richard Overman. After Figure 7a in Kusnerik et al. (2018).**

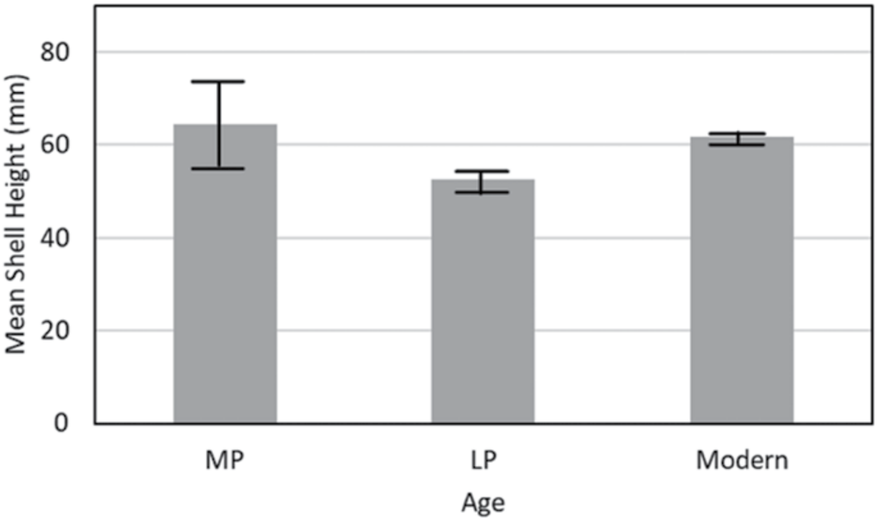

Figure 6 *(left)*. **Average shell heights for Middle Pleistocene, Late Pleistocene, and modern *Crassostrea virginica* specimens from North Carolina. Error bars represent the standard error. Image credit: Richard Overman. After Figure 8a in Kusnerik et al. (2018).**

Quaternary (Pleistocene and 'Recent') *Crassostrea* specimens. The Miocene species, named *Crassostrea titan* because of its large size, was collected from two locations in California. The Pleistocene and 'Recent' specimens, *Crassostrea virginica* (Figure 1) were obtained from Virginia and North Carolina,respectively. All specimens were obtained from between 34.6 and 36.8° north latitude.

Although Kirby does not specify whether or not the Pleistocene strata are Early-, Mid-, or Late- Pleistocene, he does refer back to Spencer and Cambell (1987), who state that the Virginia clams are from Late Pleistocene marine sediments. The Late Miocene specimens were dated (Kirby, 2001) as between 8 and 12 million years old on the uniformitarian timescale.

In agreement with expectations, the Recent and late Pleistocene oysters were generally much smaller and (apparently) shorter-lived than the Miocene specimens (Figures 7, 8, and 9). It is also evident from Figure 8 that the slopes of the Miocene growth curves approach zero at much greater ages than do the Recent and Late Pleistocene specimens, indicating that the Miocene oysters took much longer to mature. Kirby performed a Mann-Whitney *U* test that showed a statistically significant difference ($p < 0.05$) in lifespan between the Miocene *C. titan* oysters and the more recent (Modern and Late Pleistocene) *C. virginica* oysters. The results generally agree with our expectations. However, the growth curve for the Recent specimens indicated a larger average adult body size than that possessed by the Late Pleistocene specimens, even though the Pleistocene specimens were longer-lived. This is contrary to expectations, if one assumes that larger body sizes are generally associated with greater longevity.

