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The Ecological Importance of Brachiopods versus Bivalves in the Paleozoic: Taphonomy, Biomass, and Energy use

Shannon (Shin-nan) Hsieh
shsieh7@uic.edu

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The Ecological Importance of Brachiopods versus Bivalves in the Paleozoic: Taphonomy, Biomass, and Energy use

Shannon Hsieh

B.Sc., University of Toronto

A Thesis

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Approval Page

Masters of Science Thesis

The Ecological Importance of Brachiopods versus Bivalves in the Paleozoic: Taphonomy, Biomass, and Energy use

Presented by

Shannon Hsieh, B.Sc.

Major Advisor_____

Prof. Andrew Bush

Associate Advisor_____

Prof. Janine Caira

Associate Advisor_____

Prof. Lisa Park Boush

University of Connecticut

2015

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Abstract

Brachiopods have commonly been considered more important than bivalves in Paleozoic ecosystems due to their greater global diversity and greater abundance in many fossil assemblages. New sampling-standardized diversity curves verify that brachiopods were more diverse than bivalves at the global level in the Paleozoic; they declined in the Permian-Triassic extinction, largely recovered, then faded away later in the Mesozoic. However, the subordinate ecological status of bivalves within local Paleozoic ecosystems has been challenged on two fronts. First, bivalve abundance may be underestimated due to preferential dissolution of aragonitic shells. Second, bivalve contribution to ecosystem function may be underestimated by abundance or diversity data because they tend to have greater biomass and energy use than brachiopods. Here, I compare the relative importance of bivalves and brachiopods in an exceptionally preserved fauna from the Middle Pennsylvanian Breathitt Formation of Kentucky in which aragonitic bivalves are preserved as shells, not molds. I use four metrics of ecological importance – abundance, shell volume, biomass and energy use. Brachiopods outnumbered bivalves and had greater total shell volume, though the two taxa were roughly equivalent in total biomass and energy use. By all four metrics, brachiopods were more important as suspension feeders. The importance of brachiopods relative to bivalves was underestimated when occurrence-level data were used instead of abundance data, suggesting caution in interpreting global trends based on occurrences. Globally, the two taxa were fairly similar in diversity in the

Pennsylvanian, so brachiopods may have been more important relative to bivalves at other times in the Paleozoic when their diversity was greater.

Introduction

Bivalves and brachiopods are morphologically and ecologically similar—both are bivalved, benthic, and most are suspension feeders—but their diversity histories contrast strongly. Although both first appeared in the early Cambrian (Parkhovev 2008, Williams and Carson 2007), brachiopods were more diverse than bivalves in the Paleozoic and declined thereafter, whereas bivalves radiated steadily through time, becoming more diverse than brachiopods in the Mesozoic and Cenozoic (Sepkoski 1981, Sepkoski and Miller 1985). In fact, the two taxa are archetypal members of Sepkoski's (1981) Paleozoic and Modern Faunas. Their divergent fates, combined with their exceptional fossil records (Foote and Sepkoski 1999, Jablonski et al. 2003, Valentine et al. 2006), render the bivalves and brachiopods model systems for testing new theories and methods in paleontological diversity analysis.

For many years, the similarities between bivalves and brachiopods invited suggestions that the former were somehow superior to the latter and ultimately competitively replaced them (Agassiz 1857, Mayr 1959, Steele-Petrovic 1979). Gould and Calloway (1980), however, argued that the changeover of dominance between the two was the product of a singular event, the end-Permian extinction, in which brachiopods suffered greater losses than bivalves, possibly due to greater susceptibility to ocean acidification (Knoll et al. 2007). By this reasoning, the decline of brachiopods had more to do with a contingency of history than any particular biological disadvantage—at least, any disadvantage related to normal ecological interactions. Sepkoski (1996) acknowledged the importance of the Permian extinction, but noted that brachiopods

recovered in diversity in the Triassic and declined thereafter in his compilation of the stratigraphic ranges of fossil genera. He suggested that biotic interactions with the diversifying Modern Fauna may have caused this decline (Sepkoski 1996, Aberhan et al. 2006).

Despite their different interpretations of why brachiopods declined, these authors all assumed that brachiopods were more important than bivalves in the Paleozoic based on their diversity and abundance in the rock record. However, several authors have challenged this view, suggesting that bivalves were actually more important in Paleozoic ecosystems than brachiopods (Cherns and Wright 2000, 2009; Payne et al. 2014). Cherns and Wright (2000, 2009) argued that bivalves are greatly underrepresented in the Paleozoic fossil record relative to brachiopods because most have shells made of aragonite, which is more prone to dissolution than the calcite biomineralized by most brachiopods and some bivalves. Indeed, much of the Paleozoic bivalve record consists of molds of dissolved shells (McAlester 1962; Bush and Bambach 2004) instead of whole body fossils, which could lead to underrepresentation. Cherns and Wright (2000, 2009) posited that Paleozoic fossil assemblages that appear to have been dominated by brachiopods probably represented living communities numerically dominated by mollusks. However, Bush and Bambach (2004), Kidwell (2005), and Cherns et al. (2008) argued that the aragonite bias does not overwhelm many macro-scale evolutionary patterns like global diversity curves. From a different perspective, Payne et al. (2014) argued that bivalves were already ecologically more important than brachiopods in the Paleozoic because they collectively consumed more energy, despite being lower in diversity and abundance. Their analyses showed bivalves to be metabolically dominant over brachiopods beginning in the early to middle Paleozoic, and they

concluded that bivalves did not displace brachiopods — rather they consumed resources the latter did not or could not access.

Here, I evaluate the relative importance of bivalves versus brachiopods in the Paleozoic from a number of perspectives. First, I generate sampling-standardized diversity curves from the Paleobiology Database to examine the timing and nature of major shifts in diversity dominance between the two taxa. Though diversity curves for brachiopods and bivalves have been generated before (Gould and Calloway 1980, Miller and Sepkoski 1988, Sepkoski 1996, Selden (2007, p. 2913), Alroy 2010, Foote 2010, and Payne et al. 2014), direct comparisons have not been standardized for heterogeneity in sampling. Second, I examine the ecological importance of bivalves versus brachiopods with a set of fossil assemblages from the Pennsylvanian-aged Breathitt Formation of Kentucky and neighboring states in which originally aragonitic shells are preserved without dissolution, and are thought to be representative of a regional ecosystem (Bennington and Bambach 1996). This exceptional preservation provides an alternate window for comparing the relative abundance and energy use of bivalves and brachiopods in Paleozoic ecosystems.

Global Diversity Curve

Methods

Because unequal sampling among time intervals may bias diversity metrics (Alroy 2008, 2010) sampling-standardized global diversity curves were generated for brachiopods and bivalves for the Ordovician through Neogene using data downloaded from fossilworks.org. Fossilworks.org was used since bivalve and brachiopod datasets from paleobiodb.org could not be accessed easily at the time of study. A combined diversity curve for bivalves and gastropods was also produced in order to compare brachiopods to benthic mollusks in general, as in some studies of preservational bias (e.g., Cherns and Wright 2009). Gastropods and bivalves were included as the best-sampled benthic mollusks. Download criteria generally followed Alroy (2010, 2014). I downloaded all data records created before May 21, 2015 and excluded terrestrial collections, collections resolved to basin or geological group, collections from unlithified or easily sieved sediments, form taxa, and fossils preserved as adpressions, soft parts, original aragonite, or traces. I combined occurrences of the same genus from the same sample, treated subgenera as distinct genera, and excluded occurrences unresolved to the level of genus, as well as genus names qualified by *aff.*, *ex. gr.*, *sensu lato*, or quotation marks. Otherwise, default criteria were used.

Sampling was standardized using shareholder quorum subsampling (SQS) with a quorum of 0.60 and Alroy’s (2014) algorithm. The method is similar to Chao and Jost’s (2012) coverage-

based rarefaction. I used Alroy’s “three-timer” correction for all but the final time interval, for which it cannot be calculated.

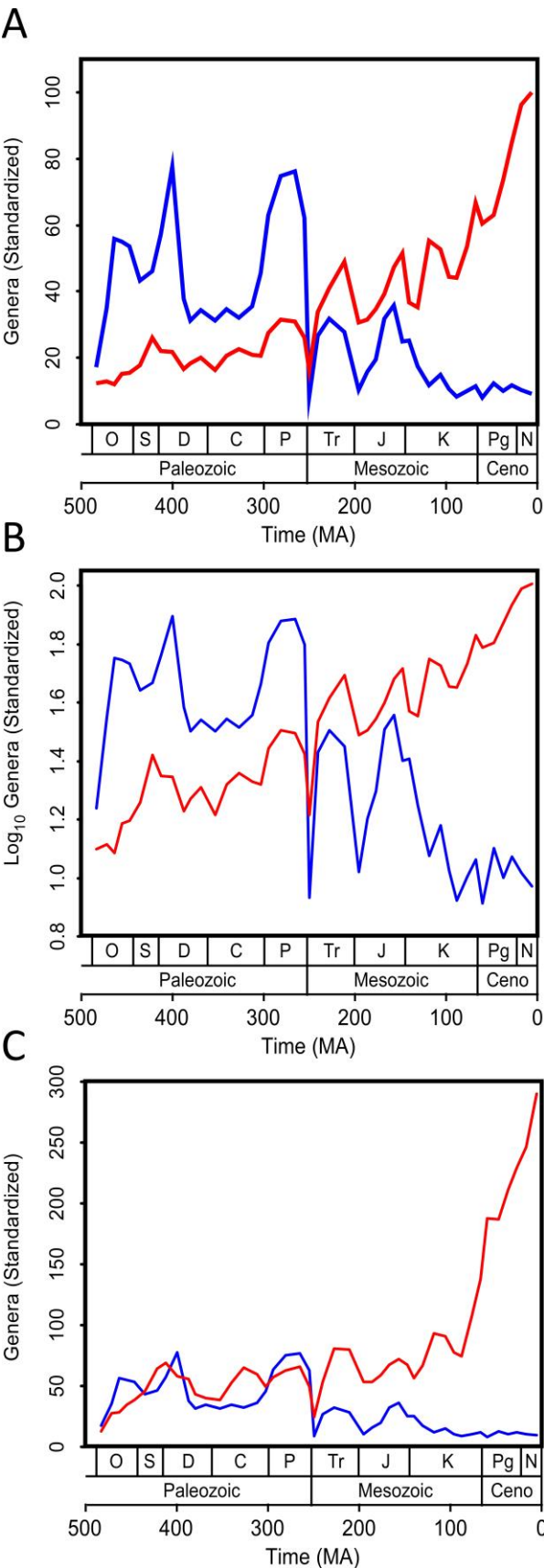


Figure 1. Sampling standardized generic diversity curves for brachiopods (blue) and mollusks (red) from Ordovician to Neogene. A. Brachiopod and bivalve richness plotted on an arithmetic scale. B. Brachiopod and bivalve richness plotted on logarithmic scale. C. Brachiopod and benthic mollusk (bivalves and gastropods combined) richness on an arithmetic scale. Abbreviations: O= Ordovician, S= Silurian, D= Devonian, C= Carboniferous, P= Permian, Tr= Triassic, J= Jurassic, K= Cretaceous, Pg= Paleogene, N= Neogene, Ceno=Cenozoic).

Results

As seen in Fig. 1A, bivalves radiated steadily throughout the Phanerozoic, with some fluctuations (Miller and Sepkoski 1988, Foote 2010, Alroy 2010); on a logarithmic scale (Fig. 1B), the increase in genera is approximately linear, suggesting slow but exponential growth, set back temporarily by mass extinctions (Miller and Sepkoski 1988, Foote 2010). Brachiopods were more diverse than bivalves during the Paleozoic, with large peaks in the Early Devonian and Permian and lower diversity in the Late Devonian and Carboniferous. Brachiopod diversity fell dramatically in the end-Permian extinction, partially rebounded in the Triassic, fell again in the end-Triassic extinction, and rebounded completely in the Jurassic. Brachiopods then declined in diversity in the Late Jurassic and Cretaceous and maintained low levels in the Cenozoic, while bivalves continued to diversify. Although Paleozoic bivalves were less diverse than brachiopods, bivalves and gastropods in combination (Fig. 1C) were quite similar in diversity to brachiopods during the Paleozoic; in fact, benthic mollusks had greater diversity than brachiopods for long stretches of Paleozoic time.

Discussion

These diversity curves for bivalves and brachiopods are broadly similar to those shown by Gould and Calloway (1980), Miller and Sepkoski (1988), Sepkoski (1996), Selden (2007, p. 2913), Alroy (2010), Foote (2010), and Payne et al. (2014), though there are some differences; for example, some curves do not show a notable brachiopod recovery after the Permian

extinction. As shown previously by Gould and Calloway (1980), bivalves became more diverse than brachiopods in the Triassic because they were affected less by the end-Permian extinction (Fig. 1A), possibly due to the former's comparatively better physiological buffering against ocean acidification (Knoll et al. 2007). They continued to radiate as they filled infaunal niches unoccupied by brachiopods as the result of mantle fusion and siphon formation (Stanley 1968). However, this analysis supports Sepkoski's (1996) assertion that brachiopods recovered substantially in the early Mesozoic (Chen et al. 2002, 2005), reaching Late Devonian-Carboniferous levels of diversity (Fig. 1A). In fact, despite the loss of several major subtaxa, they were almost as diverse as bivalves during much of the Triassic and Jurassic and also rebounded in morphological disparity (Ciampaglio 2004) and biogeographical differentiation (Dagys 1993). They declined in diversity slowly in the Late Jurassic and Cretaceous, retreating to offshore areas characterized by lower sediment and nutrient input (Tomašových 2006). The Mesozoic recovery and subsequent decline of brachiopods can also be seen in diversity curves shown by Payne et al. (2014), although these curves were not generated with standardized sampling, and the pattern is not as clear in the standardized curves generated by Alroy (2010) using an earlier version of the PBDB.

Thus, the decline of brachiopods appears to have two components: the Permian extinction and the Mesozoic decline. Sepkoski (1996) suggested that the latter could result from competition or other biotic interactions with bivalves and other members of the Modern Fauna, and it coincides with increased predation and disturbance during the Marine Mesozoic Revolution (Vermeij 1977; Kowalewski et al. 2005; Aberhan et al. 2006; Vörös 2010).

Local-regional analysis

Taphonomic Biases at Local-Regional Scales

The relative importance of bivalves and brachiopods can also be evaluated at the local scale by examining fossil assemblages, but taphonomic biases complicate such studies. Brachiopods are generally more abundant in Paleozoic assemblages, but Cherns and Wright (2000, 2009) argued for molluscan dominance based on comparisons of silicified and non-silicified assemblages. Non-silicified assemblages represent typical preservational modes such as shells and molds, and the silicified assemblages contained greater numbers of originally aragonitic shells and were presumed to more accurately preserve the original fauna. On the basis of these comparisons, they proposed that mollusk abundance was typically underestimated by two orders of magnitude due to aragonite dissolution. However, there are reasons to doubt the accuracy of these quantitative assessments, without disputing the general point that aragonite dissolution can be a problem in interpreting Paleozoic paleoecology. First, silicification itself can be biased, and it is not clear that silicified assemblages provide a quantitatively accurate view of the original fauna. Biases in silicification are still not well-understood and are a topic of ongoing research (Butts 2014, Pruss, 2014; Pruss et al. 2015).

Additionally, the silicified and non-silicified assemblages compared by Cherns and Wright (2000, 2009) do not appear to represent the same original sets of taxa, and thus one cannot accurately compute the magnitude of aragonite loss. As Bush and Bambach (2004) noted, the silicified and non-silicified assemblages tabulated by Cherns and Wright (2000) were dominated by different genera of bivalves and brachiopods. Furthermore, the faunas differed ecologically –

the silicified fauna was dominated by deposit-feeding bivalves, whereas the non-silicified fauna was dominated by suspension feeders. Since these assemblages were taxonomically and ecologically distinct, it is not possible to calculate the effects of aragonite loss. In fact, it is not surprising that there are more bivalves in the silicified fauna, if it represented a habitat where deposit-feeding was advantageous.

Cherns and Wright (2009) also compared silicified and non-silicified assemblages from the Ordovician (Holland and Patzkowsky 2004, Hoare and Pojeta 2006), but, again, it is not clear that the original communities were similar. Most bivalves in the silicified fauna were pteriomorphs that had a calcitic shell layer; the low abundance of these shells in the non-silicified fauna suggests that the bivalve faunas of the two assemblages were quite different. Abundance and presence of brachiopod species was also somewhat different between silicified mollusk-rich faunas and brachiopod-dominated faunas from Carboniferous limestones (Brunton 1987) used to argue for missing mollusks, though in this particular case, brachiopods were more abundant in both samples.

It is always possible to argue that some bivalves have been lost from a fossil assemblage through early aragonite dissolution, and although one can make some reasonable arguments, it is very hard to refute the assertion definitively. Indeed, Cherns and Wright (2009) have asserted that originally aragonitic shells occur in silicified assemblages when silicification occurred before those shells dissolved, whereas silicified assemblages that lack aragonitic shells do so because silicification occurred after aragonite dissolution. However, this assumption would make the hypothesis that aragonite-shelled animals were always present and abundant impossible to falsify using silicified faunas.

Given concerns about silicified faunas, I have taken a different approach to evaluating the relative importance of bivalves and brachiopods by examining fossil assemblages from the Pennsylvanian-aged Breathitt Formation, in which excellent aragonite preservation is known (Yochelson et al. 1967, Brand 1983, Bennington 1995). Although I cannot entirely rule out preservational biases, these assemblages are much less affected by them than is typical for the Paleozoic, providing a unique window into Paleozoic benthic ecology. First, I analyze the apparent relative ecological importance of bivalves and brachiopods with the assumption that taphonomic biases are not a problem, and then I discuss the potential effects of dissolution.

Materials and Methods

Geological and paleontological context

The Middle Pennsylvanian Breathitt Formation of eastern Kentucky (Fig. 2) comprises a number of transgressive marine shales separated by terrestrial strata. It spans a time interval when the global diversity of brachiopods and bivalves was fairly similar (Fig. 1A). Bennington (1995) collected bulk samples from the four most extensive marine shales (the Elkins Fork, Kendrick, Magoffin, and Stoney Fork) at 46 localities in eastern Kentucky and neighboring states (Fig. 2A, Appendix 1) for a test of community persistence and coordinated stasis (Bennington, 1995; Bambach and Bennington 1996; Bennington and Bambach, 1996). The bulk samples weighed 5-10 kg each and were soaked in detergent and disaggregated by Bennington (1995), such that most fossils were separated from the matrix. The extraction of fossils from the matrix helps allays concerns about the effects of lithification on paleoecological patterns (Hendy

2011, Sessa et al. 2009). Originally aragonitic shells are preserved as original shell material (Fig. 3), not molds (Yochelson et al. 1967, Brand 1983), and display the same level of fine detail as calcitic shells, even on small specimens (e.g., 1-2 mm on a side).

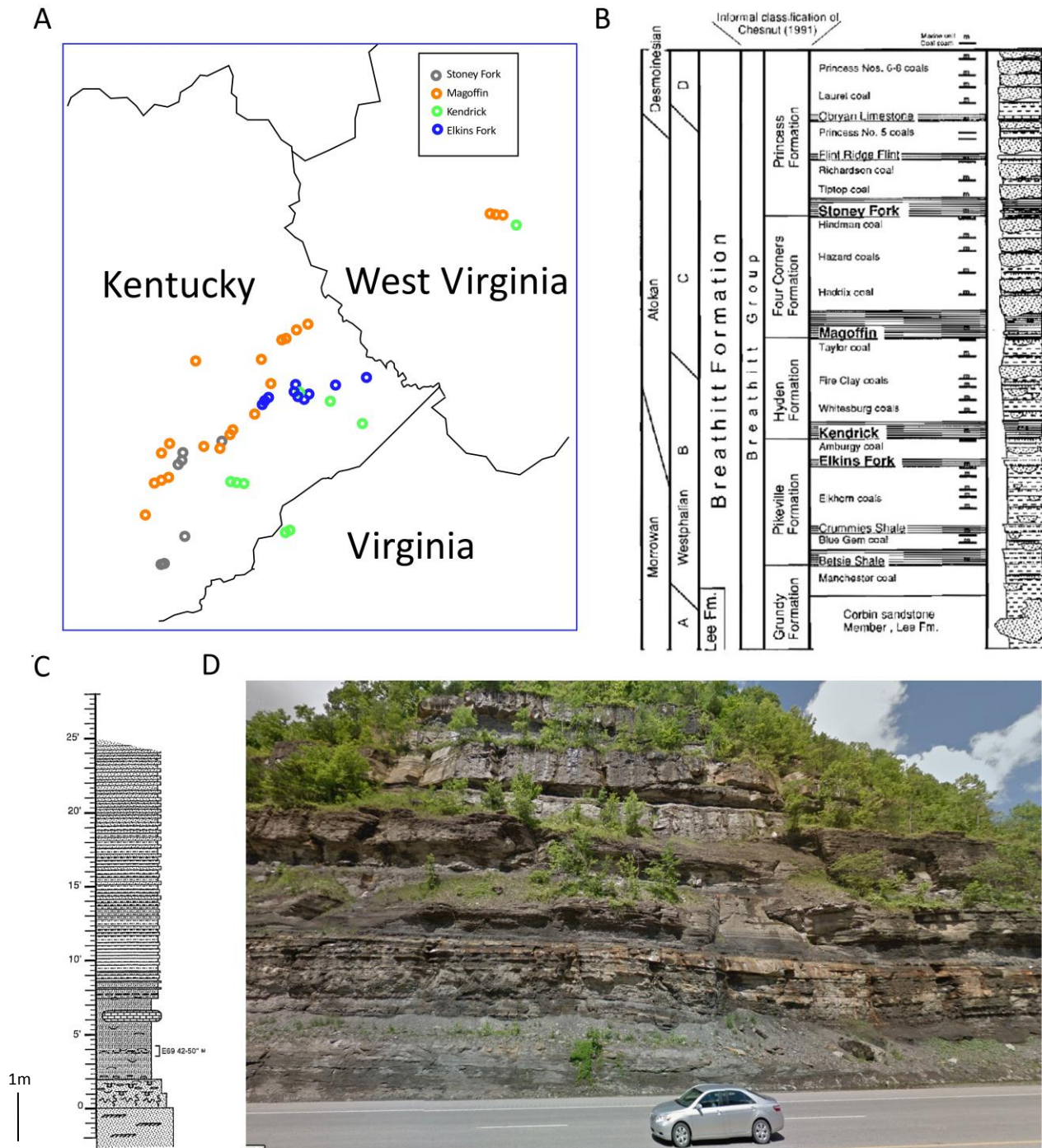


Figure 2. Locality information. A. Sampling localities in the Breathitt Formation in eastern Kentucky, USA, and equivalent strata in Virginia and West Virginia, belonging to the four marine shales. B. Stratigraphy of the Breathitt Formation showing the four marine shales (Elkins Fork, Kendrick, Magoffin, Stoney Fork) separated by terrestrial strata (from Bambach and Bennington 1996). C. Example of a local stratigraphic section in the Breathitt Formation showing sampling site E69 at N37° 33'54" W 82°45'43" (from Bennington 1995). The Elkins Fork Shale is located at 2.0-7.5 feet. D. Outcrop at locality E69, with the shale marked (photograph from Google Maps, ©2015 Google).