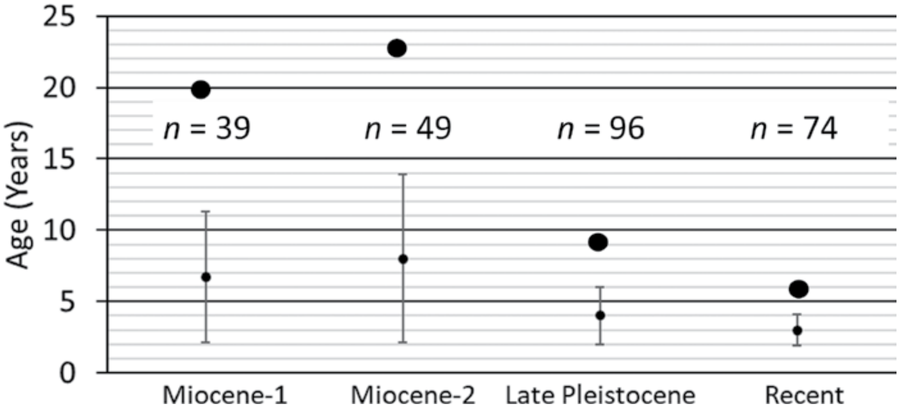

Figure 7. Maximum lifespans (large black dots) for four assemblages of California, North Carolina, and Virginia *Crassostrea* oysters, all collected between 34.6 and 36.8° north latitude. Maximum lifespans for the two Miocene (*Crassostrea titan*) fossil assemblages are much greater than those for the Late Pleistocene and 'Recent' (*Crassostrea virginica*) assemblages. Small black dots represent the average age of each assemblage, and error bar half-widths are standard deviations in assemblage ages. The number of fossil specimens in each assemblage is indicated.

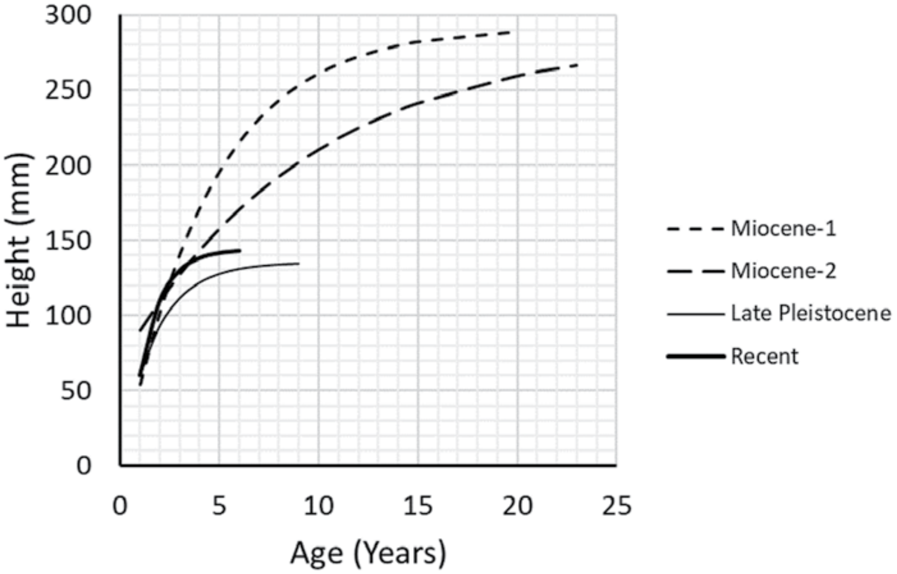

Figure 8. Height-versus-age growth curves constructed for the four *Crassostrea* oyster assemblages whose age data are summarized in Figure 7. After Figure 3B in Kirby (2001).

It should be noted that the average age of the Recent specimens was 3 years, the average age of the Miocene-1 specimen was ~7 years, and the average age of the Miocene-2 assemblage was 8 years (Figure 8). Unless Kirby over-counted the true number of annual bands in the Miocene assemblages by a factor of more than 2, it is difficult to avoid the conclusion that the Miocene *Crassostrea* speci-

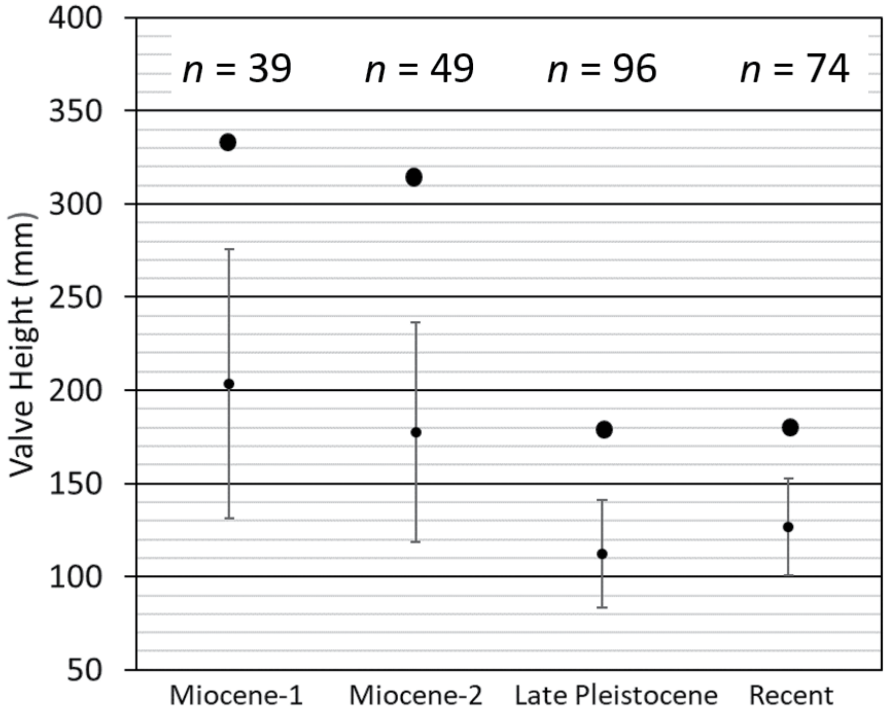

Figure 9. Valve height statistical data for the four *Crassostrea* oyster assemblages whose growth curves are shown in Figure 8. Dark black dots indicate maximum heights, small black dots indicate averages, and error bar half-widths represent height standard deviations. The number of specimens in each assemblage is indicated.

mens were indeed longer lived than the Recent specimens.

In today's world, at a given latitude, California Pacific coastal waters are considerably cooler than waters off the North American east coast (Herbert et al., 2016). For instance, according to the website of San Diego's Fleet Science Center (fleetscience.org, accessed October 31, 2023), the waters off the coast of San Diego are about 8.9° Celsius colder than waters off the coast of Charleston, South Carolina. This is because coastal California waters originates near Alaska, while waters off the eastern coast originate from the warmer Caribbean. Can uniformitarians attribute the extreme longevity of these California Miocene specimens to much colder Pacific water temperatures? Probably not. Although uniformitarians believe a cooling trend began in the Miocene about 7 million years ago, they think the Miocene 12 to 8 million years ago was considerably warmer than today's world (Holbourn et al., 2018). A recent uniformitarian temperature reconstruction (Herbert et al. 2016, especially their Figure 2f) concluded that, on average, sea surface temperatures at the southern California margin were between 6 and 9° Celsius warmer than in today's world. Hence, by uniformitarian reckoning, California coastal sea surface temperatures at this time would have been comparable to Atlantic sea surface temperatures today. Moreover, Kirby did not even suggest colder waters as a possible explanation, as he assumed that Late Miocene waters would be relatively warm. Nor can these great longevities be due to colder temperatures within a creationist framework, as most creationists think that the pre-Flood and immediate post-Flood worlds were characterized by relatively warm oceans.

Additional *Crassostrea* Observations

Some comments are in order before proceeding to the next example. Evolutionary scientists have acknowledged that the very large sizes of Tertiary *Crassostrea* oysters could be due to greater longevity (Kirby 2001, p. 84):

> The reasons for producing such large shells have not been well understood, but previous studies have considered them to be a consequence of *longer life spans* due to the absence of human predation (Stenzel 1971), the presence of photosymbionts (Jones et al. 1988; but see Cowen 1983), or life on muddy substrates (Chinzei 1995). [emphasis ours]

Moreover, not only are the valve heights of the Miocene *Crassostrea* greater, but so are their valve (shell) thicknesses when compared to Recent and late Pleistocene specimens (Kirby's Figure 3A, not shown). Kirby suggests these large thicknesses were a defense mechanism against predation, but this is not the only possible explanation.