Bennington (1995) recorded abundance counts for 78 species of brachiopods, bivalves, rostroconchs, gastropods, corals, crinoids, and trilobites; for this study, I focused on brachiopods (24 species) and bivalves (28 species), represented by 30,852 specimens (abundance information in Appendix 2). I combined replicate samples drawn from the same horizon at the same locality and excluded samples containing fewer than 30 individuals. The collection is currently housed at the Virginia Museum of Natural History in Martinsville, Virginia.

The samples represented a range of habitats along a depth gradient. Through cluster analysis, Bennington (1995) found that samples generally fell into five paleocommunity types based on species composition. At one end of the environmental spectrum, a cluster of samples dominated by semi-infaunal productid brachiopods rooted by spines was associated with high-energy, nearshore environments. At the other extreme, the “small mollusk cluster” was dominated by deposit-feeding nuculoid bivalves in deeper, quieter waters where organic matter could settle. In between were spiriferid, productid-chonetid, and chonetid-mollusk clusters, named after their dominant constituents.

These samples derive from a single geographical region, so the results of this study should not casually be extrapolated globally. However, the Breathitt fauna is rather typical of its time,

with many wide-ranging genera: 58.5% of the 5379 brachiopod occurrences and 67.8% of the 1198 bivalve occurrences in the PBDB for the Pennsylvanian of North America belong to a genus that occurs in the Breathitt dataset. Also, Bennington and Bambach (1996) and Bambach and Bennington (1996) showed that consistent faunal assemblages returned during a series of transgressions over several million years, suggesting that these assemblages are not unusual given the regional species pool.

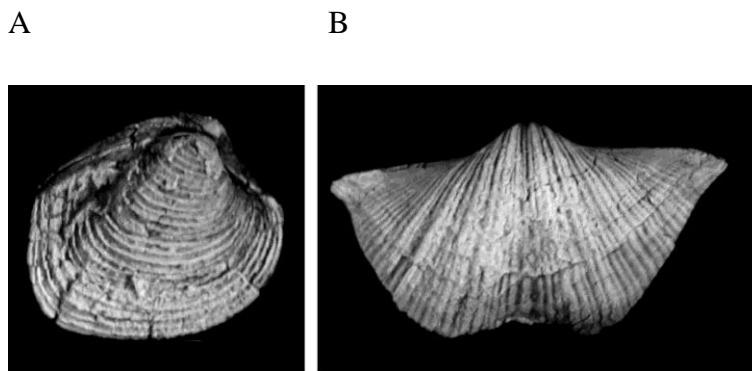


Figure 3. Fossils from the Breathitt Formation. A, *Astartella*, an aragonitic bivalve (11.6 mm maximum dimension). B, *Neospirifer*, a calcitic brachiopod (31.2 mm maximum dimension). The species show comparable detail of preservation.

Body size data

To obtain estimates of average volume, biomass, and energy use for each species, I measured lengths of the anterior-posterior, dorsal-ventral, and left-right axes (AP, DV, and LR) of a subsample of shells to the nearest tenth of a millimeter using digital calipers. I obtained 4306 measurements from 1677 specimens (Appendix 3). For abundant species, I measured 30-60

specimens drawn from numerous samples representing multiple shale units. For rarer species, I measured as many specimens as were available.

Many specimens included both valves, but when a bivalve specimen was represented by a single valve, its LR dimension was doubled based on an assumption of symmetry. DV measurements were treated similarly for single valves of equally biconvex brachiopods. All three dimensions could be determined from ventral valves of plano-convex and concavo-convex brachiopods.

Due to fragmentation, some specimens were measured in only one or two dimensions. To make use of all available information on size variation (Schafer 1997), the missing data were imputed using the program AMELIA II (Honaker et al. 2011) whenever possible. For some species, AMELIA II did not produce a result, so missing values were imputed using the mean ratio of the missing dimension to a more completely known dimension (Appendix 4). This method yielded results that were essentially identical to those produced by AMELIA II in species for which both methods could be employed.

Volume, biomass, and energy use

We modeled the volume of brachiopod and bivalve shells as ellipsoids with volumes of $(4/3)\pi(x/2)(y/2)(z/2)$, where x , y , and z are the average of the three measured dimensions for each species (Finnegan and Droser 2008). I followed Payne et al. (2014) in calculating ash-free dry mass (AFDM) in grams as $8.0 \times 10^{-7} \times L^{3.34}$ for brachiopods and $1.0 \times 10^{-5} \times L^{2.95}$ for bivalves, where L is the maximum linear dimension of a species. Chonetid brachiopods are flatter than any

of the modern taxa on which these equations are based, so I halved their length before calculating biomass. As in previous paleoecological studies (Finnegan and Droser 2008; Finnegan et al. 2011, Payne et al. 2014), I calculated average metabolic rate per species using the equation $B(M, T) = B_0 e^{-E/kT} M^{3/4}$, where B is the resting metabolic rate (in Watts), E is the average activation energy of rate-limiting metabolic reactions, k is Boltzmann's constant, T is the absolute temperature in K, M is body mass, and B_0 is a taxon-dependent scaling constant (Gillooly et al. 2001). I assume T is constant within samples, and so $e^{-E/kT}$ is constant within samples and cancels out when calculating within-sample proportions. Proportional metabolic rate depends only on B_0 and M . Following Payne et al. (2014), B_0 equals $6.5 \times 10^{10} \text{ W kg}^{-3/4}$ for rhynchonelliform brachiopods, $5.6 \times 10^{10} \text{ W kg}^{-3/4}$ for other brachiopods, $1.4 \times 10^{11} \text{ W kg}^{-3/4}$ for heterodont bivalves, and $1.3 \times 10^{11} \text{ W kg}^{-3/4}$ for non-heterodont bivalves.

Measures of ecological importance

For each sample, I estimated proportional importance of bivalves relative to brachiopods using the following metrics: 1) total number of specimens in each of the two groups; 2) shell volume summed across specimens in each group; 3) biomass summed across specimens in each group; and 4) energy use summed across specimens in each group (Table 1). Each metric was averaged across the 96 samples to obtain an overall estimate for the Breathitt ecosystem, and the distribution of sample values was visualized using kernel density estimation (Rosenblatt 1956, Parzen 1962). 95% confidence intervals around the means were estimated using a two-step resampling routine run at 1000 iterations. First, the individuals in each sample were resampled

with replacement, then the 96 samples were resampled with replacement. In calculating volume, biomass, and energy use, each specimen was assigned the average for its species, which adds some error to individual samples but should cancel out overall. To test the effects of estimating ecological importance without using local abundance data, I calculated these metrics a second time after degrading the data to species occurrences. That is, every species in a sample was treated as having equal abundance.

Finally, these analyses were run again using only suspension-feeding bivalves (21 species), which are more similar ecologically to brachiopods than deposit-feeding and chemosymbiotic species.

Table 1. Measures of ecological importance used in study to compare bivalves and brachiopods.

Measure	Definition	Ecological importance
Abundance	Number of specimens	Standard measure of numerical importance; size of populations in an ecosystem
Shell volume	Space occupied by and enclosed within an animal's shell	Competition for space; provision of hard substrates for other organisms
Biomass	Dry mass of living tissue	Amount of living matter present in the ecosystem
Energy use	Total consumption of energy by an animal	Ecosystem structure largely determined by flow of energy among trophic groups

Results

Variation among species in abundance, volume, biomass and energy use

The average proportional abundances of species in the Breathitt are skewed, with most species being rare and a few being common (Fig. 4). This is true for both bivalves and brachiopods, though there are more very abundant brachiopods. Volume, biomass, and energy use have relatively normal, bell-shaped distributions on a logarithmic scale. The average brachiopod species has greater shell volume but less estimated biomass and energy use than the average bivalve species (cf. Payne et al. 2014).

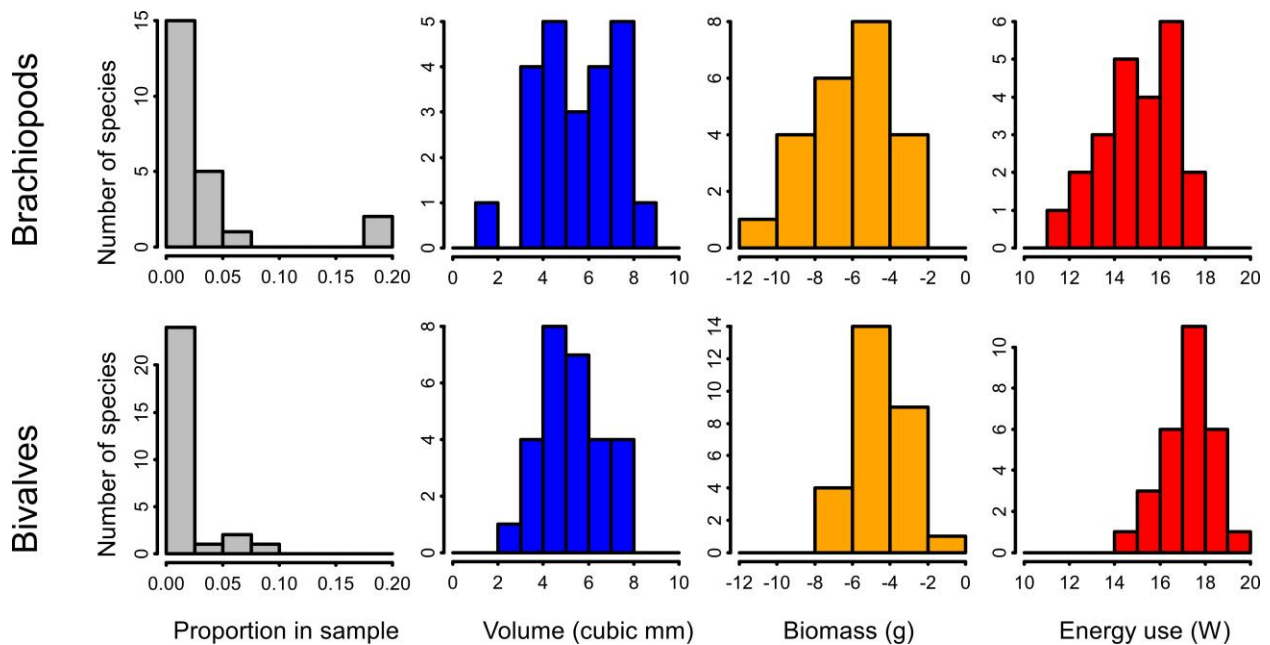


Figure 4. Distributions of brachiopod and bivalve species with regard to average proportional abundance within samples (gray), estimated shell volume (blue), biomass (orange), and energy use (red). N= 24 for brachiopods and 28 for bivalves. Shell volume, biomass, and energy use are displayed on a log₁₀ scale.

Ecological importance in the Breathitt

Bivalves constitute slightly less than a third of the specimens in the average Breathitt sample (Fig. 5A). However, the distribution is bimodal, with many samples strongly dominated by brachiopods and a smaller number dominated by bivalves. The latter corresponds with Bennington's (1995) small mollusk cluster, which is dominated by deposit-feeding nuculoids. The brachiopod-dominated and mixed samples correspond with his other community types. Only about a quarter of the total shell volume in the average sample was contributed by bivalves, with most samples heavily dominated by brachiopods. In terms of biomass, bivalves comprise nearly half the average sample, and in terms of energy use, slightly more than half (55%). For both these two metrics, the distributions of sample values are highly bimodal, with modes near 0% and 100%, and the means did not significantly differ from 50%. When only suspension-feeders were included, the relative importance of bivalves declined to 12% of specimens, 12% of total shell volume, 34% of total biomass, and 40% of total energy use (Fig. 5B). Additionally, all metrics displayed unimodal distributions with the mode near 0% bivalves.

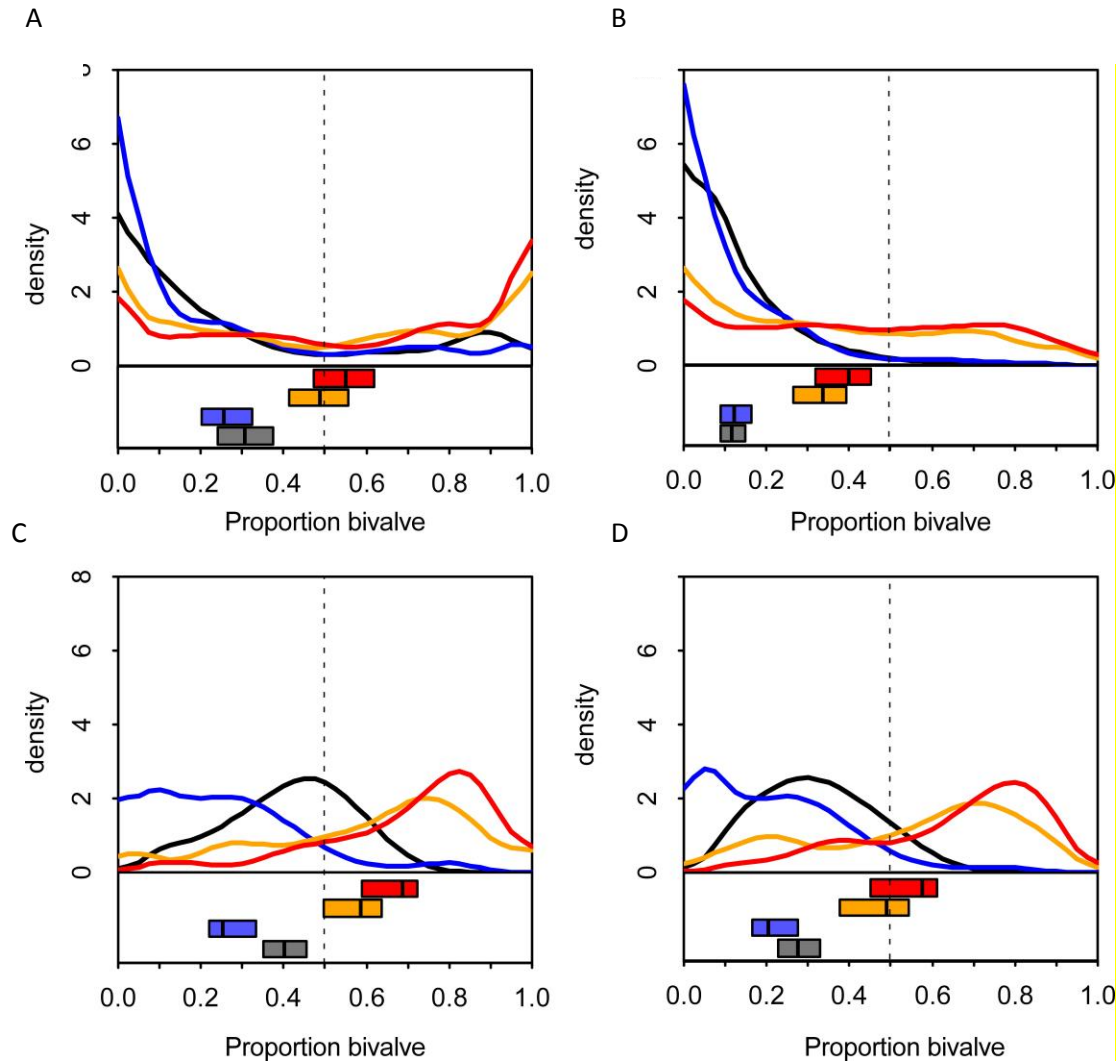


Figure 5. Proportional ecological importance of bivalves relative to brachiopods among the Breathitt samples. On each panel, the kernel density estimations of the distribution of sample values is shown on top, with mean and 95% confidence intervals underneath (rectangles). Black/grey: counts of specimens/occurrences, blue: volume, orange: biomass, and red: energy use. A. Weighted by abundance, all species. B. Weighted by abundance, suspension-feeders only. C. Weighted by occurrences, all species. D. Weighted by occurrences, suspension-feeders only.

Weighting by occurrences rather than abundances increased the apparent relative importance of bivalves for almost all metrics (Fig. 5C, D). In contrast with the results based on

counts of individuals, bivalves appeared to capture a clear, statistically significant majority of energy use when all species were considered (Fig. 5C). However, their shares of biomass and energy use were statistically indistinguishable from equal with brachiopods when only suspension feeders were considered (Fig. 5D). Additionally, weighting by occurrences altered the distributions of sample values. Many metrics previously had a mode that was approximately 0% bivalves, and these modes shifted considerably higher, up to 80% bivalves. Several bimodal distributions became unimodal (Fig. 5C, D). These figures were calculated by averaging values calculated separately for each sample, but the results are similar if occurrences for the Breathitt are pooled.

Bivalves were modeled in this study as having a higher ratio of biomass to shell size than brachiopods and a higher metabolic rate (Payne et al. 2014), so their apparent relative importance was greater when measured as biomass or energy use than as specimen proportions. Conversely, the relative importance of brachiopods was enhanced using shell volume, although this effect was lessened when deposit-feeding bivalves (which tended to be very small) were excluded.

Discussion

The importance of brachiopods relative to bivalves in Paleozoic ecosystems has been challenged on taphonomic and ecological grounds; I have tested both using an exceptionally preserved and sampled fauna from the Pennsylvanian.

Metabolism

The results suggest that bivalves and brachiopods used approximately equal amounts of energy in the Breathitt ecosystem (indistinguishable from 50%), although bivalves perhaps used slightly more. Thus, neither taxon truly “dominated” the ecosystem. When only suspension feeders are considered, however, brachiopods were found to use statistically significantly more energy than bivalves (60% of the total), suggesting that bivalves held their own against brachiopods only by exploiting more feeding mechanisms. In contrast, Payne et al. (2014) showed Pennsylvanian bivalves using ~60-95% of total energy based on occurrences or ~60-70% based on samples with abundance counts, with similar numbers if non-suspension-feeders were excluded. My numbers for bivalve energy use are lower than Payne et al.’s (2014), and the interpretation is quite different: I find bivalves and brachiopods were subequal in energy use, whereas they argued bivalves were dominant.

Our estimates may differ from Payne et al.’s (2014) for several potential reasons. In our data, degrading abundance counts to occurrences makes bivalves appear more dominant; instead of using an estimated 55% of energy (indistinguishable from 50%), bivalves used 69%, which is well within the range of values calculated by Payne et al. (2014) using occurrences. In other words, brachiopod occurrences tended to represent more specimens than bivalve occurrences, such that occurrences provided a biased view of local abundance and energy use. If this pattern turns out to be general, then conclusions based on occurrences will generally over-represent bivalves.

Payne et al.'s (2014) estimates based on samples that contained abundance counts avoid this potential bias, but they excluded samples that contained only bivalves or brachiopods, which could represent either true absence or lack of study in the PBDB. In our collections, no sample had only bivalve species, but there were samples with only brachiopod species, which may explain the discrepancy.

Taphonomy

Read literally, these results are consistent with brachiopods being twice as abundant overall as bivalves in this late Paleozoic ecosystem, and consuming about as much energy. The accuracy of these results depends in large part on the degree of aragonite dissolution in these sediments. Certainly, the aragonitic component is more well-preserved in these samples than in most Paleozoic settings, but the possibility that some aragonite shells were lost must be considered. Cherns et al. (2008) and Jordan et al. (2015) argued that aragonitic shells or skeletons can be well preserved in anoxic or dysoxic conditions that inhibit the pH-lowering oxidation reactions of bacterial decomposition of organic matter. The most heavily bivalve-dominated samples from the Breathitt belong to Bennington's (1995) "small mollusk" paleocommunity type; most bivalves in these samples are deposit-feeding nuculoids. According to Bennington (1995), these samples may in fact represent dysoxic to anoxic environments, so there could be a taphonomic explanation for the abundance of bivalves in these particular samples. In this case, the bivalve-dominated samples might represent the original assemblage fairly accurately, whereas brachiopod-dominated samples are taphonomically altered.

However, several lines of evidence suggest that aragonite loss is not a crippling problem in these samples. Aragonitic shells are preserved in almost every sample in the data set, although a few samples contain only brachiopods or only brachiopods and bimineralic bivalves (Fig. 6). Thus, aragonite was demonstrably preservable in almost every sample. Furthermore, there is no evidence that aragonitic shells were lost from these samples (e.g., preserved molds), and preservational condition was good in all samples. The only samples in which bivalves make up more than 60% of all specimens are ones in which deposit-feeders are dominant (red and orange points in Fig. 6), which is not surprising. Deposit feeders are known to be highly abundant in organic-rich sediments where their food was plentiful, and brachiopods would not be abundant in these samples simply because they are not deposit feeders. In the habitats preferred by suspension feeders, brachiopods and bivalves both occur. Similarly, the silicified fauna documented by Cherns and Wright (2000) in which bivalves were more abundant than brachiopods was also dominated by deposit feeders. Variations in the abundances of brachiopods and bivalves in the Breathitt samples shown in Fig. 6 are easily explicable by the varying ecological strategies and preferences of the taxa, and there is no evidence to suggest widespread aragonite loss.

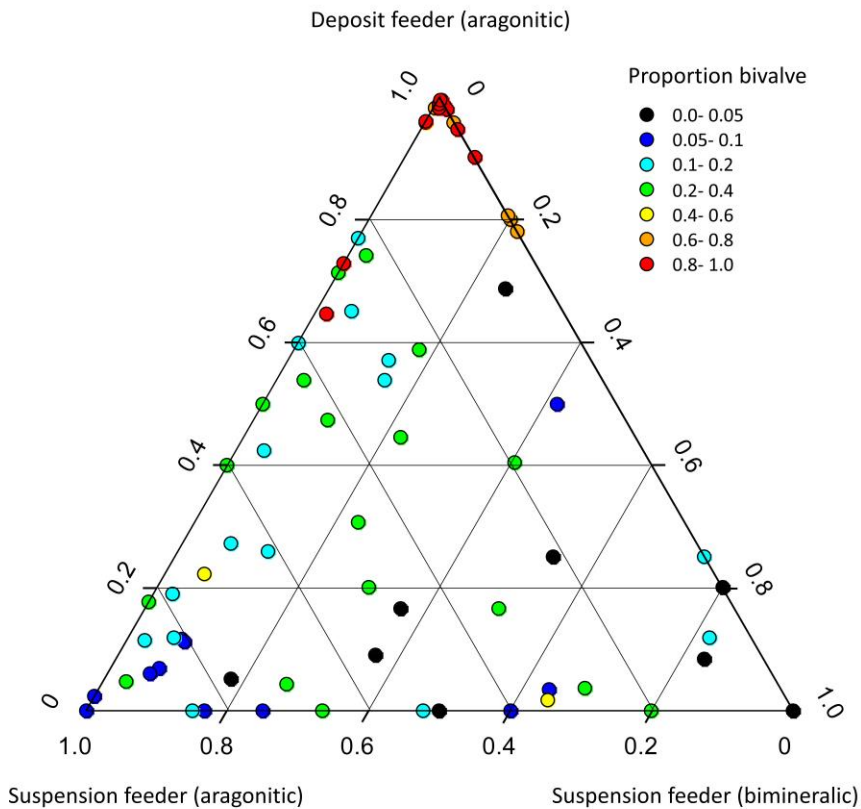


Figure 6. Ternary diagram showing the proportion of bivalves in each sample that are deposit feeders with aragonitic shells, suspension feeders with aragonitic shells, and suspension feeders with bimineralic shells. Point color shows the proportion of the sample that consists of bivalves relative to brachiopods. Two samples lacked bivalves completely and thus are not shown on this diagram. Ten samples contained only aragonitic deposit feeders, five samples contained only aragonitic suspension feeders, and three samples contained only bimineralic suspension feeders.

Ecological importance of bivalves versus brachiopods

In contrast to Cherns and Wright (2000) and Payne et al. (2014), the results of our study do not show bivalve dominance over brachiopods in a late Paleozoic ecosystem; rather, brachiopods

were twice as abundant and energy use was approximately equal. Brachiopods and bivalves were fairly close in global diversity in the Pennsylvanian (Fig. 1A), it is entirely possible that brachiopods were even more important ecologically at other times in the Paleozoic when they were much more diverse than bivalves, such as the Early Devonian and Permian. However, benthic mollusks as a whole were probably as important as or more important than brachiopods during much of the Paleozoic, judging from global diversity curves (Fig. 1C).

On another note, brachiopods were more important than bivalves in terms of shell volume, which, along with surface area, is also important ecologically, since space can be a limiting factor for benthic animals (Frechette and Lefavre 1990), particularly for species that live attached to hard substrates (Taylor and Wilson 2003), like some brachiopods and bivalves. In addition, space and surface area are ecologically important because brachiopod shells provided hard substrate habitats for other organisms (Sprinkle and Rogers 2010; Rodland et al. 2014). By modifying habitat availability, an animal can have strong ecological importance as physical ecosystem engineer, unrelated to its trophic importance (Jones et al. 1996, 1997; Hastings et al. 2007). The importance of brachiopods relative to bivalves in providing attachment sites for other organisms would be enhanced further if their calcitic shells persisted longer after death in the taphonomically active zone.

Although our study only examines one ecosystem, the sizeable difference between results based on occurrences and abundance counts highlights the importance of well-sampled, local abundance data in evaluating ecological importance, even though they can have problems of their own. Occurrence data can be useful if abundance data is unavailable or incomplete, particularly in discovering relative trends among taxa at broad scales. However, ecological

importance ultimately depends on absolute numbers of individuals in a habitat, and energy flows and biological interactions happen locally in communities of organisms.

Conclusions

- Our sampling-standardized analysis is consistent with previous studies that showed the global diversity of brachiopods sharply dropping in the Permian extinction, recovering partially, and then declining gradually in the later Mesozoic, possibly due to interactions with the Modern Fauna. Brachiopods were more diverse than bivalves in the Paleozoic, although the difference was relatively small in the Carboniferous. When gastropods are also included, it is clear that benthic mollusks in total were more diverse than brachiopods during much of the Paleozoic.
- The Middle Pennsylvanian Breathitt Formation contains equally well-preserved bivalves and brachiopods; aragonitic-shelled animals are well-represented in these samples. In theory, some aragonite shells could have been lost to dissolution, but several lines of evidence suggest the bias is not particularly strong.
- Read literally, bivalves are only half as abundant as brachiopods in the Breathitt, and individual samples were often dominated by brachiopods or bivalves. Bivalves represent half the biomass and energy use in the average Breathitt sample (statistically indistinguishable from 50%). Considering only suspension feeders, the bivalves represent significantly less than half the biomass and energy. If the proportion of aragonitic fossils is under-represented

in some samples, then bivalves would be under-represented in these analyses, but I doubt the bias is severe given the preservation of aragonitic fossils in most samples.

- Basing calculations on occurrences rather than abundance counts tends to overestimate the relative abundance, biomass, and energy use of bivalves, which underscores the importance of checking conclusions based on global databases using local, well-sampled, well-preserved ecosystems.
- Bivalves and brachiopods were *both* ecologically important in the Pennsylvanian ecosystem represented by the Breathitt fauna, with no evidence that either was strongly or clearly dominant. In general, both taxa were probably important throughout the middle and late Paleozoic.

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Appendix 1 - Localities

Sample	Type of locality	Coordinates
E17	Roadcut	N 37° 34' 30" W 82° 38' 30"
E18	Roadcut	N 37° 33' 50" W 82° 38' 00"
E19	Roadcut	N 37° 32' 06" W 82° 37' 03"
E20	Roadcut	N 37° 33' 35" W 82° 38' 19"
E36	Roadcut	N 37° 32' 00" W 82° 48' 03"
E57	Roadcut	N 37° 36' 07" W 82° 18' 00"
E58	Roadcut	N 37° 34' 08" W 82° 27' 02"
E61	Roadcut	N 37° 32' 15" W 82° 35' 40"
E69	Roadcut	N 37° 33' 54" W 82° 45' 43"
E73	Roadcut	N 37° 33' 10" W 82° 46' 17"
K1.5	Strip mine highwall	N 36° 59' 40" W 82° 42' 02"
K21	Roadcut	N 37° 33' 35" W 82° 38' 19"
K23	Roadcut	N 37° 13' 05" W 82° 57' 00"
K34	Roadcut	N 37° 13' 07" W 82° 57' 19"
K35	Roadcut	N 37° 26' 40" W 82° 18' 20"
K48	Roadcut	N 37° 11' 36" W 82° 54' 42"
K60	Roadcut	N 37° 30' 50" W 82° 29' 40"
K66	Roadcut	N 37° 01' 35" W 82° 43' 40"
K76	Roadcut	N 38° 11' 25" W 82° 28' 37"
M3	Roadcut	N 37° 15' 20" W 83° 16' 27"
M6	Roadcut	N 37° 24' 41" W 82° 57' 10"
M9	Roadcut	N 37° 13' 27" W 83° 21' 00"
M10	Roadcut	N 37° 14' 45" W 83° 18' 54"
M14	Roadcut	N 37° 21' 55" W 83° 06' 26"
M16	Roadcut	N 37° 21' 35" W 83° 00' 43"
M22	Roadcut	N 37° 45' 22" W 82° 41' 45"
M24	Roadcut	N 37° 45' 32" W 82° 41' 35"
M27	Roadcut	N 37° 29' 18" W 82° 49' 25"
M28	Roadcut	N 37° 35' 10" W 82° 46' 00"
M32	Roadcut	N 37° 22' 12" W 83° 15' 36"
M33	Roadcut	N 37° 20' 36" W 83° 16' 21"
M37	Roadcut	N 37° 38' 03" W 82° 07' 29"
M45	Roadcut	N 37° 23' 56" W 82° 57' 32"

M50	Roadcut	N 37° 06' 10" W 83° 23' 10"
M68	Roadcut	N 37° 41' 46" W 82° 47' 33"
M71	Stream cut	N 38° 09' 25" W 81° 33' 35"
M74	Roadcut	N 38° 07' 56" W 81° 26' 05"
M75	Roadcut	N 38° 08' 30" W 81° 30' 30"
M77	Roadcut	?
M78	Roadcut	N 37° 45' 50" W 82° 40' 46"
S13	Roadcut	N 37° 18' 15" W 83° 11' 05"
S29	Roadcut	N 37° 01' 11" W 83° 10' 36"
S31	Roadcut	N 37° 17' 50" W 83° 12' 47"
S39	Abandoned strip mine bench	N 37° 19' 06" W 83° 10' 35"
S51/S52	Abandoned strip mine bench	N 36° 54' 50" W 83° 19' 33– 24"
S55	Strip mine	N 37° 22' 15" W 82° 59' 12"

Appendix 2 – Samples with species abundances

Unit	Local/level	Samp Name	Cluster ID	Total Indiv.	Total Spec.
E	173	E17	P	177	18
E	1816	E18a	O	30	3
E	1820	E18b	P	132	13
E	193	E19	P	356	11
E	20A	E20	P	133	15
E	36Q311_1	E36	P	889	59
E	57275_30	E57	P	230	15
E	5810_225	E58	P	71	7
E	6180_140	E61	P	1255	48
E	6942_50	E69	P	126	13
E	7365_75	E73	P	210	13
K	1Q	K1	P	207	14
K	2115_20	K21	O	142	15
K	230_2	K23	CM	98	19
K	342_3	K34a	CM	37	12
K	3411_12	K34b	CM	32	9
K	343_4	K34c	CM	60	12
K	3410_11	K34d	CM	60	10

K	348_10	K34e	CM	204	20
K	344_8	K34f	CM	195	20
K	35B57_58	K35	P	1381	81
K	35A65_65	K35a	S	183	15
K	481_5	K48b	CM	133	16
K	486_8	K58a	CM	67	11
K	6018	K60	O	52	12
K	60F	K60f	O	88	8
K	6695_105	K66a	P	1787	67
K	66105_11	K66b	O	142	9
K	6645_5	K66c	CM	1132	52
M	106	M10A	M	469	12
M	1040	M10B	CM	139	16
M	140_1	M14a	M	142	16
M	141_2	M14B	M	271	18
M	142_3	M14C	M	399	16
M	143_4	M14D	M	602	20
M	16A55_65	M16A	M	282	25
M	16B75_9	M16b	M	199	13
M	16B65_75	M16B	M	283	29
M	16A75_9	M16c	M	185	13
M	16A95_11	M16d	M	71	10
M	22B5	M22A	M	379	34
M	228A	M22B	S	179	14
M	2435_4	M24	M	102	14
M	2712_16	M27	M	208	12
M	28225	M28a	CM	57	4
M	28A75_22	M28A	S	65	10
M	28A8_83 1	M28B	M	1218	60
M	2821	M28C	CP	1091	68
M	3215	M32	M	283	15
M	3717_18	M37A	M	154	8
M	3721_28	M37B	CP	1146	103
M	37425_47	M37C	CP	884	60
M	376_65	M37D	P	909	32
M	3A0_6	M3a	O	344	17
M	3A6_12	M3b	O	523	16
M	328	M3C	CM	180	24
M	45Q35_10	M45	M	1440	52
M	501_6	M50A	S	229	22
M	506_11	M50B	S	271	18

M	6	M6	CM	46	13
M	6824_30	M68A	M	537	17
M	6842_48	M68B	M	77	9
M	6865_7	M68C	CP	373	20
M	7125_30	M71a	CP	308	17
M	710_8	M71b	S	202	14
M	74LOWERB	M74A	S	256	15
M	74B7	M74B	CP	291	16
M	75BASE	M75A	S	169	13
M	75UZ	M75b	CP	368	15
M	7716_20	M77A	CP	40	13
M	7730_34	M77B	CP	404	23
M	7865_7	M78	S	226	20
M	96	M9	M	368	15
M	9A6	M9a	M	676	13
S	132	S13	CP	100	11
S	29A0_5	S29A	P	337	19
S	296_12	S29B	P	958	38
S	2919_21	S29C	CM	391	39
S	2921_23	S29D	CM	35	9
S	2925	S29E	P	56	12
S	311	S31A	CM	68	14
S	3125	S31B	CP	600	76
S	3135	S31C	CP	375	60
S	3918_24	S39A	CP	133	20
S	392_25	S39B	CP	506	57
S	3925_30	S39C	CP	78	14
S	514_45	S51A	CP	40	13
S	5115_25	S51B	P	976	76
S	51525_57	S51C	CP	75	19
S	52925_97	S52A	CP	68	13
S	521025_1	S52B	CP	82	15
S	5211_117	S52C	CP	115	15
S	5520_35	S55A	CP	466	27
S	5535_45	S55B	P	561	25
S	5545_525	S55C	P	1953	93
S	55525_60	S55D	P	731	22

KEY

Abbrev	Genus	Taxon	feeding
ACANTH	ACANTHOPECTEN_SP	BIVALVIA	suspension
AVICUL	AVICULOPECTEN_SPP	BIVALVIA	suspension
CLAVIC	CLAVICOSTA_CF_C_ECHINATA	BIVALVIA	suspension
DUNBAR	DUNBARELLA_CF_D_STRIATA	BIVALVIA	suspension
EUCHON	EUCHONDRIA_SP	BIVALVIA	suspension
LEPTOD	LEPTODESMA_CF_L_OHIOENSE	BIVALVIA	suspension
MYALIN	Myalinella_sp	BIVALVIA	suspension
PROMYT	PROMYTILUS_POTTSVILLENSIS	BIVALVIA	suspension
SEPTIM	SEPTIMYALINA_PERATTENUATA	BIVALVIA	suspension
POSIDO	POSIDONIA_FRACTA	BIVALVIA	suspension
SOLEMY	SOLEMYA_SP	BIVALVIA	other
CLINOP	CLINOPISTHA	BIVALVIA	mining
NUCUL1	NUCULOPSIS_GIRTYI	BIVALVIA	mining
NUCUL2	NUCULOPSIS_CRONEISI	BIVALVIA	mining
PALAEON	PALAEONEILO_OWENI	BIVALVIA	mining
PALEYO	Paleyoldia_glabra	BIVALVIA	mining
PHESTI	PHESTIA_ATTENUATA	BIVALVIA	mining
ASTART	ASTARTELLA_CF_A_COMPACTA	BIVALVIA	suspension
EDMOND	EDMONDIA_OVATA	BIVALVIA	suspension
EXOCHO	EXOCHORHYNCHUS_CF_ALTIROSTRATUS	BIVALVIA	suspension
PALAEO	<u>PALAEOLIMA_SP</u>	BIVALVIA	suspension
SCHIZO	SCHIZODUS_CUNEATUS	BIVALVIA	suspension
WILKIN	WILKINGIA_TERMINALE	BIVALVIA	suspension
CYPRIC	CYPRICARDINIA_CF_C_CARBONARIA	BIVALVIA	suspension
GONIOP	Goniophora_sp	BIVALVIA	suspension
PARALL	PARALLELODON_OBSOLETUS	BIVALVIA	suspension
PERMOP	PERMOPHORUS_CF_P_TROPIDOPHORUS	BIVALVIA	suspension
PLEURO	?PLEUROPHORELLA_CF_SESQUIPLICATA	BIVALVIA	suspension
ANTHRA	ANTHRACOSPIRIFER_OCCIDUS	BRACHIOPOD	suspension
ANTIQU	ANTIQUATONIA_PORTLOCKIANA	BRACHIOPOD	suspension
BEECHE	BEECHERIA_SP	BRACHIOPOD	suspension
CHONET	CHONETIDS_(EOLISSO_AND_RUGOSO)	BRACHIOPOD	suspension
CLEIOT	CLEIOTHYRIDINA_ORBICULARIS	BRACHIOPOD	suspension
COMPOS	COMPOSITA_SUBTILITA	BRACHIOPOD	suspension
CRURIT	CRURITHYRIS_CF_C_PLANOCONVEXA	BRACHIOPOD	suspension
DERBYI	DERBYIA_CRASSA	BRACHIOPOD	suspension
DESMOI	DESMOINESIA_MURICATINA	BRACHIOPOD	suspension
HUSTED	HUSTEDIA_MISERI	BRACHIOPOD	suspension
JURESA	JURESANIA_NEBRASCENSIS	BRACHIOPOD	suspension
KOZLOW	KOZLOWSKIA_HAYDENENSIS	BRACHIOPOD	suspension

LINGUL	LINGULA_CARBONARIA	BRACHIOPOD	suspension
LINOPR	LINOPRODUCTUS_CF_L_PLATYUMBONUS	BRACHIOPOD	suspension
NEOSPI	NEOSPIRIFER_CF_N_GOREIL	BRACHIOPOD	suspension
ORBICU	ORBICULOIDEA_MISSOURIENSIS	BRACHIOPOD	suspension
PLICOC	PLICOCHONETES_DOTUS	BRACHIOPOD	suspension
PUNCTO	PUNCTOSPIRIFER_KENTUCKYENSIS	BRACHIOPOD	suspension
RHIPID	RHIPIDOMELLA_CF_R_CARBONARIA	BRACHIOPOD	suspension
SCHIZO	SCHIZOPHORIA_CF_S_RESUPINOIDES	BRACHIOPOD	suspension
TRIGON	TRIGONOGLOSSA_NEBRASCENSIS	BRACHIOPOD	suspension
OEHLER	Oehlertella	BRACHIOPOD	suspension
RHYNCH	Rhynch_unid	BRACHIOPOD	suspension

Samp Name	ACANTH	AVICUL	EUCHON	LEPTOD	PARALL	SEPTIM	MYALIN	PROMYT	GONIOP	WILKIN
E17	8	9	0	0	2	2	0	0	1	0
E18a	0	0	0	0	0	0	0	0	0	0
E18b	4	8	0	0	0	0	0	0	0	0
E19	1	7	0	0	0	0	0	0	0	0
E20	2	11	0	0	0	0	0	1	0	0
E36	0	6	0	0	5	0	0	3	0	2
E57	0	2	0	0	2	2	0	0	0	0
E58	0	1	0	0	1	0	0	0	0	0
E61	0	5	0	1	0	1	0	2	0	0
E69	0	1	0	0	1	2	0	0	0	0
E73	0	3	0	0	1	0	0	0	0	0
K1	5	0	0	0	0	0	0	0	0	0
K21	0	2	0	0	0	0	0	0	0	0
K23	0	2	0	1	2	0	0	0	0	0
K34a	0	1	0	0	0	0	0	0	0	0
K34b	0	0	0	0	1	0	0	0	0	0
K34c	0	0	0	0	0	0	0	0	0	0
K34d	0	0	0	0	2	0	0	0	0	0
K34e	0	1	0	0	5	0	0	0	0	1
K34f	0	2	0	0	2	0	0	0	0	0
K35	0	12	0	0	30	46	0	12	0	0
K35a	0	10	0	0	6	29	0	1	0	0
K48b	0	2	0	0	4	0	0	0	0	0
K58a	0	3	0	0	5	0	0	0	0	0
K60	0	0	0	0	0	0	0	0	0	0
K60f	0	0	0	0	0	0	0	0	0	0
K66a	2	4	0	1	15	0	0	0	0	0
K66b	0	1	0	0	0	0	0	0	0	0
K66c	0	3	1	0	1	0	0	0	0	0
M10A	0	0	1	0	0	0	0	0	0	0
M10B	0	0	0	6	1	0	0	0	0	0
M14a	0	6	8	0	0	0	0	0	0	0
M14B	0	8	9	0	0	0	0	0	0	0
M14C	1	3	9	0	0	0	0	0	0	0
M14D	1	6	9	0	0	0	0	0	0	0
M16A	0	0	0	0	0	0	0	0	0	0
M16b	0	0	0	0	0	0	0	0	0	0