It should be noted that, in this and the following examples, some of these oysters were growing very rapidly in absolute terms, *faster* than many modern-day extant oysters. That is, the length or mass they gained per year was higher than that experienced by comparable extant organisms at the same ontogenetic stage. Kirby summarizes (2001, p. 89):

> Estimation of life spans from ligamental increments and measurements of valve thicknesses and height shown that the *C. titan* specimens

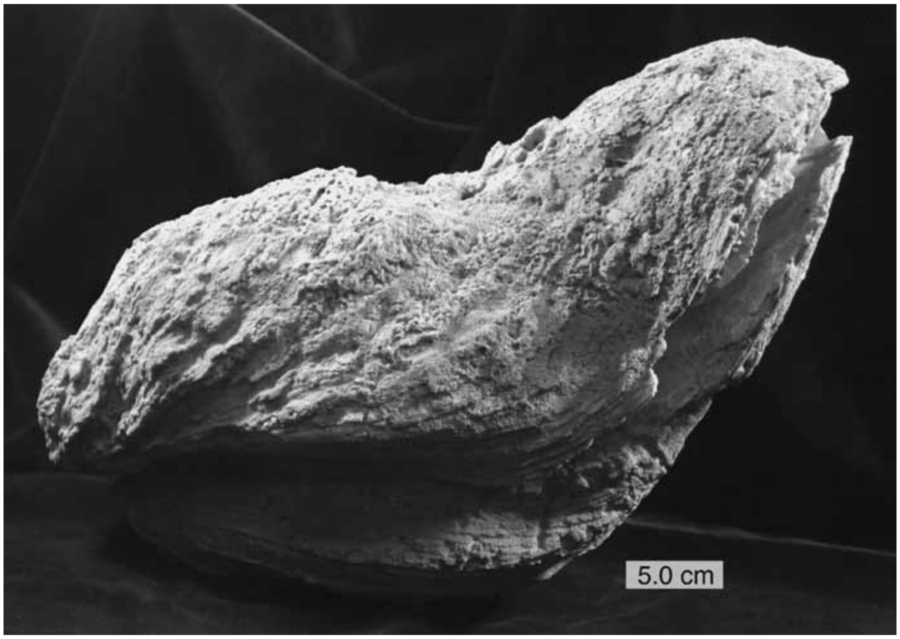

Figure 10. *Crassostrea gigantissima* fossil. Image Credit: Wilson44691. Creative Commons BY-SA 3.0 License.

> lived two to three times longer and grew significantly faster than the *C. virginica* specimens.

Even though they were growing rapidly in absolute terms (millimeters or grams of growth per year), attainment of their larger adult body sizes required longer growth intervals than extant forms. Hence, the net effect was longer growth intervals, despite these higher absolute growth rates.

In a study of Pliocene *Crassostrea* oysters from the tropical Americas, Kirby and Jackson (2004) concluded that Miocene-Pliocene *C. cahobasensis* growth rates (in mass per year) were 2.5 times faster than those of Quaternary *C. virginica and C. columbiensis*. They concluded that the fast-growing *C. cahobasensis* went extinct, while the more slowly-growing *C. virginica* and *C. columbiensis* survived. But what if *C. virginica* and C. *columbiensis* are direct and more slowly-growing descendants of *C. cahobasensis*? We return to this particular example later below.

Eocene *Crassostrea* oysters from Texas (Finch, 1824) and Georgia (Edwards, 2016) can also be quite large and have been given the species names *Crassostrea gigantissima* (Figure 10). The extinct Micoene-Pliocene *C. ingens* from New Zealand was also classified as a giant *Crassostrea* oyster. According to Wikipedia, it had shell heights of 200 to more than 300 mm, comparable to the heights of the Miocene *Crassostrea* whose growth curves are shown in Figure 8. Unfortunately, it was not possible to confirm this size for *C. ingens* from a more scholarly source. It should also be noted that *C. ingens* was recently reclassified, although we have been unable to find its new taxonomic designation. Likewise, *C. gigas* was recently reclassified as *Magallana gigas* (World Register of Marine Species).