M16B	0	0	0	0	0	0	0	0	0	0
M16c	0	0	0	0	0	0	0	0	0	0
M16d	0	0	0	0	0	0	0	0	0	0
M22A	0	0	0	0	0	0	0	0	0	0
M22B	0	0	0	0	0	0	0	0	0	0
M24	0	0	1	0	0	0	0	0	0	0
M27	0	0	0	0	0	0	0	0	0	0
M28a	0	0	0	0	0	0	0	0	0	0
M28A	0	0	0	0	3	1	0	0	0	0
M28B	0	4	0	0	0	0	0	0	0	0
M28C	0	0	0	0	11	3	0	4	0	1
M32	0	0	1	0	0	0	0	0	0	0
M37A	0	0	0	0	0	0	0	0	0	0
M37B	1	0	0	0	6	4	0	2	0	0
M37C	0	0	0	0	0	1	0	0	0	0
M37D	0	2	0	0	0	0	0	0	0	0
M3a	0	2	0	0	0	0	0	0	0	0
M3b	0	0	0	0	0	0	0	0	0	0
M3C	0	1	0	0	1	2	0	1	0	1
M45	0	0	0	0	0	0	0	0	0	0
M50A	0	11	0	0	5	37	0	9	0	0
M50B	0	13	0	0	9	45	0	16	0	0
M6	0	2	0	0	0	0	0	0	0	0
M68A	0	0	0	0	1	0	0	0	0	0
M68B	0	0	0	0	0	0	0	0	0	0
M68C	0	0	0	0	6	0	0	1	0	0
M71a	0	0	0	0	1	0	0	1	0	0
M71b	0	9	0	0	6	1	0	0	0	0
M74A	0	0	0	0	5	0	0	0	0	0
M74B	1	0	0	0	1	0	0	0	0	0
M75A	0	2	0	0	5	1	0	0	0	0
M75b	0	0	0	0	3	0	0	0	0	0
M77A	0	0	0	0	0	0	0	0	0	0
M77B	0	0	0	1	3	1	0	0	0	0
M78	2	0	0	0	2	3	0	3	0	0
M9	0	2	1	0	0	0	0	0	0	0
M9a	0	0	0	0	0	0	0	0	0	0
S13	0	0	0	0	0	0	0	0	0	0
S29A	0	0	0	0	0	0	1	0	0	0
S29B	0	0	0	0	0	0	0	0	0	0

S29C	0	8	1	0	0	0	0	0	0	0
S29D	0	0	0	0	0	0	0	0	0	0
S29E	0	0	2	0	2	0	0	0	0	0
S31A	0	0	3	0	0	0	0	0	0	0
S31B	1	0	0	0	20	0	0	0	0	0
S31C	0	0	0	0	8	1	0	0	0	0
S39A	0	0	0	0	4	6	0	0	0	2
S39B	0	0	0	0	2	0	0	0	0	0
S39C	0	0	0	0	1	0	0	0	0	0
S51A	0	0	0	0	2	0	0	0	0	0
S51B	1	0	0	4	25	1	0	2	0	0
S51C	0	0	0	0	2	0	0	0	0	2
S52A	0	0	0	0	6	0	0	0	0	0
S52B	0	0	0	0	3	0	0	0	0	0
S52C	0	0	0	0	0	0	0	0	0	0
S55A	0	2	0	0	142	3	0	0	0	0
S55B	0	0	0	0	63	2	0	0	0	0
S55C	2	2	0	2	133	5	0	2	0	0
S55D	0	2	0	1	38	1	0	0	0	0

Samp Name	NUCUL1	NUCUL2	PALAEN	PALEYO	PHESTI	ASTART	CLAVIC	CLINOP	DUNBAR	EDMOND
E17	0	1	0	0	18	6	0	0	0	0
E18a	0	0	0	0	0	0	0	0	0	0
E18b	0	1	1	0	2	0	0	0	0	0
E19	0	1	0	0	1	0	0	0	0	0
E20	0	0	0	0	2	1	0	0	0	0
E36	0	1	0	0	0	4	0	0	0	5
E57	0	0	0	1	0	0	0	0	0	0
E58	0	0	0	0	0	0	0	0	0	1
E61	0	2	0	0	3	1	0	0	5	5
E69	0	0	0	0	0	0	0	0	0	2
E73	0	0	0	0	0	1	0	0	0	0
K1	0	0	0	0	6	1	0	0	0	0
K21	6	3	0	0	0	0	0	0	0	0
K23	2	2	4	0	2	2	0	0	0	0
K34a	0	0	0	0	0	2	0	0	0	2

K34b	0	0	0	0	1	0	0	0	0	0
K34c	1	1	0	0	0	2	0	0	0	0
K34d	0	0	2	0	1	0	0	0	0	0
K34e	0	0	8	0	5	0	0	0	0	0
K34f	0	0	6	0	1	1	0	0	0	1
K35	0	0	0	0	4	0	0	0	0	4
K35a	0	0	0	0	0	0	0	0	0	1
K48b	4	3	0	0	1	0	0	0	0	0
K58a	0	0	0	0	2	0	0	0	0	0
K60	1	0	19	0	4	0	0	0	0	0
K60f	0	0	0	0	4	0	0	0	0	0
K66a	1	0	34	0	40	75	0	0	0	0
K66b	0	0	3	0	11	10	0	0	0	0
K66c	0	0	0	0	11	0	0	0	0	0
M10A	117	59	0	0	30	0	0	0	0	0
M10B	0	0	0	0	1	15	0	0	0	0
M14a	39	8	0	0	3	0	0	0	0	0
M14B	58	10	0	0	3	0	0	0	0	0
M14C	115	49	0	0	72	0	0	0	0	0
M14D	30	28	0	0	89	0	0	0	0	0
M16A	52	19	0	0	15	0	0	0	0	0
M16b	60	28	0	0	4	0	0	0	0	0
M16B	57	31	0	0	6	0	0	0	0	0
M16c	35	20	0	0	5	0	0	0	0	0
M16d	5	6	0	0	28	0	0	0	0	0
M22A	97	71	0	0	148	0	0	0	0	0
M22B	3	2	0	0	0	0	0	0	0	0
M24	58	12	0	0	8	0	0	0	0	0
M27	7	26	0	0	61	0	0	0	0	0
M28a	0	0	0	0	0	1	0	0	0	0
M28A	0	0	0	0	0	0	0	0	0	0
M28B	596	390	0	0	509	2	0	0	0	0
M28C	1	0	1	0	0	14	0	0	0	1
M32	74	24	0	0	16	1	0	0	0	0
M37A	81	42	0	0	17	0	0	0	0	0
M37B	50	66	0	0	87	58	0	0	0	0
M37C	0	0	0	0	0	0	0	0	0	0
M37D	0	0	0	0	0	0	0	0	0	0
M3a	5	55	0	0	19	41	0	0	0	0
M3b	10	47	0	0	26	31	0	0	0	0
M3C	0	5	0	1	2	17	0	0	0	0

M45	434	160	0	0	83	7	0	0	0	0
M50A	1	0	0	0	2	12	0	0	0	3
M50B	1	0	0	0	1	12	0	0	0	15
M6	0	1	0	0	3	3	0	0	0	0
M68A	140	98	0	0	164	0	0	0	0	0
M68B	10	22	0	0	9	0	0	0	0	0
M68C	3	0	0	0	4	23	0	0	0	0
M71a	0	0	0	0	0	3	0	0	0	0
M71b	0	0	0	0	0	9	0	0	0	4
M74A	0	0	0	0	0	3	0	0	0	0
M74B	0	0	0	0	0	0	0	0	0	0
M75A	0	0	0	0	0	8	0	0	0	1
M75b	0	0	0	0	0	2	0	0	0	0
M77A	0	4	0	0	1	2	0	0	0	0
M77B	0	0	0	0	2	21	0	0	0	0
M78	0	0	0	0	0	3	0	0	0	0
M9	63	58	0	0	24	0	0	0	0	0
M9a	98	43	0	0	9	0	0	0	0	0
S13	0	0	0	0	0	0	0	0	0	0
S29A	0	0	0	0	0	0	0	0	0	0
S29B	0	0	0	0	0	1	0	0	0	0
S29C	1	0	0	0	0	0	0	0	0	1
S29D	1	0	0	0	0	0	0	0	0	0
S29E	0	0	0	0	2	0	0	0	2	2
S31A	0	2	0	0	2	6	0	0	0	0
S31B	0	0	0	0	3	24	0	0	0	0
S31C	0	0	0	0	0	21	2	4	0	0
S39A	0	0	0	0	0	5	0	0	0	0
S39B	0	0	0	0	1	39	0	0	0	0
S39C	0	0	0	0	0	5	0	0	0	0
S51A	0	4	0	0	0	11	1	0	0	0
S51B	0	26	0	0	9	52	1	0	0	0
S51C	4	1	0	0	3	4	0	0	0	0
S52A	0	3	0	0	0	6	0	0	0	0
S52B	1	9	0	0	0	12	0	0	0	0
S52C	0	8	0	0	2	3	0	0	0	0
S55A	2	6	0	0	0	14	1	0	0	0
S55B	5	3	0	0	1	4	0	0	0	0
S55C	9	12	0	0	2	18	0	0	0	2
S55D	1	4	0	0	1	3	0	0	0	0

Samp Name	PERMOP	PLEURO	POSIDO	SCHIZO	PALAEO	CYPRIC	EXOCHO	SOLEMY	ANTIQU	KOZLOW
E17	0	0	0	0	0	0	0	0	4	0
E18a	0	0	0	0	0	0	0	0	0	0
E18b	0	0	0	0	0	0	0	0	26	0
E19	0	0	0	0	0	0	0	0	0	0
E20	0	0	0	0	0	0	0	0	5	0
E36	0	0	0	1	4	0	0	5	2	0
E57	2	0	0	0	0	1	1	0	3	0
E58	0	0	0	0	0	1	0	0	0	0
E61	0	0	0	0	1	0	0	2	1	0
E69	0	0	0	0	0	0	0	0	0	0
E73	0	0	0	0	0	0	0	0	1	0
K1	0	0	0	0	0	0	0	0	0	0
K21	0	0	0	0	0	8	0	0	0	0
K23	0	0	0	0	0	0	0	0	0	0
K34a	0	0	1	0	0	0	0	0	0	0
K34b	0	0	0	0	0	0	0	0	0	0
K34c	0	0	0	0	0	0	0	0	0	0
K34d	0	0	0	0	0	0	0	0	0	0
K34e	0	0	0	0	0	0	0	0	0	0
K34f	0	0	0	0	0	0	0	0	0	0
K35	5	0	1	0	5	0	0	0	126	0
K35a	1	0	0	2	0	0	0	0	16	0
K48b	0	0	0	0	0	0	0	0	0	0
K58a	0	0	0	0	0	0	0	0	0	0
K60	1	0	0	0	0	0	0	0	0	0
K60f	0	0	1	0	0	0	0	0	0	0
K66a	1	0	0	4	0	0	0	0	0	0
K66b	0	0	0	1	0	0	0	0	0	0
K66c	0	0	0	0	0	0	0	0	0	0
M10A	0	0	0	0	0	0	0	0	0	0
M10B	0	0	0	0	0	0	0	0	0	0
M14a	0	0	0	0	0	0	0	0	0	0
M14B	0	0	0	0	0	0	0	0	0	0
M14C	0	0	0	0	0	0	0	0	0	0

M14D	0	0	0	0	0	0	0	0	0	0
M16A	0	0	0	0	0	0	0	0	0	0
M16b	0	0	0	0	0	0	0	0	0	0
M16B	0	4	0	0	0	0	0	0	0	0
M16c	0	0	0	0	0	0	0	0	0	0
M16d	0	0	0	0	0	0	0	0	0	0
M22A	0	0	0	0	0	0	0	0	0	0
M22B	0	0	0	0	0	0	0	0	31	0
M24	0	0	0	0	0	0	0	0	0	0
M27	0	0	4	0	0	0	0	0	0	0
M28a	0	0	0	0	0	0	0	0	0	0
M28A	0	0	0	2	0	0	0	0	14	0
M28B	0	0	0	0	0	0	0	0	0	0
M28C	0	0	0	0	0	3	0	0	80	0
M32	0	0	0	0	0	0	0	0	0	0
M37A	0	0	0	0	0	0	0	0	0	0
M37B	0	0	0	0	0	0	0	0	41	0
M37C	0	0	0	0	0	0	0	0	56	0
M37D	0	0	0	0	0	0	0	0	15	0
M3a	0	0	0	0	0	0	0	0	0	0
M3b	0	0	0	0	0	0	0	0	0	0
M3C	0	0	0	0	0	0	0	0	6	0
M45	0	4	1	0	0	0	0	0	0	0
M50A	1	0	0	2	0	0	0	0	7	0
M50B	0	0	0	3	0	0	0	0	52	0
M6	0	0	0	0	0	0	0	0	0	0
M68A	0	1	2	1	0	0	0	0	0	0
M68B	0	0	0	0	0	0	0	0	0	0
M68C	0	0	0	0	0	0	0	0	11	0
M71a	0	0	0	1	0	0	0	0	14	0
M71b	1	0	0	0	0	0	0	0	0	0
M74A	0	0	0	0	0	0	0	0	40	0
M74B	0	0	0	0	0	0	0	0	11	0
M75A	2	0	0	1	0	0	0	0	1	0
M75b	0	0	0	0	0	0	0	0	12	0
M77A	0	0	0	0	0	0	0	0	0	0
M77B	0	0	0	1	0	0	0	0	29	0
M78	0	0	1	0	0	1	0	0	26	0
M9	0	0	0	0	0	0	0	0	0	0
M9a	0	0	0	0	0	0	0	0	0	0

S13	0	0	0	0	0	0	0	0	6	4
S29A	0	0	0	0	0	0	0	0	5	0
S29B	0	0	0	0	0	0	0	0	30	0
S29C	0	0	0	0	1	0	0	0	2	0
S29D	0	0	0	0	0	0	0	0	0	0
S29E	0	0	2	0	0	0	0	0	0	0
S31A	0	0	0	0	0	0	0	0	0	0
S31B	0	0	0	0	2	0	0	0	24	22
S31C	0	0	0	0	0	0	0	0	23	8
S39A	0	0	0	0	4	0	0	0	1	5
S39B	0	0	0	0	0	0	0	0	23	11
S39C	0	0	0	0	0	0	0	0	3	2
S51A	0	0	0	0	0	0	0	0	0	0
S51B	7	0	0	1	0	0	0	0	14	0
S51C	0	0	0	0	0	0	0	0	1	0
S52A	1	0	0	1	0	0	0	0	1	0
S52B	0	0	0	0	0	0	0	0	0	0
S52C	0	0	0	0	0	0	0	0	0	0
S55A	0	0	0	4	0	0	0	0	8	0
S55B	0	0	0	1	0	0	0	0	5	0
S55C	0	0	0	2	0	4	1	0	12	0
S55D	0	0	0	0	0	1	0	0	2	0

Samp Name	DESMOI	JURESA	LINOPR	CHONET	PLICOC	ANTHRA	NEOSPI	PUNCTO	CLEIOT	COMPOS
E17	87	6	7	1	0	3	0	0	0	0
E18a	0	3	26	0	0	0	0	0	0	0
E18b	29	8	44	0	0	3	0	0	0	0
E19	179	60	102	0	0	1	0	0	0	0
E20	38	20	42	0	0	4	0	0	0	2
E36	600	31	184	1	0	5	0	0	0	5
E57	154	11	40	0	0	1	0	0	0	0
E58	25	21	21	0	0	0	0	0	0	0
E61	661	158	352	0	0	26	0	0	1	16
E69	75	12	16	0	0	1	0	0	2	9
E73	125	8	53	0	0	3	0	0	0	7
K1	127	0	4	34	0	6	1	0	0	0

K21	5	0	0	6	0	0	0	0	0	1
K23	18	0	0	35	0	1	0	0	3	0
K34a	4	0	0	7	0	0	0	0	0	0
K34b	0	0	0	15	0	0	0	0	0	0
K34c	17	0	0	11	0	0	0	0	0	0
K34d	4	0	0	33	0	1	0	0	0	0
K34e	20	0	0	100	0	1	0	1	0	0
K34f	21	0	0	61	0	3	0	0	0	0
K35	514	118	254	21	0	48	0	42	0	35
K35a	5	5	9	34	0	56	0	0	0	4
K48b	20	0	0	32	0	2	0	0	0	0
K58a	9	0	0	18	0	1	0	0	0	0
K60	0	0	1	2	0	0	0	0	0	0
K60f	0	1	0	0	0	0	0	0	0	0
K66a	869	0	2	453	0	42	0	0	0	9
K66b	6	0	0	52	0	0	0	0	0	0
K66c	318	1	6	645	0	9	1	0	0	1
M10A	0	0	0	6	0	0	0	0	0	0
M10B	26	0	1	43	0	0	0	1	0	2
M14a	2	0	0	2	0	0	0	0	0	0
M14B	8	0	0	14	0	0	0	1	0	0
M14C	2	0	0	12	0	0	0	0	0	0
M14D	0	0	0	8	0	1	2	1	0	0
M16A	1	0	0	10	0	0	0	0	0	0
M16b	2	0	0	15	0	0	0	0	0	0
M16B	5	0	0	18	0	0	0	0	0	0
M16c	2	0	0	13	0	0	0	0	0	0
M16d	1	0	0	6	0	0	0	0	0	0
M22A	2	0	0	21	0	0	0	3	0	4
M22B	0	0	0	0	0	104	0	9	0	19
M24	0	0	0	4	0	0	0	2	2	0
M27	2	0	1	43	0	0	0	0	0	0
M28a	0	0	0	50	0	0	0	0	0	0
M28A	0	0	0	5	0	23	0	0	0	14
M28B	0	0	0	23	0	0	0	1	0	1
M28C	134	37	32	469	0	51	0	4	19	33
M32	4	0	0	0	1	0	0	0	0	0
M37A	0	0	0	2	0	0	0	0	0	0
M37B	151	2	4	20	51	112	0	174	31	89
M37C	180	2	60	255	8	72	0	20	14	62
M37D	732	3	27	18	0	44	0	4	0	45

M3a	2	0	0	15	0	0	0	5	0	2
M3b	2	0	0	4	0	0	0	2	0	0
M3C	27	12	5	61	0	8	0	0	2	7
M45	4	0	0	220	0	0	0	0	0	0
M50A	0	0	0	10	0	44	0	0	0	24
M50B	0	0	0	3	0	5	0	0	0	64
M6	5	1	0	19	0	0	0	2	0	0
M68A	0	0	0	24	0	0	0	1	0	0
M68B	1	0	0	0	0	0	0	0	0	0
M68C	56	0	0	29	64	25	0	17	16	15
M71a	44	0	1	20	116	30	0	17	9	6
M71b	3	0	0	1	0	123	0	0	0	35
M74A	42	0	0	1	2	67	0	3	7	61
M74B	72	1	3	9	49	25	0	16	5	11
M75A	5	0	0	0	0	103	0	0	0	30
M75b	146	1	0	25	57	27	0	9	21	16
M77A	3	0	0	4	0	0	0	4	0	2
M77B	105	4	1	5	66	39	0	29	15	18
M78	9	2	14	6	0	71	0	15	0	22
M9	0	0	0	0	0	0	0	0	0	0
M9a	0	0	0	1	0	0	0	0	0	0
S13	24	0	0	23	0	8	1	7	5	17
S29A	233	4	2	8	0	2	0	4	0	10
S29B	656	0	2	62	0	18	2	11	0	12
S29C	114	0	0	148	0	4	0	27	0	19
S29D	6	0	0	11	0	0	0	2	0	2
S29E	25	0	0	8	0	0	0	6	0	1
S31A	6	0	0	20	0	0	0	9	0	0
S31B	71	0	1	211	0	40	11	50	17	33
S31C	42	0	0	97	0	17	19	31	26	15
S39A	7	0	0	52	0	5	2	9	3	8
S39B	15	0	0	110	0	15	18	125	44	38
S39C	2	0	0	8	0	0	5	23	14	7
S51A	2	0	0	9	0	3	0	0	0	1
S51B	420	3	8	318	0	15	0	3	0	1
S51C	17	0	0	10	0	9	0	0	0	4
S52A	8	0	0	21	0	0	0	0	0	3
S52B	5	0	0	23	0	0	0	0	0	11
S52C	13	0	1	33	0	12	0	0	0	9
S55A	87	2	1	59	0	21	0	30	2	16