A study of 1,121 complete shells in a Miocene *C. gryphoides* bed in Austria (48° N latitude) showed that *C. gryphoides* apparently lived for at least 40 years (Harzhauser et al., 2016) and attained heights of about 80 cm (Figure 11). Before it's reclassification as *M. gryphoides*, it was the largest known *Crassostrea* oyster, fossil or modern. Given that it's adult size is so much larger than the Miocene specimens shown in Figures 8 and 11, it probably does belong to a different genus than *Crassostrea*.

Interestingly, the vast majority of the clams in this Austrian assemblage lived less than ten years and grew to be 'only' about 30 cm in length, an intriguing observation in light of Robert Carter's (2023) recent suggestion that extremely long-lived individuals should be very rare in a given population.

Because of its recent change in classification, and because these Austrian *C. gryphoides* (or *M. gryphoides*) oysters were found at significantly higher latitudes than those in Kirby's study, it is probably inappropriate to directly compare the *C. gryphoides* growth curve to the other growth curves in Figure 11, even though they have all been depicted on the same graph.

However, *Crassostrea gigas*, the Pacific giant oyster, has been reclassified as *Magallana gigas*. The paleoenvironment for the Austrian *M. gryphoides* shell bed has been described (Harzhauser et al., 2016, p. 1225) as "comparable to the settings of modern *Crassostrea* reefs in the subtropical parts of the Asian Pacific." In that light, it is worth noting (Anonymous b, California Sea Grant, no date) that the Pacific giant oyster (*C. gigas* or *M. gigas*) has been known to grow to a size of 38 cm (15 inches). However, Cowles (2005) states *M. gigas* has a maximum size of 25 cm and "may live 20 years or more." According to Nehring (2011), unharvested *C.* (or *M.*) *gigas* oysters can live to be 30 years old. Yet Figure 11 shows that *M. gryphoides* took 40 years just to mature. So despite apparently living in a comparable subtropical environment, the Austrian fossil *M. gryphoides* was approximately twice as large and longer-lived than the extant giant Pacific oyster *M. gigas*!