S55B	235	0	4	44	0	17	0	49	0	10
S55C	833	7	98	196	0	42	4	159	2	21
S55D	322	4	62	51	0	8	0	31	0	4

Samp Name	CRURIT	DERBYI	HUSTED	RHYNCH	RHIPID	SCHIZO	BEECHE	LINGUL	OEHLER	ORBICU	TRIGON
E17	0	0	0	0	0	0	0	0	0	4	0
E18a	0	0	0	0	0	0	0	0	0	0	0
E18b	0	0	0	0	0	0	0	0	0	2	0
E19	0	2	0	0	0	0	0	0	0	0	0
E20	0	1	0	0	0	0	0	0	0	0	0
E36	0	9	0	0	0	0	0	0	0	3	1
E57	0	3	1	0	0	0	0	0	0	6	0
E58	0	0	0	0	0	0	0	0	0	0	0
E61	0	2	0	0	0	0	0	1	0	0	0
E69	0	0	0	0	0	0	0	2	0	0	0
E73	0	0	1	0	0	0	0	0	0	0	0
K1	5	0	0	5	0	0	0	0	6	0	0
K21	15	0	0	0	0	0	0	12	0	9	0
K23	0	0	0	0	0	0	0	0	0	0	0
K34a	5	0	0	1	0	0	0	0	0	7	0
K34b	0	1	0	0	0	0	0	0	0	0	0
K34c	4	0	0	3	0	0	0	1	0	4	0
K34d	0	0	0	0	0	0	0	0	0	1	0
K34e	2	0	0	1	0	0	0	0	0	1	0
K34f	0	0	0	1	0	0	0	0	0	0	0
K35	9	9	60	0	0	0	0	1	0	2	0
K35a	0	4	0	0	0	0	0	0	0	0	0
K48b	3	0	5	0	0	0	0	0	0	19	0
K58a	0	0	1	0	0	0	0	0	0	2	0
K60	0	0	0	0	0	0	0	0	0	0	0
K60f	0	0	0	0	0	0	0	0	0	2	0
K66a	1	3	1	0	0	0	0	1	0	7	0
K66b	0	0	0	0	0	0	0	0	0	1	0
K66c	24	2	9	0	0	0	0	2	0	51	0
M10A	6	0	0	0	0	0	0	1	0	0	0
M10B	5	0	5	0	0	0	0	1	0	0	0

M14a	13	0	0	0	0	0	0	0	0	7	0
M14B	14	0	0	0	0	0	0	0	0	9	0
M14C	16	0	0	0	0	0	0	0	0	6	0
M14D	11	0	0	0	0	0	0	0	0	2	0
M16A	28	3	0	0	0	0	0	1	0	14	0
M16b	16	4	0	0	0	0	0	2	0	4	0
M16B	53	3	0	0	0	0	0	8	0	23	0
M16c	12	6	0	0	0	0	0	0	0	10	0
M16d	0	0	0	0	0	0	0	0	0	1	0
M22A	10	6	0	0	0	1	0	0	0	1	0
M22B	0	10	0	0	0	0	0	0	0	1	0
M24	5	1	0	0	0	0	0	0	0	1	0
M27	0	2	0	0	0	0	0	0	0	0	0
M28a	0	2	0	0	0	0	0	0	0	4	0
M28A	0	0	0	0	0	0	0	0	0	0	0
M28B	6	2	0	0	0	0	0	0	0	3	0
M28C	0	140	41	0	0	0	0	0	0	1	0
M32	5	0	0	0	1	0	0	0	0	0	0
M37A	2	0	0	0	0	0	0	0	0	0	0
M37B	25	55	72	0	5	16	3	0	0	2	0
M37C	0	83	66	0	0	0	0	0	0	1	0
M37D	0	19	0	0	0	0	0	0	0	0	0
M3a	0	0	4	0	0	0	0	0	0	1	0
M3b	2	0	3	0	0	0	0	0	0	0	0
M3C	0	1	2	0	0	0	0	1	0	0	0
M45	30	2	0	0	0	0	0	0	0	3	0
M50A	0	50	0	0	0	0	0	0	0	1	0
M50B	0	24	0	0	0	0	0	0	0	2	0
M6	0	0	1	0	0	0	0	0	0	2	0
M68A	3	0	2	0	0	0	0	1	0	0	1
M68B	3	0	0	0	0	0	0	0	0	2	0
M68C	0	17	55	0	24	0	0	0	0	1	0
M71a	0	8	18	0	16	3	0	0	0	0	0
M71b	0	4	0	0	0	0	0	0	0	0	0
M74A	0	17	0	0	0	1	0	0	0	0	0
M74B	0	39	9	0	38	0	0	0	0	0	0
M75A	0	8	0	0	0	0	0	0	0	0	0
M75b	0	14	10	0	24	1	0	0	0	0	0
M77A	2	5	6	0	0	1	0	0	0	0	0
M77B	1	31	11	0	12	6	0	0	0	0	0

M78	0	41	1	0	1	0	0	0	0	0	0
M9	17	3	0	0	0	0	0	0	0	1	0
M9a	8	1	0	0	0	0	0	0	0	2	0
S13	4	1	0	0	0	0	0	0	0	0	0
S29A	0	60	0	0	0	0	0	0	0	7	0
S29B	0	113	0	0	0	10	0	0	0	40	0
S29C	4	35	0	0	0	4	0	0	0	15	0
S29D	5	6	0	0	0	0	0	0	0	1	0
S29E	0	0	0	0	0	0	0	0	0	3	0
S31A	1	2	0	0	0	0	0	0	0	0	0
S31B	1	30	1	0	1	15	0	0	0	0	0
S31C	5	22	0	0	1	20	1	0	0	1	0
S39A	0	3	1	0	0	0	0	0	0	1	0
S39B	5	24	0	0	1	14	0	0	0	0	0
S39C	2	4	0	0	0	0	0	0	0	0	0
S51A	0	1	0	0	0	0	0	0	0	0	0
S51B	2	19	0	0	0	0	0	0	0	1	0
S51C	1	3	0	0	0	0	0	0	0	0	0
S52A	0	10	0	0	0	0	0	0	0	0	0
S52B	0	5	0	0	0	0	0	0	0	0	0
S52C	0	6	0	0	0	0	0	0	0	0	0
S55A	2	43	0	0	0	0	0	0	0	1	0
S55B	10	86	0	0	0	0	0	0	0	0	0
S55C	27	329	0	0	0	1	0	0	0	0	0
S55D	8	184	0	0	0	0	0	0	0	0	0

Appendix 3 – Measurements

<i>Bivalves</i>					
Taxon	Sample	A-P	D-V	L-R	One Valve
Astartella	M37 21-36 Q3	16	14.9		3.1
Astartella	M37 21-36 Q3	16			
Astartella	M37 21-36 Q3	14.4	11.8		2.7
Astartella	M37 21-36 Q3	12.4	9.8		2.5
Astartella	M37 21-36 Q3	14.1	10.8		2.8
Astartella	M37 21-36 Q3	12.1	9.4		4.2
Astartella	M37 21-36 Q3	13.8	12.3		
Astartella	M37 21-36 Q3	14.3	12.7		4
Astartella	M37 21-36 Q3	13.2	10.5		4.6
Astartella	M37 21-36 Q3	9.4	7.9		2.9
Astartella	M37 21-36 Q3	10.7	7.8		2.5
Astartella	M37 21-36 Q3	12	9.8		3.8
Astartella	M3F	16.5	13.6	11.3	
Astartella	M3F	13.8	11.9	8.1	
Astartella	M3F	13.2	12	6.8	
Astartella	S51 2.5-3.5	9.8	7.6		3.2
Astartella	S51 2.5-3.5	11.3			3.9
Astartella	S51 2.5-3.5	5.9	4.9		
Astartella	S51 2.5-3.5	4.5	4.1		1.4
Astartella	S51-52	13.3	9.5	6.4	
Astartella	S51-52	12.7	9.5	5.6	
Astartella	S51-52	8.4	5.4	4.6	
Astartella	S51-52	10.4	8.3		4.1
Astartella	K23 0-2	7.9	6.8		2.6
Astartella	E36 11-15	7.8	6.4		
Astartella	E36 11-15	8.1	6.4		
Astartella	E36 FLOAT	16.8	14.6	9.5	
Astartella	M50 1-6	14.5	11.1		4.8
Astartella	M50 1-6	15.6	12.2		

Astartella	M50 1-6	12.1	9.8		
Astartella	M 10.40	18.3	14.9		3.8
Astartella	M 10.40	11.9	8.4		
Astartella	M 10.40	8.7	6.6		2.9
Astartella	M 10.40	2.6	2.3		
Astartella	M 10.40	3.9	3.6		
Aviculopecten	M28 Upper lighter shale zone	77.6			21.1
Aviculopecten	W75 Base	9.1	9		
Aviculopecten	M3A 0-6	7.3	7		0.7
Aviculopecten	M37 6-6.5		17		
Aviculopecten	M28A 8-8.3		8.3		1
Aviculopecten	M28A 8-8.3	4.1	4.3		0.5
Aviculopecten	M3.28	20.7	22.8	7.7	
Aviculopecten	K48 6-8		11		1.8
Aviculopecten	K48 6-8	6.6	6.9		1.6
Aviculopecten	K35B	11	11.4		
Aviculopecten	K35B	11.6	12		
Aviculopecten	K35B	14.4			
Aviculopecten	K35B	5.6	5.5		
Aviculopecten	K35B	8.8	9.9		
Aviculopecten	K35B		12.3		
Aviculopecten	K35B	12.1	11.7		
Aviculopecten	M50 1-6	13.2	11.5		
Aviculopecten	M50 1-6	12.5			
Aviculopecten	M50 1-6	7.5	7.4		
Aviculopecten	K34 2-3	8.5	8.1		1
Aviculopecten	K23 0-2	8.5	7.9		
Aviculopecten	K23 0-2	6.5	6.4		
Aviculopecten	W71 0-8	18.1			
Aviculopecten	W71 0-8	9.3	9.5		
Aviculopecten	W71 0-8	8.9	8	2	
Aviculopecten	W71 0-8	12.9	12.6	2	
Aviculopecten	W71 0-8	7.1	7.8		1.7
Aviculopecten	W71 0-8		11.5		
Aviculopecten	W71 0-8		12.3		
Aviculopecten	W71 0-8	3.9	5.7		1.1
Aviculopecten	W71 0-8	7.4	9.1		
Aviculopecten	W71 0-8		11		2.2
Aviculopecten	E20A		17	3.4	

Aviculopecten	E20A	11.7	11		2.3
Euchondria	M14 3-4	7.2	7.6		1
Euchondria	M16A 7.5-9	6.9	6.2		
Euchondria	M16A 7.5-9	8.5	7.5		
Euchondria	M16A 7.5-9	3.6	3.6		
Euchondria	M16A 7.5-9	6	6.3		1.1
Euchondria	M16A 7.5-9	7	6		
Euchondria	M16A 5.5-6.5		8		
Euchondria	M16A 5.5-6.5	1.8	1.8		
Euchondria	M16A 5.5-6.5	4.8	4.5		
Euchondria	M14 0-1	8.4	9.2		0.8
Euchondria	M14 0-1	2.7	3		0.5
Posidonia	M16A 5.5-6.5	3.6	2.5		0.4
Posidonia	M16A 5.5-6.5	3.9	2.7		0.4
Posidonia	M16A 5.5-6.5	6.6	5.3		1.7
Posidonia	M16A 5.5-6.5	2.1	1.8		
Posidonia	M16A 5.5-6.5	4.2	3.6		0.6
Posidonia	M16A 5.5-6.5	2.2	1.9		0.4
Posidonia	M28	32.4	39.4		3.9
Posidonia	K60F	18.3	19.6		
Posidonia	K21 1.5-2.0	10.4	13.7		
Posidonia	M27 12-16	14.5	15.6		
Clavicosta	S51 4-4.5	3.7	4.1		1.7
Clavicosta	S51 2.5-3.5	5.2	5.8		1.1
Acanthopecten	EF17.3	4.7	3.9		0.5
Acanthopecten	EF17.3	8.3	7.6		
Acanthopecten	EF17.3	8.3	7.9		
Acanthopecten	EF17.3	10.7	10.7		0.8
Acanthopecten	M3F	12.8	12.4		
Acanthopecten	M78 6.5-7.0	14.3			
Acanthopecten	AH-Q (Kendrick)	7.9	6.6		
Acanthopecten	K66 9.5-10.5	9.5	10.2		
Acanthopecten	E18.20		6.3		
Acanthopecten	E18.20		7.5		
Acanthopecten	E18.20	6.8	6.9		1.1
Edmondia	M50 6-11	23.3	20.6		4.7
Edmondia	M50 6-11	23.8	17.9		
Edmondia	M50 6-11	23.4	14.6		
Edmondia	M50 6-11		20.6		
Edmondia	M50 6-11	16.2	12.2		

Edmondia	M50 6-11	19.1	12.5		
Edmondia	AH-Q (Kendrick) K1.5	16.9	12.3		3.1
Edmondia	AH-Q (Kendrick) K1.5		16.2		3.9
Edmondia	AH-Q (Kendrick) K1.5	17.8			4.6
Edmondia	AH-Q (Kendrick) K1.5	26.8	20.1		5.7
Edmondia	E58 1-2.25	11.2	10.1		2
Edmondia	E58 1-2.25	13.9	9.7		2.9
Edmondia	K34 2-3	10.7	9.4		3.3
Edmondia	M28 21 Q3	12.4	8.1		1.7
Edmondia	S29 2.5	8.1	5.7		3.2
Edmondia	K35B	15.6	10.7		2.3
Edmondia	K35B	10.4	6		
Edmondia	E61 Q1	3.8	7.8		
Edmondia	M50 1-6	24.4	20.4		6.6
Edmondia	M50 1-6	18.2	12.7		
Edmondia	M50 1-6	28	20.1		
Leptodesma	M3.28	7.5	2.7		1.5
Leptodesma	S51 2.5-3.5	9.6	5.2		3.5
Leptodesma	K66 9.5-10.5	8.4	4		
Leptodesma	M10.40	4.5	2.8		1
Leptodesma	M10.40	5	2.9		
Leptodesma	M10.40	7	3.9		
Leptodesma	M10.40	6.6	2.9		2.2
Leptodesma	M10.40	6.5	4.1		1.3
Leptodesma	M10.40	7.1	4.5		
Leptodesma	M10.40	6.8	3		2
Dunbarella	E61 8-14	11.6	9.9		0.8
Dunbarella	E61 Q2	9.2	6.7		
Myalinella	S29 0-5	7.8	4.2		2.3
Exochorynchus	E57 2.75-3.0		19.2		2.8
Goniophora	E17.3	11.1	5.4		1.8
Cypricardinia	M28.21	17.4	7.5		3.1
Cypricardinia	K21 1.5-2.0	27.2	18.5		
Cypricardinia	K21 1.5-2.0	36.4	16		
Cypricardinia	K21 1.5-2.0	23.4	12.8		

Cypricardinia	K21 1.5-2.0	25.7	14.5		
Cypricardinia	K21 1.5-2.0		14.7		
Cypricardinia	K21 1.5-2.0	21.4	12.5		
Cypricardinia	K21 1.5-2.0	17.3			
Cypricardinia	K21 1.5-2.0	15.1	8		2
Cypricardinia	K21 1.5-2.0	11.8	6.2		2.5
Cypricardinia	K21 1.5-2.0	9	5.5		
Paleoneilo	K60.18	6.5	5.1		
Paleoneilo	K60.18	10			1.7
Paleoneilo	K60.18	7.7	5.3		1.5
Paleoneilo	K60.18	12.5	7.2		1.8
Paleoneilo	K60.18	9.5	6.2		1.6
Paleoneilo	K60.18		5.6		2.1
Paleoneilo	K60.18	6	4		
Paleoneilo	K60.18	7.1	4.5		
Paleoneilo	K60.18	6	3.7		
Paleoneilo	K60.18	4.7	2.7		1.7
Paleoneilo	K23 0-2	9.9	6.2		2.3
Paleoneilo	K23 0-2	8.4	4.3		2
Paleoneilo	K66 10.5-11	8.2	4.7		1.8
Paleoneilo	K66 10.5-11		6.7		1.4
Paleoneilo	K66 10.5-11	10.3	6.4		1.4
Paleoneilo	K66 10.5-11	7.7	4.8		3.3
Paleoneilo	D(K)76.1	20.6	11.1		3.7
Paleoneilo	E18.20	15.5	10.6	6.9	
Paleoneilo	M28.21	7.3	4.1		
Paleoneilo	K23 0-2	10.8	6.2		
Paleoneilo	K34 8-10	10.6	5.9		2.6
Paleoneilo	K34 8-10	12.4	7.6		3.8
Paleoneilo	K34 8-10	13.9	8.7		3.5
Paleoneilo	K66 9.5-10.5	14.1	8.6		2.6
Paleoneilo	K66 9.5-10.5	9.6	6		2.7
Paleoneilo	K66 9.5-10.5	11.2	8.4		2.2
Paleoneilo	K66 9.5-10.5	9.9	5.9		2.8
Paleoneilo	K66 9.5-10.5	8.8	7.5		2.4
Paleoneilo	K66 9.5-10.5	13.2	8.2		2.7
Paleoneilo	K66 9.5-10.5	11	5.7		
Paleoneilo	K66 9.5-10.5	12.3	8.5		
Paleoyoldia	S51-52 Float	22.1	12.6	7	
Paleoyoldia	S51-52 Float	16	11.6	5.9	

Paleoyoldia	M3.28	16.9	13.3		
Nuculopsis	M22.5	10.4	8.3	5.4	
Nuculopsis	M22.5	12.1	8.1		3.6
Nuculopsis	M22.5	10.1	8	2.3	
Nuculopsis	M22.5	10.3	7	4.1	
Nuculopsis	M22.5	8.3	6.3	1.7	
Nuculopsis	M22.5	7.5	6.8	4.3	
Nuculopsis	M22.5	4.1	3.4	2.2	
Nuculopsis	M22.5	4.2	3.1	1.5	
Nuculopsis	M22.5	7.6	5	3	
Nuculopsis	M22.5	4.6	3.8	1.3	
Nuculopsis	M22.5	9.7	7.8	4.4	
Nuculopsis	M22.5	5.4	3.3		
Nuculopsis	M22.5	4.3	3.5	2.5	
Nuculopsis	S51 1.5-2.0 Q3	13.5	9.2	6.6	
Nuculopsis	S51 1.5-2.0 Q3	12.3	8	6	
Nuculopsis	S51 1.5-2.0 Q3	5.4	3.8	2.7	
Nuculopsis	S51 1.5-2.0 Q3	5.3	4.3	2.8	
Nuculopsis	S51 1.5-2.0 Q3	11.9	8.2	6.1	
Nuculopsis	S51 1.5-2.0 Q3	8.6	6		2.6
Nuculopsis	E19.3	7.7	5.6	4.8	
Nuculopsis	E18.20	5.9	4.7		
Nuculopsis	M10.6	9	6.5	4.3	
Nuculopsis	M10.6	9.1	6.2	4.7	
Nuculopsis	M10.6	5.6	3.9	2.5	
Nuculopsis	M10.6	5.9	4.1	2.7	
Nuculopsis	M10.6	10.4	6.5	5.1	
Nuculopsis	M10.6	4.8	4	2	
Nuculopsis	M10.6	3			
Nuculopsis	M10.6	8	5.7	3.2	
Nuculopsis	K23 0-2	2.5			
Nuculopsis	S51-52 Float	9.2	6.3	4.2	
Nuculopsis	S51-52 Float	12.6		7	
Nuculopsis	S51 2.5-3.5	10.1	7.7		3.5
Nuculopsis	S51 2.5-3.5	4	3.2	1.3	
Nuculopsis	M14 3-4	11.1	7		
Nuculopsis	M14 3-4	7.8	5.6	4	
Nuculopsis	M14 3-4	4.9	3.6	2.7	
Nuculopsis	M14 3-4	11.1	7.8	5	
Nuculopsis	M14 3-4	6.8	4.9	3.3	

Nucula	M14 3-4	3.4	3.6	2.4	
Nucula	M14 3-4	3.5	3.4	2.1	
Nucula	M14 3-4	3.3	3.3	2.3	
Nucula	M14 3-4	3.6	3.7	2.1	
Nucula	M14 3-4	3.3	3	2.1	
Nucula	M10.6	4.2	3.2	2.2	
Nucula	M10.6	4.1	3.8	2.2	
Nucula	M10.6	4.6	4.5	2.2	
Nucula	M10.6	4.7	4.3	3.2	
Nucula	M10.6	5.2	4.1	2.1	
Nucula	M10.6	2.5	2.1	1.2	
Nucula	M10.6	3.6	4.2	2.6	
Nucula	M10.6	4.9	5.2	2.2	
Nucula	M10.6	4.5	3.8	1.8	
Nucula	M10.6	4.7	3.9	2.9	
Nucula	S51 5.25-5.75	3.3	2.9	1.9	
Nucula	S51 5.25-5.75	2.9	2.6	2.1	
Nucula	S51 5.25-5.75	2.8	2.5	1.7	
Nuculoidea	M68 42-48	4.9	3.8		2.2
Nuculoidea	M68 42-48	3.3	2.9		
Nuculoidea	M68 42-48	2.9	2.5	1.4	
Nuculoidea	M68 42-48	4.2	3.6		1.5
Nuculoidea	M68 42-48	2.1	1.7	1.2	
Nuculoidea	M3a 6-12	5.1	4.9	2.6	
Nuculoidea	M3a 6-12	3.5	2.9		
Nuculoidea	M3a 6-12	7.3	6.6		
Nuculoidea	M3a 6-12	4.3	3	1.9	
Nuculoidea	M3a 6-12	5.6	5.2	2.7	
Parallelodon	M50 1-6	25.9	13.3		4.6
Parallelodon	M71 Base	20.5	9.1		2.7
Parallelodon	S51 1.5-2.5 Q1a	6.5	2.3		2.6
Parallelodon	S51 1.5-2.5 Q1a	7.8	3.5		2.1
Parallelodon	S51 1.5-2.5 Q1a	8.3	3.8		2.4
Parallelodon	S51 1.5-2.5 Q1a	10	5.7		2
Parallelodon	W75 Base	20.2	9.7		3
Parallelodon	W75 Base	24.8	9.8		3.7
Parallelodon	M78 6.5-7.0	27.9	13.2		2.1

Parallelodon	M78 6.5-7.0	17.7	9.4		
Parallelodon	W75 U2	22.3	10		3.2
Parallelodon	W75 U2	14.1	7.3		
Parallelodon	M37 21-28	29	12.3		4.5
Parallelodon	M50 6-11	33	15.7		5.2
Parallelodon	M50 6-11	25.2	12.1		4.9
Parallelodon	M50 6-11	18.2	11.5		4.7
Parallelodon	E58 1-2.25	15.3	6		2.7
Parallelodon	K35 Q2	19	8.6		3.1
Parallelodon	S55 2.0-3.0	13.4	6.7		3.6
Parallelodon	S55 2.0-3.0	7.9	4.9		1.8
Parallelodon	S55 2.0-3.0	7.5	3.7		1.9
Parallelodon	S55 2.0-3.0	6.8	3.9		2
Parallelodon	S55 2.0-3.0	9.1	4.4		2.8
Parallelodon	S55 2.0-3.0	6.6	3		1.9
Parallelodon	S55 2.0-3.0	5	3.3		1.6
Parallelodon	S55 2.0-3.0	7.3	4		1.9
Parallelodon	S55 2.0-3.0	6.1	3		2.4
Parallelodon	S55 2.0-3.0	7	3.8		2.3
Parallelodon	S55 2.0-3.0	8.5	4.4		2.1
Parallelodon	S55 2.0-3.0	6.2	3.3		2.3
Phestia	M3.28	6.6	3.7		1.5
Phestia	M3.28		4.5		1.8
Phestia	K66 10.5-11	8.1	4.7	3.5	
Phestia	K66 10.5-11	11.7	6.1		
Phestia	K66 10.5-11		4.4	2.3	
Phestia	K66 10.5-11		5.8		
Phestia	K66 10.5-11		8.6		
Phestia	K66 10.5-11		6.4		2
Phestia	M3A 0-6	8.2	3.8		2.2
Phestia	M3A 0-6	8.8	3.9		2.4
Phestia	M3A 0-6	8.7	4		2
Phestia	E 19.3	12.6	6.7		1.9
Phestia	E 61 Q3	11.2	5.3		
Phestia	K 60.F	29.4	14.4	9.2	
Phestia	K 60.F	25.3	12.8	9.1	
Phestia	K 60.F	25.7	14.8	8.3	
Phestia	K 60.F		16.6		
Phestia	S52 3.75-4.25	3.5	2.4	1.6	
Phestia	S31.1	8.9	3.9		

Phestia	S31.1		3.2		
Phestia	S31.1		2.4		
Phestia	M14 3-4	7.8	4.7	3.3	
Phestia	M14 3-4		4.9	3.7	
Phestia	M14 3-4	8.2	5	3.5	
Phestia	M14 3-4	8.2	5.2	3.3	
Phestia	M14 3-4	4.6	2.8	2.2	
Phestia	M14 3-4		3.4	2.3	
Phestia	M14 3-4	6.2	4.8	3.1	
Phestia	M68 24-30	9.7	5.8	3.3	
Phestia	M68 24-30	5.9	3.6	2.9	
Permophorus	K60.18	26	11.2		
Permophorus	K35b	12.2	7		
Permophorus	K35b	25.2	12.6		4.2
Permophorus	K35b	25.4	11.2		2.2
Permophorus	K35 Q3	27.6	13.7		3
Permophorus	M28a 14-19"		25.2	17.2	
Permophorus	E57 2.75-3.0 "also in vial"	17.5	8.4		
Permophorus	K66 9.5-10.5	8.5	5.3		
Permophorus	M50 1-6"	13.1			
Permophorus	S51 1.5-2.5 Q1	21.4	10.4		3.1
Permophorus	S51 1.5-2.5 Q1	10.4	5.2		2.1
Permophorus	W75 Base	14.6	8.5		
Wilkingia	E36 Q3	26.3	14.2		
Wilkingia	E36 FLOAT	21			
Wilkingia	M 3.28	20	9.9		5.5
Wilkingia	M28.21		9.1		4.3
Wilkingia	M3F		19	16.9	
Wilkingia	M3F	25.6	19.3	16.1	
Wilkingia	S51 5.25-5.75	15.2	10.3		
Schizodus	M3F	24.1	20.2		2.9
Schizodus	M28A 0.75- 2.25	39.4	32.4		10.6
Schizodus	M28A 0.75- 2.25	19.1	14.7		6.8
Schizodus	K66 9.5-10.5	11.9	10.2		3.5
Schizodus	K66 9.5-10.5	9.2	6.9		3.1
Schizodus	K66 9.5-10.5	2.7	6.6		
Schizodus	K66 9.5-10.5	7.4	6.5		
Schizodus	K66 10.5-11	6.8	5.2		1.9

Schizodus	M77 30-34"	18.3	17.7		4.9
Schizodus	S55 2-3.5	51.1			18.1
Schizodus	S55 2-3.5	10.4	8.3		3.2
Schizodus	S55 2-3.5	8.2	6.5		2.8
Schizodus	S55 2-3.5	9.3	8.1		3.5
Schizodus	S55 2-3.5	14.6	12.6		3.2
Schizodus	S52 9.25- 9.75 or S55 float	37.7	34.2		
Schizodus	M50 6-11	29.7	26.3		6.1
Schizodus	M50 6-11	30.6	31.9		10.8
Schizodus	M50 1-6		33.5		11.4
Septomyalina	K35a	20	8.9		3.8
Septomyalina	K35a	22	11.3		3.6
Septomyalina	M3.28	31.9	14.5		8.2
Septomyalina	M3.28	10.2	6.8		1.9
Septomyalina	M50 6-11'	37.8	20.1		4.5
Septomyalina	M50 6-11'	17	8.6		2.5
Septomyalina	M50 6-11'	35	17.5		
Septomyalina	M50 6-11'	30.2	18		6
Septomyalina	M50 6-11'	11.1	4		3.2
Septomyalina	M50 6-11'	27.7			
Septomyalina	M50 6-11'	29.1	16.5		5.6
Septomyalina	M50 6-11'	31.4	14.8		
Septomyalina	M50 6-11'	16.3	7.3		4.4
Septomyalina	EF 17.3		8.1		
Septomyalina	K35 Q2	19.1	6.8		3.8
Septomyalina	K35 Q2	29.2	19.6		9.4
Septomyalina	K35 Q2	32.1	21		7.5
Septomyalina	K35 Q2	25.6	14.7		4
Septomyalina	S55 4.5-5.25	34.8	20.9		7.5
Septomyalina	M78 6.5-7	44	28.2		10
Septomyalina	K35 Q1	36.1	17.8		4.9
Septomyalina	K35 Q1	34	13.7		7.6
Septomyalina	K35 Q1	23	11.4		9.1
Septomyalina	K35 Q1	14.3	6.8		1.8
Septomyalina	K35 Q1	17	6.4		4.3
Septomyalina	K35 Q1	20.5	7.1		4.8
Septomyalina	K35 Q1	10.9	5.9		3.1
Septomyalina	K35 Q1	16.1	9.8		3.5
Septomyalina	M50 1-6	11.7			
Septomyalina	M50 1-6	9.7	3.6		2.6

Septomyalina	M50 1-6	25.4	14		4.9
Solemya	E36Q3	18.2	9.7		
Solemya	E36Q3	10.5	6		
Solemya	E36Q3	17.8	9.9		
Solenomorpha	K34 8-10"	11	4.6		0.5
Pleurophonella	M45 5-10" Q2		8.2		
Pleurophonella	M68 24-30"	10.2	5.9		
Pleurophonella	M68 24-30"	10.6	5.9		1.9
Pleurophonella	M68 24-30"	11.7	6.9		1.3
Pleurophonella	M68 24-30"	9.22	7		1.8
Pseudoconocardium	K66 9.5-10.5	9.9			
Pseudoconocardium	K66 9.5-10.5 Q1	5.7	4.6	5	
Pseudoconocardium	K66 4.5-5.0	6.3	4.9	5.3	
Pseudoconocardium	K34 3-4"		7		
Promytilus	E20A	17.8	10.3	6.7	
Promytilus	K35A	19.7	11.1		
Promytilus	M3.28		8.7		2.2
Promytilus	M68 6.5-7	3.2	2		
Promytilus	E61 Q1	24.6			
Promytilus	M78 6.5-7.0	15.7	8.1		2.3
Promytilus	M78 6.5-7.0	11.4			
Promytilus	M78 6.5-7.0	11.9	6		1.9
Promytilus	M78 6.5-7.0	11	7.2		
Promytilus	E36 Q3	7.6	4.1		
Promytilus	E36 Q3	6.2	3.2		
Promytilus	E36 Q3	6.3	3.1		
Promytilus	E36 Q3	13.1	5		3.5
Promytilus	K35B	10.4	5.6		
Promytilus	K35B	11.7	4.8		1.9
Promytilus	K35B	6.3	3.7		
Promytilus	M50 6-11	18.9	9.6		2.4
Promytilus	M50 6-11		5.6		
Promytilus	M50 6-11	18.3	9.9		2.1
Promytilus	M50 6-11	14.1	7.3		2.2
Promytilus	M50 6-11	10.5	8.1		2.5
Promytilus	M50 6-11		8.4		2.3
Promytilus	M50 6-11		5.4		1.3
Promytilus	M50 6-11	12	7.1		
Promytilus	M50 6-11	13.7			
Promytilus	M50 6-11	16.8	6.2		

Paleolima	S39 18-24"	6.7	4.4		3.2
Paleolima	S39 18-24"	5.3	3.7		2.1
Paleolima	S39 18-24"	6.1	3.4		
Clinopsitha?	S31 3.5a?	4	3.2		1.5
Clinopsitha?	S31 3.5a?	3.7	3.8		0.7
Clinopsitha?	S31 3.5a?	2.8	3.6		1.2
Clinopsitha?	S31 3.5a?	17.3	14		2.8
Clinopsitha?	S31 3.5a?	9.1	6.1		2.6
Clinopsitha?	S31 3.5a?		17.4		4.7
Nucula	M 16a 5.5-6.5	3.7	2.6	2.2	
Nucula	M 16a 5.5-6.5	3.4	3.1	2.3	
Nucula	M 16a 5.5-6.5	2.7	2.9	1.7	
Nucula	M 16a 5.5-6.5	3.6	2.6		1.6
Nucula	M 16a 5.5-6.5	3.8	2.4		
Nucula	S52 10.25-11	3.1	2.9		
Nucula	S52 10.25-11	3.8	3.3	2.9	
Paleyoldia	E57 2.75-3.0	9.4	4.6		
Paleolima	S31 2.5 Q3	5.1			1.3

Notes on bivalve measurements: Taxonomic assignment was questionable for *Aviculopecten* specimen from M28 Upper lighter shale zone; *Exochorynchus* specimen from E57 2.75-3.0 might be compressed; Nucula and Nuculoidea were transferred into a Nuculopsis species.

Brachiopods								
Taxon	Sample	Dorsal or Ventral valve?	A-P	L-R	D-V	Dorsal alone	Ventral alone	D or V?
Antiquatonia	M28- 21 Q3		24.2	25.7			12.2	
Antiquatonia	M28- 21 Q3		22.8	25.1			10.9	
Antiquatonia	M77 - 30-34"		21.7	28.2			12.5	
Antiquatonia	M77 - 30-34"		21.2	27.7			11.1	
Antiquatonia	S39 - 2- 2.5		19.5	24.1			12.7	
Antiquatonia	S39 - 2- 2.5		15.3	24.2			10.9	
Antiquatonia	S39 - 2- 2.5		15.8	23.6			12.6	
Antiquatonia	S39 - 2- 2.5		16.5	23.7			13.3	
Antiquatonia	S39 - 2- 2.5		14.5	20.3			10.8	
Antiquatonia	M37- 4.25-4.75		18.7	24.4			10.2	
Antiquatonia	M37- 4.25-4.75		20.2	21.8			8.7	
Antiquatonia	M37- 4.25-4.75		20.8	24.5			9.2	
Antiquatonia	M37 28-36"		20	23.9			12.1	
Antiquatonia	S52 9.25-9.75		16.1	23.7			14.4	
Antiquatonia	S13.2		25.6	35.8			18.4	
Antiquatonia	S55 3.5-4.5		22.4	26.5			11.8	
Antiquatonia	S31 3.5 Q1		15.6	16.8			12.5	
Antiquatonia	S55 4.5-5.25		18.9	21.7			12.9	
Antiquatonia	S55 4.5-5.25		15.7	19.3			10.9	
Antiquatonia	S55 4.5-5.25		16.6	21			10.8	
Antiquatonia	S55 4.5-5.25		13.9	20.2			9.3	
Antiquatonia	M3.28		36.4	32.3			22.7	
Antiquatonia	M3.28		24.1	26			17.8	
Antiquatonia	M3.28		18.5	21.1			13.2	
Antiquatonia	M68 6.5-7.0		18.7	27.4			11.6	
Antiquatonia	S55 2.35		19.5	23			16.9	
Antiquatonia	M78 6.5-7.0		20.3	27.9			10	
Antiquatonia	M78 6.5-7.0		13.4	18.2			5.3	
Antiquatonia	S51 2.5-3.5		18.9	26.4			12.9	
Antiquatonia	S51 2.5-3.5		19.5	27.4			14	
Antiquatonia	M50 6-11		23.3	29.5			14.6	
Antiquatonia	M50 1-6		23.8	28.3			12.5	
Antiquatonia	M3 Float		30	36.5			16.8	

Antiquatonia	M3 Float		24.3	34.6			15.4	
Antiquatonia	S31 2.5 Q2		14.8	18.5			8.4	
Antiquatonia	S31 2.5 Q2		14.1	17.7			7.6	
Antiquatonia	S31 2.5 Q2		15.7	19			9.7	
Antiquatonia	S31 2.5 Q2		17.8	20.1			10.3	
Antiquatonia	W 74 B7		16.3	18.6			7.4	
Antiquatonia	W 71 2.5-3.0		17.5	23.2			11.5	
Antiquatonia	W 71 2.5-3.0		19.9	21.7			8.4	
Antiquatonia	S39 2-2.5 Q1		15	26.6			9.7	
Antiquatonia	M22.8		12.6	16.3			5.7	
Antiquatonia	S51 1.5-2.5Q		14.9	17.6			7.5	
Antiquatonia	S51 1.5-2.5Q		20.9	20.3			13.3	
Antiquatonia	S51 1.5-2.5Q		19.8	24			12.5	
Antiquatonia	S51 1.5-2.5Q		17.1	19.5			8.8	
Antiquatonia	S51 1.5-2.5Q		21.1	22.6			12.4	
Antiquatonia	S51 1.5-2.5Q		17.8	27.4			14.9	
Antiquatonia	S51 1.5-2.5Q		19.7	21.7			13.8	
Antiquatonia	S51- S52 float		22.9	29.1			14.9	
Antiquatonia	S51- S52 float		20.5	24.4			12	
Antiquatonia	S31 2.5 Q3		21.7	27.1			13.4	
Antiquatonia	S 55 4.5-5.25 Q1		21.2	25.4			14	
Antiquatonia	S 55 4.5-5.25 Q1		24.5	25.9			12.5	
Antiquatonia	S31 3.5 Q2		21.6	30.3			12.4	
Antiquatonia	S31 3.5 Q2		19.6	22.3			12.1	
Anthracospirifer	S13.2		19.3	23.8			8.9	
Anthracospirifer	S13.2		19.4	28.4			8.3	
Anthracospirifer	S13.2		7	8.8			3	
Anthracospirifer	S13.2		7.7	9.7			2.5	
Anthracospirifer	M77 30-34"		13.3	16.8			5.9	
Anthracospirifer	M77 30-34"		8.7	12.3			5.3	
Anthracospirifer	W74 B7		13.6	20.3		2.9		
Anthracospirifer	W74 B7		10.3	16.2			8	
Anthracospirifer	S29 0-5"		11.7	23.4			6.2	
Anthracospirifer	S55 2-3.5		3.5	5.6			2.9	
Anthracospirifer	S55 2-3.5		6.5	8.1			3.6	
Anthracospirifer	S55 2-3.5		13.5	21			6.3	
Anthracospirifer	S51 2.5-3.5		12.8	13.9			6.2	
Anthracospirifer	S51 2.5-3.5		12.1	16		5.8		
Anthracospirifer	S51 2.5-3.5		5.3	6.7		4.8		
Anthracospirifer	S51 5.25- 5.75		10.6	16			6.4	

Anthracospirifer	S51 5.25- 5.75		7.1	8.5			4.7	
Anthracospirifer	S51 5.25- 5.75		10.8	16.6			8.7	
Anthracospirifer	S51 1.5-2.5Q2		11.9	21.8		5		
Anthracospirifer	S51 1.5-2.5Q2		10.1	19.4		6.1		
Anthracospirifer	S51 1.5-2.5Q2		17.6	25.3			11.8	
Anthracospirifer	S51 1.5-2.5Q2		11.3	20.3			7.4	
Anthracospirifer	S51 1.5-2.5Q2		16.1	26.7		6.8		
Anthracospirifer	Magoffin W 75 Base		16.3	20.6			6.6	
Anthracospirifer	Magoffin W 75 Base		15.7	21.9		3		
Anthracospirifer	Magoffin W 75 Base		8.6	10.8			2.9	
Anthracospirifer	Magoffin W 75 Base		15.3	20.2			6.5	
Anthracospirifer	Magoffin W 75 Base		10.5	13.6			5	
Anthracospirifer	Magoffin W 75 Base		9.9	16			4.3	
Anthracospirifer	Magoffin W 75 Base		20.8	29.6			6.8	
Anthracospirifer	Magoffin W 75 Base		15.3	19.2			7.1	
Anthracospirifer	Magoffin W 75 Base		5.7	7.1			3.5	
Anthracospirifer	Magoffin W 75 Base		10.8	12.7			3.9	
Anthracospirifer	M28.21 Q3		9.7	12.5			3.6	
Anthracospirifer	M28.21 Q3		10.2	7.7			5	
Anthracospirifer	S55 4.5-5.25		21.7	33.3			7.1	
Anthracospirifer	S55 4.5-5.25		14.8	18.2			6.1	
Anthracospirifer	S55 4.5-5.25		11.2	15.2			5.3	
Anthracospirifer	S55 4.5-5.25		14.2	22.1			6.6	
Anthracospirifer	S55 4.5-5.25 Q2		9.9	14.7		3		
Anthracospirifer	S55 4.5-5.25 Q2		6.7	7.6			3.2	
Anthracospirifer	S55 4.5-5.25 Q2		4.7	7.8		2		
Anthracospirifer	S55 4.5-5.25 Q2		2.9	5.2		1.1		
Anthracospirifer	M22.8		18.1	29.4			8.1	
Anthracospirifer	M22.8		12.4	19.7			5.7	
Anthracospirifer	M22.8		15.9	24.7			6.1	
Anthracospirifer	M22.8		6.8	10.1			3.3	
Anthracospirifer	Magoffin W 71 0-8		16.6	20.4			9	
Anthracospirifer	Magoffin W 71 0-8		14.2	16.4			8.6	
Anthracospirifer	Magoffin W 71 0-8		14.7	22			6.5	
Anthracospirifer	Magoffin W 71 0-8		10.9	12.8			5.2	
Anthracospirifer	Magoffin W 71 0-8		16.1	19.2			7.2	
Anthracospirifer	Magoffin W 71 0-8		12.6	17.5			5.3	