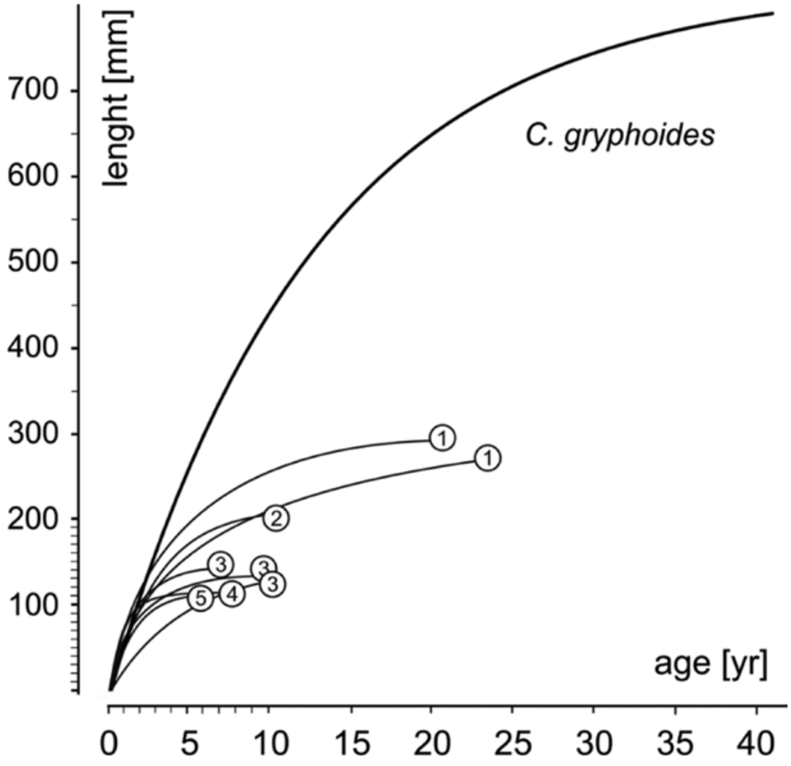

Figure 11. Figure 10 in Harzhauser et al. (2016), depicting the growth curve for *Crassostrea gryphoides* (now *Magallana gryphoides*) constructed from 1121 Early Miocene shells (Austria). Creative Commons Attribution 3.0 License. Growth curves labeled 1 are the same Miocene growth curves shown in Figure 8. Growth curve 2 is for *C. madrasensis* (recent, Bangladesh), growth curve 4 is for *C. corteziensis* (recent, Mexico), and growth curve 5 is for *Crassostrea gigas*, or *Magallana gigas* (recent, France). Two of the curves labeled "3" are the two *C. virginica* curves from Kirby (2001) shown in Figure 8, with the third such curve from a Chesapeake and Delaware Bay study of recent *C. virginica* by Powell et al. (2011). Despite the broad geographical distribution of the Recent oysters, their growth curves are *all* consistent with accelerated maturation and smaller body sizes compared to the Miocene specimens (curves 1).

It should also be noted that *all* the modern *Crassostrea* growth curves from France, Bangladesh, Mexico, and the Atlantic coast of the United States (curves 2–5 in Figure 11) indicate smaller body sizes and accelerated maturation compared to the two Miocene *Crassostrea* curves from California (curves 1), despite their wide latitude distribution and the taxonomic uncertainty of the *C. gigas* or *M. gigas* specimen from France (curve 5).

Some evolutionists have acknowledged a close link between fossil and extant *Crassostrea* clams, despite their assignment to different species. Sohl and Kauffman (1964, p. H1) argued that *C. virginica* may be the modern representation of both the Cretaceous *C. cusseta* (now a defunct classification) and the Eocene *C. gigantissima*:

> *C. cusseta* is the terminal Cretaceous member of the *C. soleniscus* lineage in [American] gulf coast sediments; the lineage continues, however, with little basic modification, through the Cenozoic, being represented in the Eocene by *G. gigantissima* (French) and probably, in modern times, by *C. virginica* (Gmelin).

Lawrence (1991, p. 342) goes even further, saying, *C. gigantissima* "is most certainly the direct ancestor of *C. virginica*." If *C. gigantissima* is the "direct ancestor" of today's *C. virginica*, isn't this just another way of saying that *C. virginica* and *C. gigantissima* are really the same Genesis 'kind' or baramin? The much greater sizes and growth intervals of *C. gigantissima* compared to *C. virginica* are indirect evidence that *C. gigantissima* was experiencing much greater longevity than its modern-day descendants. According to the World Registry of Marine Species (marinespecies.org), *C. virginia* commonly has a length of about 8.5 cm, whereas *C. gigantissima* was much, *much* larger. Some *C. gigantissima* specimens (Figure 10) were more than 55 cm in length (Edwards, 2016, p. 5).

In passing, we should note that if we accept the respective taxonomic reclassifications of *C. gigas* and *C. gryphoides* to *M. gigas* and *M. gryphoides*, we now have evidence of extreme past longevity from *two* different oyster genera, rather than just one.

Crassostrea Oysters from the Tropical Americas

Kirby and Jackson (2004) compared body sizes and growth rates of 542 Miocene, Pliocene, and Quaternary juvenile (ages less than 7 years) *Crassostrea* oysters from the tropical Americas. Their study included Recent, Holocene, and Pleistocene *C. virginica* from Venezuela, Trinidad, Panama, Barbados, and Costa Rica; Recent and Pleistocene *C. columbiensis* oysters from Panama; Pliocene and Miocene *C. cahobasensis* from Venezuela and Panama, and Pliocene *Crassostrea aff. C. virginica* specimens,

Table II. Results of Mann-Whitney U tests for differences in shell heights between Late Pleistocene (LP), Middle Pleistocene (MP), colonial, and modern *Crassostrea* specimens. Statistically significant differences are highlighted in bold. After Table 2 from Kusnerik et al. (2018).

	Maryland	Virginia	North Carolina
MP vs. LP	–	–	**$Z_{225,21} = -2.93$** **$p = 0.003$**
MP vs. Colonial	–	**$Z_{647,364} = -4.48$** **$p < 0.0001$**	–
MP vs. Modern	–	**$Z_{647,6916} = -15.15$** **$p < 0.0001$**	$Z_{21,5443} = -1.05$ $p < 0.29$
LP vs. Colonial	$Z_{36,3} = -1.69$ $p = 0.09$	–	–
LP vs. Modern	**$Z_{36,1176} = -6.44$** **$p < 0.0001$**	–	**$Z_{225,5443} = -3.76$** **$p < 0.0001$**
Colonial vs. Modern	$Z_{3,1176} = -0.69$ $p = 0.49$	**$Z_{364,6916} = -9.56$** **$p < 0.0001$**	

whose taxonomic status was uncertain, from Trinidad, Jamaica, and Venezuela (Table III). With the exception of the Jamaica specimens (18° N latitude), all oyster specimens were collected from a latitude band of ~4.6° (Figure 1 in Kirby and Jackson, 2004).

Kirby and Jackson (2004) calculated estimated carbonate content of these shells. They also used an allometric relationship to estimate total biomass for the specimens. The Miocene and Pliocene *C. cahobasensis* specimens were consistently larger, at all ages, than the Quaternary *C. virginica* and *C. columbiensis* oysters (Figure 12). This was true regardless of whether estimated carbonate content or biomass was used as a measurement of body size. With the exception of some Recent *C. columbiensis* oysters from Panama, most of the Recent oysters seem to have been *C. virginica*. It is thus striking that the Recent *C. virginica* oysters are consistently smaller than the Pleistocene

Table III. Uniformitarian age assignments and locations from which *Crassostrea* specimens were collected from the tropical Americas. The *C.* aff. *C. virginica* specimens are of uncertain taxonomic classification but have an affinity (aff.) or resemblance to *C. virginica*.

Conventional Age Assignment	Species	Location(s)
Recent	*C. virginica*	Venezuela and Trinidad
Recent	*C. columbiensis*	Panama
Holocene	*C. virginica*	Panama
Late Pleistocene	*C. virginica*	Panama
Pleistocene	*C. virginica*	Costa Rica, Venezuela, Barbados, Panama
Pleistocene	*C. columbiensis*	Panama
Early Pleistocene	*C. virginica*	Trinidad
Pliocene	*C.* aff. *C. virginica*	Trinidad, Venezuela, and Jamaica
Pliocene	*C. cahobasensis*	Venezuela
Early Pliocene	*C. cahobasensis*	Venezuela
Late Miocene	*C. cahobasensis*	Panama and Venezuela
Miocene	*C. cahobasensis*	Panama