Anthracospirifer	Magoffin W 71 0-8	7.3	10.6		1.5		
Anthracospirifer	Magoffin W 71 0-8	15	10.7			6.8	
Anthracospirifer	Magoffin W 71 0-8	13.2	16.2			6.3	
Anthracospirifer	Magoffin W 71 0-8	16.5	21			7.6	
Anthracospirifer	Magoffin W 71 0-8	12.5	22.4			6.6	
Anthracospirifer	M3F	17	18.5			7.4	
Anthracospirifer	M3F	18.8	24.8			12.9	
Anthracospirifer	M50 1-6	16.6	22.5			7	
Anthracospirifer	M50 1-6	16.7	20.8		4.2		
Anthracospirifer	M50 1-6	12.3	15.4			5.3	
Lingula	K66 4.5-5.0 Q3	6.2	3.6				
Lingula	K66 4.5-5.0 Q3	4.2	2.2				
Lingula	K66 4.5-5.0 Q3	11.2	7.2				
Lingula	M106"	3.8	2.5				
Lingula	M106"	2.1	1.6				
Lingula	M106"	2.9	2.1				
Lingula	E61 8-14"	5.7	3.2				0.8
Lingula	E61 8-14"	1.7	1.2				
Lingula	E61 8-14"	2.8	1.7				
Lingula	E61 8-14"	2.5	1.4				
Lingula	E61 8-14"	1.6	1.5				
Lingula	E61 8-14"	2	1.3				
Lingula	E61 8-14"	2.5	1.5				
Lingula	E61 8-14"	1.4	0.8				
Lingula	K21 1.5-2.0	4.6	2.8				
Lingula	K21 1.5-2.0	3.5	2.5				
Lingula	K21 1.5-2.0	1.5	1.1				
Lingula	K21 1.5-2.0	3.3	2.2				
Lingula	K21 1.5-2.0	2.6	1.4				
Lingula	K21 1.5-2.0	2.5	1.7				
Lingula	K21 1.5-2.0	4.9	3.5				
Lingula	K21 1.5-2.0	1.7	1.3				
Lingula	K21 1.5-2.0	2.9	2				
Lingula	K21 1.5-2.0	2.8	1.8				
Lingula	K21 1.5-2.0	3.1	1.7				
Lingula	K21 1.5-2.0	2.2	1.6				
Lingula	K21 1.5-2.0	2.4	1.7				
Lingula	K21 1.5-2.0	2.7	1.9				
Lingula	K21 1.5-2.0	1.7	1.5				
Lingula	K21 1.5-2.0	2.9	2				

Lingula	K21 1.5-2.0		2.4	1.7				
Lingula	K21 1.5-2.0		2.4	1.4				
Lingula	K21 1.5-2.0		2.4	1.3				
Lingula	K21 1.5-2.0		1.7	1.1				
Trigonoglossa	E36 15-18"		13.2	15.8				1.6
Trigonoglossa	M68 24-30"		12.3	16.2				
Trigonoglossa	E36 Q3		11.5	11.7				1.6
Orbiculoidea	E36 Q3		19.5	19.5		3.7		
Kozłowska	S31 2.5 Q2		13.6	12.5			8.9	
Kozłowska	S31 2.5 Q2		9.1	15.9			6.5	
Kozłowska	S31 2.5 Q2		11	12.1			6.3	
Kozłowska	S31 2.5 Q2		10.7	12.5			6.2	
Kozłowska	S31 2.5 Q2		8.6	14			7.1	
Kozłowska	S31 2.5 Q2		11.6	10.2			6.6	
Kozłowska	S31 2.5 Q2		7.4	10.1			5.2	
Kozłowska	S31 2.5 Q2		9.6	12.6			5.2	
Kozłowska	S31 2.5		9.1	12.4			5.2	
Kozłowska	S13.2		8.8	10.3			4.3	
Kozłowska	S39 2- 2.5 Q1		13.6	14.1			9.7	
Kozłowska	S39 2- 2.5 Q1		11.7	12.3			7.7	
Kozłowska	S39 2- 2.5 Q1		8.7	11.3			4.5	
Kozłowska	S39 2- 2.5 Q1		11.2	12.9			5.4	
Kozłowska	S39 2- 2.5 Q1		10.1	13.3			6.3	
Kozłowska	S39 18-24"		7.7	11.5			5.4	
Kozłowska	S39 18-24"		9.8	12.4			4.3	
Kozłowska	S39 2-2.5		12.3	14.8			7.7	
Kozłowska	S31 3.5 Q1		14.4	15.3			8.3	
Kozłowska	S31 3.5 Q1		10.8	16.4			10.1	
Kozłowska	S31 3.5 Q1		10.7	14.2			7.4	
Kozłowska	S31 3.5 Q1		14.3	14.6			8.2	
Kozłowska	S31 2.5A		10.7	12.7			7.4	
Kozłowska	S31 2.5A		11.5	14.3			8.1	
Kozłowska	S31 2.5A		11.2	13.8			8.2	
Kozłowska	S31 2.5A		10	13.4			9.5	
Cleiothyridina	S39 2.5-3.0		9.8	11.3				
Cleiothyridina	S39 2.5-3.0		9.2	8				3.2
Cleiothyridina	S39 2.5-3.0		9.1	8.6				
Cleiothyridina	S39 2.5-3.0		9.9	12.9				
Cleiothyridina	S39 2.5-3.0		6.8	7				
Cleiothyridina	S39 2.5-3.0		7	6.9				

Cleiothyridina	S39 2-2.5 Q1		7.8	9.2				
Cleiothyridina	S39 2-2.5 Q1		8.1	9.9				
Cleiothyridina	S39 2-2.5 Q1		8	8.3				
Cleiothyridina	S39 2-2.5 Q1		5.4	4.8				
Cleiothyridina	S39 2-2.5 Q1		9.5	12				3.4
Cleiothyridina	S39 2-2.5 Q1		10.2	11.5				2.3
Cleiothyridina	S39 2-2.5 Q1		9.8	10.5				3.2
Cleiothyridina	S39 2-2.5 Q1		8.6	10				
Cleiothyridina	S39 2-2.5 Q1		10	12				
Cleiothyridina	S39 2-2.5 Q1		9.8	10.5				
Cleiothyridina	S39 2-2.5 Q1		7.3	7.8				
Cleiothyridina	S39 2-2.5 Q1		4.8	4.6				
Cleiothyridina	S39 2-2.5 Q1		10.4	11.3				
Cleiothyridina	S39 2-2.5 Q1		3.5	4.6				
Cleiothyridina	S39 2-2.5 Q1		7.6	7.7				3.2
Cleiothyridina	S39 2-2.5 Q1		9.7	10				2.2
Cleiothyridina	S39 2-2.5 Q1		3.4	5.3				2
Cleiothyridina	S39 2-2.5 Q1		8.7	10.9				2.5
Cleiothyridina	S39 2-2.5 Q1		5.8	6.7				1.8
Cleiothyridina	S39 2-2.5 Q1		4.5	4.8				1.1
Cleiothyridina	S31 2.5 Q1		11.1	8.5				
Cleiothyridina	S31 2.5 Q1		8.8	9.9				2.6
Cleiothyridina	S31 2.5 Q1		8.5	9.9				
Cleiothyridina	S31 2.5 Q1		5.2	5				1.7
Cleiothyridina	S31 2.5 Q1		10.2	10.6				
Cleiothyridina	S31 2.5 Q1		7.5	8.8				2.3
Cleiothyridina	S31 2.5 Q1		8.6	10.9				3.1
Cleiothyridina	S31 2.5 Q1		5.2	8				1.7
Cleiothyridina	M28.21 Q2		11.8	10.9				
Cleiothyridina	M28.21 Q2		10.6	10.7				
Cleiothyridina	M28.21 Q2		8.5	8.7				2.2
Cleiothyridina	M28.21 Q2		7.9	7.6				1.8
Cleiothyridina	M28.21 Q2		10.6	10.8				1.9
Cleiothyridina	M28.21 Q2		9.3	9.7				1.5
Cleiothyridina	M28.21 Q2		3.8	3.5				
Cleiothyridina	M28.21 Q2		9.2	7.1				
Cleiothyridina	S31 3.5 Q1		10.8	11.6				3.6
Cleiothyridina	S31 3.5 Q1		10.2	11.6				3.3
Cleiothyridina	S31 3.5 Q1		7.8	9.6	4			
Cleiothyridina	S31 3.5 Q1		11	10.6				

Cleiothyridina	S31 3.5 Q1		7.1	7.3				1.5
Cleiothyridina	S31 3.5 Q1		9.7	11.2				
Cleiothyridina	S31 3.5 Q1		5.2	6.2				2
Cleiothyridina	S31 3.5 Q1		4.8	5.4				
Cleiothyridina	S31 3.5 Q1		5.9	6.1				
Cleiothyridina	S31 3.5 Q1		9.5	10.7				3.2
Cleiothyridina	M68 6.5-7.0		8.3	6.8				
Cleiothyridina	M68 6.5-7.0		8.3	7.9				
Cleiothyridina	M68 6.5-7.0		6.1	5.8				2.1
Cleiothyridina	M68 6.5-7.0		5.5	5.3				
Cleiothyridina	M68 6.5-7.0		7.1	6.4				
Cleiothyridina	M68 6.5-7.0		7.1	7.7				
Cleiothyridina	M68 6.5-7.0		6.8	7.1				
Cleiothyridina	M68 6.5-7.0		5.9	6.3				
Cleiothyridina	M 3.28		7.6	9.1				
Cleiothyridina	M 3.28		8.5	9.4				
Cleiothyridina	E20 A		11.7	10	4.8			
Beecheria	S31 3.5 Q3		7.1	6.1	1.7			
Crurithyris	AH- Q Kendrick		5.5	4.6			2.9	
Crurithyris	AH- Q Kendrick		4.9	5.6			2.3	
Crurithyris	K66 4.5-5		4.4	5.1			1.8	
Crurithyris	K66 4.5-5		5.1	4.9			2.2	
Crurithyris	K66 4.5-5		3.5	5			2.1	
Crurithyris	K66 4.5-5		5.2	7.1			4.7	
Crurithyris	K66 4.5-5		3.2	5.1			2.5	
Crurithyris	K66 4.5-5		3.8	4.6				
Crurithyris	K66 4.5-5		8.7	6.8				
Crurithyris	S13.2		3.1	4.2			1.6	
Crurithyris	S13.2		4.2	3.9			1.8	
Crurithyris	M14 1-2		4.3					
Crurithyris	M14 1-2		3.6	4.4			2.4	
Crurithyris	M14 1-2		6.9	8.4				
Crurithyris	M14 1-2		2.3	3				
Crurithyris	M14 1-2		2.6	2.3			1.2	
Crurithyris	M14 1-2		5.3	4.5				
Crurithyris	M14 1-2		4.2	4.8				
Crurithyris	M14 1-2		4.6	4.2				
Crurithyris	M14 0-1		3.9	5.4				
Crurithyris	M14 0-1		3.3	3.3			1.2	
Crurithyris	M14 0-1		3.1	4.5			1.6	

Crurithyris	S31.35a		5.6	5.5			2.2	
Crurithyris	S31.35a		8.8	12.4				
Crurithyris	S31.35a		3.7	4.8			1.4	
Crurithyris	S31.35a		3.5	3.5				
Crurithyris	S31.35a		4.1					
Crurithyris	M10.40		5.6	6.2			3.4	
Crurithyris	M10.40		5.2	5.8				
Crurithyris	M10.40		6.2	7.1				
Crurithyris	M10.40			5				
Crurithyris	M10.40		6.2	6.8				
Crurithyris	K21 1.5-2.0		5.3	5.8				
Crurithyris	K21 1.5-2.0			4.5				
Crurithyris	K21 1.5-2.0		5.4	6.5				
Crurithyris	K21 1.5-2.0		6	7.3				
Crurithyris	K21 1.5-2.0		4.3	4.6				
Crurithyris	K21 1.5-2.0		4.5	5.1				
Crurithyris	S51 2.5-3.5		5.4	6.4			3.4	
Crurithyris	M10.6"		4.4	4.5			2.8	
Crurithyris	M10.6"		4.5	5				
Crurithyris	M10.6"		3.2					
Crurithyris	M10.6"		2.7	3.1			1.2	
Crurithyris	K34 3-4"		5.3	6.3				
Crurithyris	K34 3-4"		6.1					
Crurithyris	S55 4.5-5.25 Q1		5.3					
Crurithyris	S55 4.5-5.25 Q1		5.8					
Crurithyris	S55 4.5-5.25 Q1		4.7	5.8			2.2	
Crurithyris	S55 4.5-5.25 Q1		4.2	4.2				
Crurithyris	S55 4.5-5.25 Q1		4.9					
Crurithyris	S55 4.5-5.25 Q1		7					
Crurithyris	S51 5.25- 5.75		4.5	4.5			1.8	
Crurithyris	S29 21"-23"		3.4	3.6			2	
Crurithyris	S29 21"-23"		2.8	2.9				
Crurithyris	S29 21"-23"		3.8	3.9			1.7	
Crurithyris	S29 19"-21"		3	4			1.5	
Crurithyris	S29 19"-21"		2.7	2.3				
Crurithyris	M14 3-4		3.9	3.9			1.7	

Crurithyris	M14 3-4		2.3	3.1			3.5	
Crurithyris	M14 3-4		3.5	6.1				
Crurithyris	M14 2-3		2.6	3.3			1.3	
Crurithyris	M14 2-3		3.7	3.9	2.4			
Crurithyris	M14 2-3		4.9					
Crurithyris	M14 2-3		5.3	4.7				
Crurithyris	M14 2-3		3.5	2.7				
Crurithyris	M14 2-3		3.2	4.1				
Crurithyris	M 68 24- 30"		5.3	7			3.2	
Crurithyris	M 68 24- 30"		3.3	4.5				
Crurithyris	M 68 24- 30"		4.9					
Derbyia	M 3.28	V	23.7	24.4	11			
Derbyia	M 3.28	D	20.5	24.4	11			
Derbyia	S55 4.5-5.25 Q3	D	9	11				
Derbyia	S55 4.5-5.25 Q3	V	9.3	11.6				
Derbyia	S55 4.5-5.25 Q3	D	12.6	17.8				
Derbyia	S55 4.5-5.25 Q3	V	16.5	20.3				
Derbyia	M78 6.5-7.0	D	18.4	23.5		8.1		
Derbyia	M78 6.5-7.0	V	23.4	27.3				
Derbyia	M78 6.5-7.0	V	30.3	33.3				
Derbyia	M78 6.5-7.0	D	23.4	30.1				
Derbyia	S55 4.5- 5.25 Q1	D	13.7	18		4.7		
Derbyia	S55 4.5- 5.25 Q1	V	9.7	10.2				
Derbyia	S55 4.5- 5.25 Q1	V	10.5	11.7				
Derbyia	S55 4.5- 5.25 Q1	V	12.2	10.9				
Derbyia	S55 4.5- 5.25 Q1	D	9.8	12.1				
Derbyia	S55 4.5- 5.25 Q1	V	7.6	8.1				
Derbyia	M 28.21	D	16.3	25		3.9		
Derbyia	M 28.21	D	19.1	26.8		4.4		
Derbyia	M 28.21	D	11.5	15.6		3.3		
Derbyia	K35 Q2	D	14.1	17.5		4.1		
Derbyia	K35 Q2	D	8.9	11.9		1.8		
Derbyia	E 36 Q3	V	13.8	15.2			2.5	

Derbyia	E 36 Q2	D	8.1	9.3				
Derbyia	S 29 6-12"	V	14.2	17.7				
Derbyia	S 29 6-12"	V	10.8	13.1				
Derbyia	S55 2-35	D	16.5	20.6		3.1		
Derbyia	S55 2-35	V	16.6	19.4			3.2	
Derbyia	S55 2-35	V	9.7	11.2			2.2	
Derbyia	S55 2-35	V	18.4	18.6			2.4	
Derbyia	S55 2-35	D	19.2	23.9		4.6		
Derbyia	S55 2-35	D	5.5	7.8		1.9		
Derbyia	S55 2-35	V	9.6	11			1.9	
Derbyia	S55 2-35	V	16	19.1			2.8	
Derbyia	S55 2-35	V	9.3	11.6			1	
Derbyia	S55 2-35	V	7.7	12.1			2.7	
Derbyia	W75 Base	D	18.9	26.4		8.1		
Composita	M3F	D	14.9	15.7	13		6	
Composita	M3F	V	18	15.7	13			
Composita	M3F	D	18	19.2	12.4		6.7	
Composita	M3F	V	19.8	19.2	12.4			
Composita	M3F	D	17.7	20				
Composita	M3F	V	19.7					
Composita	S51- S52 float	D	19	22.6	14.5			
Composita	S51- S52 float	V	23.1	22.6	14.5			
Composita	S51- S52 float	V	19	19.8			6.2	
Composita	S51- S52 float	V	17.1	17.2			7.5	
Composita	S51- S52 float	V		18.9				
Composita	S51- S52 float	V	19.1	16.5			8.8	
Composita	S51- S52 float	V	12.9	11			5.9	
Composita	S51- S52 float	V	16.1	16.2			8.4	
Composita	S51- S52 float	V		20.3				
Composita	S51- S52 float	V	16	14.5			9.3	
Composita	E36 15-18"	D	12.4	13				
Composita	E36 15-18"	V	14.9	13				
Composita	S29 19-23" Q1	V	12.7	10.4	4.3			
Composita	S29 19-23" Q1	V	6.2	5	3.3			
Composita	S29 19-23" Q1	V	4.9	5.6	1.9			
Composita	S55 2-3.5	V	20.1	20.3	13.8		6.7	
Composita	S55 2-3.5	D	16.8	20.3				
Composita	S55 2-3.5	V	19.3	16.8			6.2	
Composita	S55 2-3.5	V	10.7	9.6			3.5	
Composita	S55 2-3.5	V	9.7	10.2			3.4	

Composita	S55 2-3.5	V		23.2				
Composita	K66 9.5-10.5 Q1	V	16.5	14.7	11		5.5	
Composita	K66 9.5-10.5 Q1	D	14.2	14.7	11			
Composita	K66 9.5-10.5 Q1	V	15.3					
Composita	K35 Q2	V	22.1	20.8			7.1	
Composita	K35 Q2	V	23.9	22.7				
Composita	K35 Q2	V	19.5	21.3			5.7	
Composita	K35 Q2	V	18.7	17.6			5.9	
Composita	K35 Q2	V	23.2	23.6				
Composita	E61 Q2	V	15.7	14.8				
Composita	E61 Q2	V	12.8	12.4			3.3	
Composita	E61 Q2	V	11.8					
Composita	K66 9.5-10.5	V	17.9	15.3	11.5		4.6	
Composita	K66 9.5-10.5	D	16.1	15.3	11.5			
Composita	Magoffin W 74 lower bed	V	19.4	18.7				
Composita	Magoffin W 74 lower bed	V	16.2	19.6				
Composita	Magoffin W 74 lower bed	V	20.3	22.7			7	
Composita	Magoffin W 74 lower bed	V	20.4	19.5				
Composita	Magoffin W 74 lower bed	V	19	19.8				
Composita	Magoffin W 74 lower bed	V	14.3	12.7				
Composita	Magoffin W 74 lower bed	V	22.5	21.3				
Composita	Magoffin W 74 lower bed	V	6.3	5.7				
Composita	Magoffin W 74 lower bed	V	17.5	15.9				
Composita	Magoffin W 74 lower bed	V	19.6	19.6				
Composita	Magoffin W 74 lower bed	V	22.1	21.9			7.8	
Composita	Magoffin W 74 lower bed	V	20.4	19.9				
Composita	Magoffin W 74 lower bed	V	16.5	18.4				
Desmoinesia	S51 5.25- 5.75	V	10.5	10.7			5.9	

Desmoinesia	S51 5.25- 5.75		12.1	11.7			7.3	
Desmoinesia	S51 5.25- 5.75		9.5	11.7			6.8	
Desmoinesia	S51 5.25- 5.75		9.6	12.8			5	
Desmoinesia	S51 1.5-2.0 Q3		14.7	20.5			5.9	
Desmoinesia	S51 1.5-2.0 Q3		11.5	15.3			7.2	
Desmoinesia	S51 1.5-2.0 Q3		10.6	12.1			6.5	
Desmoinesia	S51 1.5-2.0 Q3		10.9	14			6.7	
Desmoinesia	S51 1.5-2.0 Q3		11	12.9			6	
Desmoinesia	S51 1.5-2.0 Q3		12.3	12.7			6.6	
Desmoinesia	S51 1.5-2.0 Q3		10.2	11.3			7.8	
Desmoinesia	S51 1.5-2.0 Q3		9.5	11.7			4.7	
Desmoinesia	S51 1.5-2.0 Q3		11.3	12.7			6.7	
Desmoinesia	S51 1.5-2.0 Q3		11.4	15.2			8.5	
Desmoinesia	W75 U2 Magoffin		12.7	15.5				
Desmoinesia	W75 U2 Magoffin		12.4	17				
Desmoinesia	W75 U2 Magoffin		13.8	14.3				
Desmoinesia	W75 U2 Magoffin		9.9	14				
Desmoinesia	W75 U2 Magoffin		14	13.8				
Desmoinesia	W75 U2 Magoffin		10	12.4				
Desmoinesia	W75 U2 Magoffin		11.1	12.7				
Desmoinesia	W75 U2 Magoffin		10.2	15.8				
Desmoinesia	W75 U2 Magoffin		13.2	15.6				
Desmoinesia	W75 U2 Magoffin		12.1	16.7				
Desmoinesia	W75 U2 Magoffin		11.6	14.6				
Desmoinesia	S29 6-12"		9.5	11.8			5.5	
Desmoinesia	S29 6-12"		9.5	11.9			5.7	
Desmoinesia	S29 6-12"		9.1	11.5			5.5	
Desmoinesia	S29 6-12"		11.8	15.2			6.2	
Desmoinesia	S29 6-12"		8.6	8.8			3.8	
Desmoinesia	S29 6-12"		9.8	11.9			5.2	
Desmoinesia	S29 6-12"		9.4	10.2			4.3	
Desmoinesia	S29 6-12"		7.7	11.1			4	
Desmoinesia	S29 6-12"		10.7	12.5			4.5	
Desmoinesia	S29 6-12"		7.6	12			7	
Desmoinesia	S29 6-12"		10	12.3			6.1	
Desmoinesia	M37 28"- 36"		12	13.7	7.5			
Desmoinesia	M3a 0-6"		13	14.2	6.1			
Desmoinesia	M3a 0-6"		12.2	14.6	6.3			
Desmoinesia	M3a 0-6"		11.7	14.5	6			
Desmoinesia	M3a 0-6"		9.1	14.6	4.9			