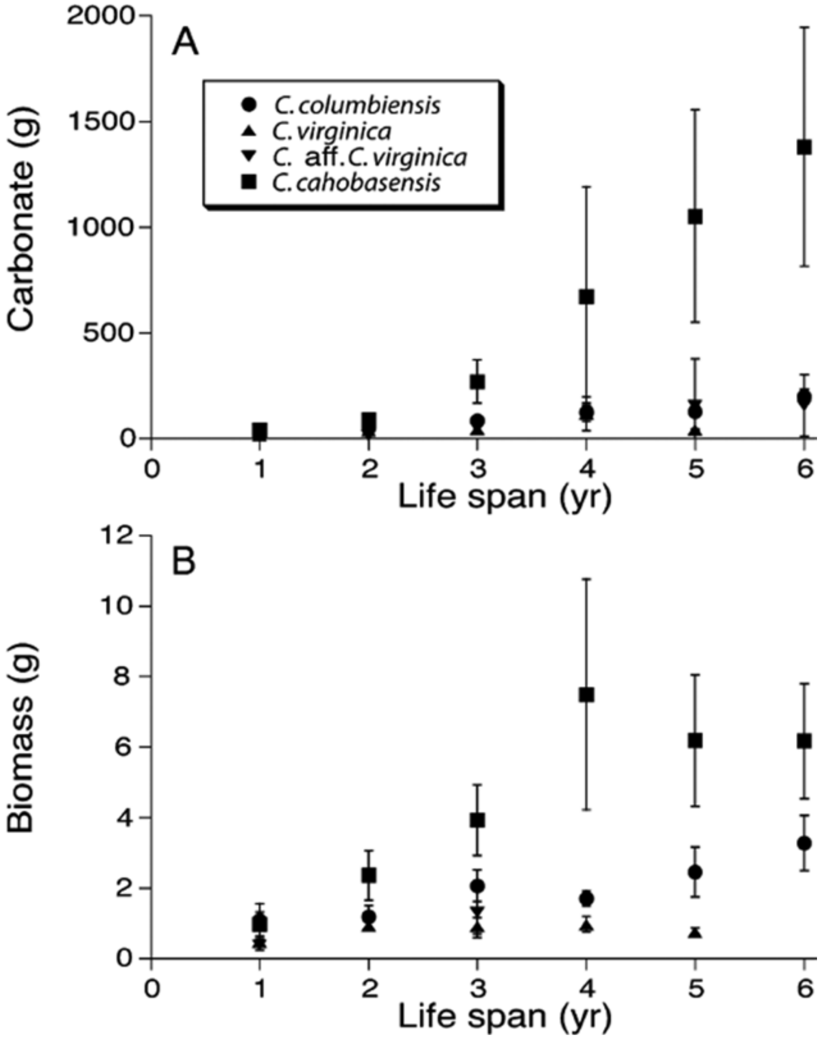

Figure 12. Figure 3 from Kirby and Jackson (2004), showing that juvenile Pliocene and Miocene *C. cahobasensis* specimens have larger body sizes at all stages of ontogenetic development compared to juvenile Recent and Pleistocene *C. columbiensis* and *C. virginica* specimens, regardless of whether estimated carbonate shell content (a) or total estimated biomass (b) is used as a measurement of size. Error bars represent 95% confidence intervals. Fair Use Application, used by general permission of the Geological Society of America.

C. columbiensis oysters, which are consistently smaller than the Miocene and Pliocene *C. cahobasensis* oysters. With the one exception of the Pliocene *C.* aff. *C. virginica* oysters, whose taxonomic status is uncertain, the pattern is consistent with our working hypotheses that adult body sizes are associated with longer-lived organisms, and that both human and animal longevities were decreasing after the Flood.

Note also that a Pacific-Atlantic temperature gradient is insufficient to explain these size differences, as inspection of the data in Table I and Figure 1 in Kirby and Jackson (2004) show that nearly all the *Crassostrea* specimens were collected from locations on the Atlantic side of Central and South America.

Concluding Remarks

Hebert (2023) accumulated preliminary evidence of extreme longevity in fossil forms (bivalves, alligators and crocodiles, sharks, and possibly birds). Since humans once experienced much greater longevity, and since whatever conditions enabled this longevity likely also affected the animal kingdom, this result makes good sense in light of the Bible's testimony. It also has the potential to be a great encouragement to Bible-believing Christians, especially if it can be shown that this longevity was experienced by a wide array of organisms. Although these preliminary results are potentially encouraging, they require more in-depth analysis, and potential objections to these arguments need to be addressed. This paper was an attempt to do that in the case of *Crassostrea* oysters, specifically. This paper also helps illustrate some of the steps suggested by Overman (2021) in performing creationist scientific research. Specifically, the Bible's statements regarding past human longevity were taken seriously and used to derive conclusions that could be (and were) tested.

Because bivalve fossils are extremely abundant (Morris and Sherwin, 2011), creation researchers could potentially do original field work in this area. However, the already-published research in the mainstream paleontological literature should not be neglected, as it is likely that much evidence of such longevity has already been published but has simply been overlooked by evolutionary researchers.

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