Desmoinesia	M3a 0-6"		12.3	14.5	6.8			
Desmoinesia	M3a 0-6"		13	14.6	7.2			
Desmoinesia	M3a 0-6"		11.7	14	4.7			
Desmoinesia	S52 11-11.75		10	12.1	5.5			
Desmoinesia	S52 11-11.75		8.1	12.3	5			
Desmoinesia	S52 11-11.75		11.1	13.5	6.7			
Desmoinesia	S52 11-11.75		11.2	12.8				
Desmoinesia	S52 11-11.75		8.2	10.6				
Desmoinesia	S52 11-11.75		7.9	10.6				
Juresania	E57 2.75-3		30.2	39.9	16.2			
Juresania	E57 2.75-3		30.4	33.6	18			
Juresania	E57 2.75-3			32.1	14.1			
Juresania	E57 2.75-3	D	28.7	37.4				
Juresania	E57 2.75-3	D	28.5	40.2				
Juresania	M3.28		30.4	39.7	17.1			
Juresania	M3.28		14.1	19.8	7.1			
Juresania	M3.28		31.4	46.1				
Juresania	M3.28		24.4	25.7				
Juresania	E19.3		18.7	23.3	10.2			
Juresania	E19.3		21.5	24.3				
Juresania	E19.3		19.9	22.4				
Juresania	E19.3		18.6	20				
Juresania	E61 8-14"	V	21.2	22.6	8.4			
Juresania	E61 8-14"	D		21.6				
Juresania	E61 8-14"	D		23.6				
Juresania	E61 8-14"	D		12.1				
Juresania	E61 8-14"	D		19.4				
Juresania	E61 8-14"	D		22.8				
Juresania	E61 8-14"	D		14.7				
Juresania	E61 8-14"	D		19.8				
Juresania	E61 8-14"	V	14.3	16.2				
Juresania	E61 8-14"	V	14.9	15.2				
Juresania	E61 8-14"	V	15.4	16.6				
Juresania	E61 8-14"	V	10.2					
Juresania	E61 8-14"	V	18.4					
Juresania	E20 A		20.8	21.9				
Juresania	E20 A		26.3	24.1				
Juresania	E20 A		12.7	16.3				
Juresania	E20 A	D		19.7				
Juresania	E20 A		6.4	7.2				

Juresania	E20 A	D		22.5				
Juresania	K35B	V	14.3	17.7				
Juresania	K35B	V	11.7	14.9				
Juresania	K35B	V	10.5	14.4				
Juresania	K35B	V	13.2	16.9				
Juresania	K35B	V	17.9	19				
Juresania	K35B	V	14.3	15.7				
Juresania	K35B	V	8.3	9.3				
Juresania	K35B	V	14.1	15.6				
Juresania	K35B	V	18.6					
Juresania	E 61 Q3		17	23.2				
Juresania	E 61 Q3	D		23.6				
Juresania	E 61 Q3		19.7	19.3				
Juresania	E 61 Q3			22.7				
Juresania	E 61 Q3		23					
Juresania	E 61 Q3		14.6	16.6				
Juresania	S51 1.5-2.5 Q2		19	25.3				
Juresania	S51 1.5-2.5 Q2			22.8				
Juresania	M37 28- 36"		39	38.8				
Rhynchopora	AH-Q Kendrick		8.1	7.8				1.6
Rhynchopora	AH-Q Kendrick		6.3					
Rhynchopora	AH-Q Kendrick		7.5	7.7				1.2
Rhynchopora	AH-Q Kendrick		8.1	8.4				1.7
Rhynchopora	AH-Q Kendrick		7.1					1.7
Rhynchopora	AH-Q Kendrick		5.4	5				
Rhynchopora	AH-Q Kendrick		9.1	8.7				2.7
Rhynchopora	K34 4-8"		7.3					
Rhynchopora	K34 8-10"		5.8	6.8				
Eumetria	M10.40		9.1	9.2				
Eumetria	M10.40		9.9					
Eumetria	M3.28		10.5	10.3				
Eumetria	M6		12.8	11.4				
Hustedia	M3a 6-12"		9.2	10.8	5.3			
Hustedia	M3a 6-12"		8.3	7.5				
Hustedia	M3a 6-12"		10.6	8.4				3.1
Hustedia	K15 Andy Hall Strip Kendrick		8.3	8.7				1.8
Hustedia	K15 Andy Hall Strip Kendrick		8.3	9.6				2.6
Hustedia	M28.21 Q2		5.7	5.1	2.8			
Hustedia	M28.21 Q2		5.9	6.2				1.7

Hustedia	M28.21 Q2		5.4	4.7				2.1
Hustedia	M28.21 Q2		3.2	3.6				1.2
Hustedia	M28.21 Q2		4.7					
Hustedia	M28.21 Q2		7.9	7.5				2.2
Hustedia	M28.21 Q2		6.7	5.8				1.2
Hustedia	M68 6.5-7.5		8	7.4				
Hustedia	M68 6.5-7.5		7.6	6.6				
Hustedia	M68 6.5-7.5		7.7	7.6				2
Hustedia	M68 6.5-7.5		6.3	6.2				1.7
Hustedia	M68 6.5-7.5		5.6	5.5				
Hustedia	M68 6.5-7.5		5.2	5.5				
Hustedia	M68 6.5-7.5		8	9.4				
Hustedia	M68 6.5-7.5		10.4	11.2				
Hustedia	M68 6.5-7.5		6.2	6.6				3.2
Hustedia	M68 6.5-7.5		10.4	9.1				
Hustedia	M68 6.5-7.5		8.9	8.7				2.2
Hustedia	M68 6.5-7.5		6.3	5.9				
Hustedia	M68 6.5-7.5		7.8	7				2.4
Hustedia	M68 6.5-7.5		5.8	4.8				1.4
Hustedia	M68 6.5-7.5		4.7	4.9				1.6
Hustedia	M68 6.5-7.5		3.8	4.5				
Hustedia	M28.21		5.9	5.2				2.5
Hustedia	M28.21		8.3	7.5				2.2
Hustedia	M28.21		6.8	7.2				
Hustedia	M28.21		3.5	3.4				
Hustedia	M28.21			6.1				
Hustedia	M37 21-28"		7.9	8.3				
Hustedia	M37 21-28"		6.1	7.1				
Hustedia	M37 21-28"		5.3	5				
Hustedia	M37 21-28"		6.5					
Hustedia	M37 21-28"		5	6				
Hustedia	M37 21-28"		6.3	7.5				2.6
Hustedia	M37 21-28"		6.5	7.1				
Hustedia	M37 21-28"		5.7	5.3				
Orbiculoidea	K35B		17.6	21.2		10.9		
Orbiculoidea	K60.F	V	17.4	16.1				
Orbiculoidea	K60.F	V	7.9	7.8				
Orbiculoidea	S29 0-12" Q1		2.9	2.8				
Orbiculoidea	S29 0-12" Q1		5.1	5.3				
Orbiculoidea	K48 1-5"		6	6.1		4		

Orbiculoidea	K48 1-5"		4.8	4.3		1.1		
Orbiculoidea	K66 10.5-11.0		9.6	11.8			1.5	
Orbiculoidea	S29 0-10" Q3		7.2	6.4		2.9		
Orbiculoidea	S29 0-10" Q3		7.3	6.7				
Orbiculoidea	S29 0-10" Q3		4.1	4.2		1.2		
Orbiculoidea	S29 0-10" Q3		5.9	5.2		1.3		
Orbiculoidea	S29 0-10" Q3		3.7	3.4				
Orbiculoidea	S29 0-10" Q3			12.7				
Orbiculoidea	S29 0-10" Q3		3.1	3.1				
Orbiculoidea	S29 0-10" Q3		6.5	5.2		2		
Orbiculoidea	S29 0-10" Q3		6.4					
Orbiculoidea	S29 0-10" Q3		7.7			2.8		
Orbiculoidea	M50 6-11"		17.2	16.4				
Orbiculoidea	M50 6-11"		5.3	4.7		1.6		
Orbiculoidea	M28 22.5		4.8	4.4		1.2		
Orbiculoidea	M28 22.5		11.6	10.1		2.5		
Orbiculoidea	M28 22.5		4.2	3.9		1.2		
Orbiculoidea	S51-S52 float		18.4	23		4.5		
Orbiculoidea	S29 0-5"		6.4	5.9				
Orbiculoidea	S29 0-5"		1.9	1.8				
Orbiculoidea	S29 0-5"		6	5.2				
Orbiculoidea	S29 0-5"		5.1	4.8				
Orbiculoidea	E18.20		9.7	9.6				
Orbiculoidea	S.29 19-23" Q1		24.3	25.3		16.3		
Orbiculoidea	S.29 19-23" Q1		19	19.1		9.3		
Oehlertella	Kendrick AH-Q		2.5	2.3				
Oehlertella	Kendrick AH-Q		3.2	3.8		1.6		
Oehlertella	Kendrick AH-Q		5.4	5.6				
Oehlertella	Kendrick AH-Q		5.6	6		2.6		
Oehlertella	Kendrick AH-Q		7.4			3.3		
Neospirifer	S39 2.5-3.0		12.7	19				
Neospirifer	Kendrick AH-Q		23.7	37.4			9.9	
Neospirifer	S51-S52 float		26.2	52.1			10.9	
Neospirifer	S39 18-24"		20.4				7.4	
Neospirifer	S39 2-2.5		16.9	38.4			7.6	
Neospirifer	S39 2-2.5		18.4				7.2	
Neospirifer	S39 2-2.5	D	24.1					
Neospirifer	S13.2		16				6.8	
Neospirifer	K35 float		18.8	49.9			9	
Neospirifer	S55 4.5-5.25 Q1	D	25	42.4		4.9		

Neospirifer	S31 2.5 Q3		28.3	41.2			10.2	
Neospirifer	S31 2.5 Q3		23.3	30.4			9.4	
Neospirifer	S31 2.5 Q3		16.1	27.5			6.5	
Neospirifer	S31 2.5 Q3			22.7			7	
Neospirifer	S31 2.5 Q3			38.2			8.5	
Neospirifer	S31 2.5 Q3		11.6				6	
Neospirifer	S31 2.5 Q3		14.4	18.6			4.3	
Neospirifer	S31 2.5 Q3			13			5	
Neospirifer	S31 7.5 Q1		40.9					
Neospirifer	S31 7.5 Q1		28.2		8.9			
Neospirifer	S31 7.5 Q1		28.6					
Neospirifer	S31 7.5 Q1		14.8		6.2			
Neospirifer	S31 7.5 Q1		19.4	32.1	5.7			
Neospirifer	S31 7.5 Q1		26.9		8.6			
Neospirifer	S31 7.5 Q1		12.9	6.2				
Neospirifer	S31 7.5 Q1		20.2	8.7				
Neospirifer	S31 7.5 Q1		24.3	37.1	8.3			
Neospirifer	S31 7.5 Q1		8.9	19.4	3.2			
Neospirifer	S31 7.5 Q1		10.2		4			
Neospirifer	Kendrick AH stripmine float	V	24.2	40	15.8	7.4	8.11	
Neospirifer	Kendrick AH stripmine float	D	20.5	40	15.8	7.4	8.11	
Neospirifer	Kendrick AH stripmine float	V	24	42.6				
Neospirifer	Kendrick AH stripmine float	D	18.4	42.6				
Neospirifer	Kendrick AH stripmine float		19.2				8.5	
Neospirifer	Kendrick AH stripmine float			24.2			5.3	
Neospirifer	Kendrick AH stripmine float		15	30.8			6.3	
Linoproductus	E36Q1		16.4	21.2			4.9	
Linoproductus	E36Q1		23.1	23.2			10.5	
Linoproductus	E36Q1		22.8	23.5			13.3	
Linoproductus	E36Q1		19.8	20.2			10.7	
Linoproductus	E36Q1		11.3	14.2			5.4	
Linoproductus	E36Q1		13.7					
Linoproductus	E36Q1		28.3				11.2	
Linoproductus	E36Q1		19.9				6.6	
Linoproductus	K35Q2		15.1	14.4			4	
Linoproductus	K35Q2		19.8	22.1			7.1	
Linoproductus	K35Q2		11.5	14.1			4.5	

Linoproductus	K35Q2		11.5				
Linoproductus	K35Q2		15.8	21.2			
Linoproductus	K35Q2		13.3	16.2		5	
Linoproductus	E61 8-14"		20.1	24		12.3	
Linoproductus	E61 8-14"		13.6	17.6			
Linoproductus	E61 8-14"		13.5	16			
Linoproductus	E61 8-14"		17.4	21.3		6	
Linoproductus	E61 8-14"		9.8	12		4.6	
Linoproductus	E18.26		14.3	19.1		5.7	
Linoproductus	E18.26		18.7	22.1		9.5	
Linoproductus	E18.26		17			6.7	
Linoproductus	E18.26			28.5		10.2	
Linoproductus	unknown		18.9	23.4		8.4	
Linoproductus	unknown		15.9	16.6		8.5	
Linoproductus	unknown		18	22.6		7.7	
Linoproductus	unknown		14.4	20.1		6	
Linoproductus	unknown		16.3	17.8		5.3	
Linoproductus	E36 Q3		26.9	26.2		11.2	
Linoproductus	E36 Q3		21.1	25.6		4.6	
Linoproductus	E36 Q3		18.7	21.6		9.7	
Linoproductus	E36 Q3		18.2	20		9.6	
Linoproductus	E36 Q3		14.7	18.9		5.9	
Linoproductus	E36 Q3		16.9	20.2			
Linoproductus	E36 Q3		8.1	10.4			
Linoproductus	E36 Q3		9.8	11.4		3.2	
Linoproductus	E 36 11- 15"		18.8	19.2		6.7	
Linoproductus	E 36 11- 15"		11.7	16.2			
Linoproductus	E 36 11- 15"		14.6	16.8		4.7	
Linoproductus	E 36 11- 15"		20.5	19.3		8	
Linoproductus	E 36 11- 15"		15.1	20.2			
Linoproductus	E 36 11- 15"		17.9				
Linoproductus	E 36 11- 15"		19	23.1			
Linoproductus	E36 11- 15"		17.8				
Linoproductus	E36 11- 15"		25.9				
Linoproductus	E36 11- 15"		15.8				
Linoproductus	E36 11- 15"		14.2				
Linoproductus	E36 11- 15"		12.3	13.2			
Linoproductus	E36 11- 15"		9.6	14.2			
Linoproductus	M37 21-36 Q3			34.6			
Linoproductus	M 3.28		40.3			23	

Linoproductus	M 3.28			30.62				
Linoproductus	S55 4.5-5.25 Q3		30.7					
Linoproductus	S55 4.5-5.25 Q3		18.3	25.2				
Linoproductus	S55 4.5-5.25 Q3		23.5	20.7	10.6			
Linoproductus	S55 4.5-5.25 Q1		21.2	23.6				
Linoproductus	S55 4.5-5.25 Q1		19.1	23.8				
Linoproductus	S55 4.5-5.25 Q1			24.7				
Linoproductus	S55 4.5-5.25 Q1			17.33				
Linoproductus	M 28.21		24.4	31.2			13.5	
Linoproductus	M3 float		42.9	44.6				
Linoproductus	M3 float		31				22	
Linoproductus	M3 float		35.7	38.8				
Linoproductus	M3 float		24.4	26.8				
Punctospirifer	K35 Q3	D	9.9	16		5.1		
Punctospirifer	K35 Q3	V	13.6	22.3			5.4	
Punctospirifer	K35 Q3	V	11.8				5.5	
Punctospirifer	K35 Q3	V	9.2				3.3	
Punctospirifer	S39 2.5-3.0	V	6.7	11.2				
Punctospirifer	S39 2.5-3.0	V	6.3	10				
Punctospirifer	S39 2.5-3.0	V		13.3				
Punctospirifer	S39 2.5-3.0	V	5.8	6.8			1.7	
Punctospirifer	S39 2.5-3.0	V	8	12.8				
Punctospirifer	S55 4.5-5.25	V	7.3	11.1			3.4	
Punctospirifer	S55 4.5-5.25	D	8.5	16.3		2.3		
Punctospirifer	S55 4.5-5.25	V	6.5	13.2			2.9	
Punctospirifer	S55 4.5-5.25	V	7.1	8.7			2.6	
Punctospirifer	S55 4.5-5.25	V	7.7	11			2.8	
Punctospirifer	S55 4.5-5.25	D	8.2	14.2		2		
Punctospirifer	S55 4.5-5.25	D	7.8	12.4		2.2		
Punctospirifer	S55 4.5-5.25	D	7.2	12.5		3.3		
Punctospirifer	S55 4.5-5.25	V	7.9	10.8			4.2	
Punctospirifer	S55 4.5-5.25	D	9.6	15.4		3.7		
Punctospirifer	S55 4.5-5.25	V	5.1	7.7			2.2	
Punctospirifer	S55 4.5-5.25	V	12	18.6			5.7	
Punctospirifer	Magoffin W71	D	7	9.7			2.9	

	2.5-3.0						
Punctospirifer	Magoffin W71 2.5-3.0	V	4.3	5.9			
Punctospirifer	Magoffin W71 2.5-3.0	V	4.5	5.5			
Punctospirifer	Magoffin W71 2.5-3.0	V	4.4	6.7			
Punctospirifer	Magoffin W71 2.5-3.0	V	5.6	8.1			
Punctospirifer	M 37 28"-36"	V	5.7	10.4			
Punctospirifer	M 37 28"-36"	V	5.3	8.1		2	
Punctospirifer	M 37 28"-36"	V	8.5	15.6		3.2	
Punctospirifer	M 37 28"-36"	V	5.9	8.9			
Punctospirifer	M 37 28"-36"	V	7.6	10.6		3.8	
Punctospirifer	M 37 28"-36"	V	5.5	6.9		3	
Punctospirifer	M 37 28"-36"	V	6.4	9.9		2.8	
Punctospirifer	M 37 28"-36"	V	5.6	9.4		3.5	
Punctospirifer	M22.8	D	11.7	27.3			
Punctospirifer	K35B	V	9.9	15.2		5.9	
Punctospirifer	K35B	V	11.3	17.3		4	
Punctospirifer	K35B	V	11.7	17.4			
Punctospirifer	K35B	V	10.4	16.9			
Punctospirifer	K35B	V	11.9	21.3			
Rhipidomella	W74 B7 Magoffin		8.2	9.4			
Rhipidomella	W74 B7 Magoffin		6.9	8.3			
Rhipidomella	W74 B7 Magoffin		4.5	5.8			
Rhipidomella	W74 B7 Magoffin		9.3	13.1		3.9	
Rhipidomella	W74 B7 Magoffin		11.6	12.2		4	
Rhipidomella	W74 B7 Magoffin		8.1	9.2		3.1	
Rhipidomella	W74 B7 Magoffin		3.5	4.3			
Rhipidomella	W74 B7 Magoffin		4.6	5			
Rhipidomella	W74 B7 Magoffin		9.7				
Rhipidomella	W74 B7 Magoffin		9.5	8.1			
Rhipidomella	W74 B7 Magoffin		15.4				
Rhipidomella	W75 UZ Magoffin		7.8	9.7		2.1	
Rhipidomella	W75 UZ Magoffin		7.3	8.3		3.1	
Rhipidomella	W75 UZ Magoffin		8	9.8		1.6	
Rhipidomella	W75 UZ Magoffin		6.5	8.5		1.9	
Rhipidomella	W75 UZ Magoffin		5.8	8.1		1	
Rhipidomella	W75 UZ Magoffin		5.8	7.2		0.8	
Rhipidomella	M 68 6.5-7.5		9.9	14.5		4.1	

Rhipidomella	M 68 6.5-7.5		8.7	10.5			1.9	
Rhipidomella	M 68 6.5-7.5		8.7	10.3			2.5	
Rhipidomella	S31 3.5 Q3		8.4	10.1			2.4	
Rhipidomella	M37 21-28		11.3	14.7				
Rhipidomella	M77 30-34"		8.9	10.1			2.5	
Rhipidomella	M77 30-34"		7.6	9.3			3.2	
Rhipidomella	M77 30-34"		8.1	10.5			2.6	
Rhipidomella	M77 30-34"		9.9	10.9			2.3	
Rhipidomella	M77 30-34"		6.6	7.8				
Rhipidomella	M77 30-34"		3.1	4.5			1.3	
Rhipidomella	M77 30-34"		8.5	11.5				
Rhipidomella	M77 30-34"		6.8	9.9			1.9	
Rhipidomella	M77 30-34"		4.5	5.4				
Plicochonetes	W75 U2		6.3	8.7			1.5	
Plicochonetes	W75 U2		5.6	7.5			1.1	
Plicochonetes	W75 U2		4.9	6.1			0.6	
Plicochonetes	W75 U2		5.9	8.7			2.1	
Plicochonetes	W75 U2		5.3	7.1			1.5	
Plicochonetes	W75 U2		6.6	7.9				
Plicochonetes	W75 U2		5.4	7.7			1.5	
Plicochonetes	W75 U2		5.8	8.2			1.7	
Plicochonetes	W74 B7		4.9	8.9			2.5	
Plicochonetes	W74 B7		6.8	9.4			2.2	
Plicochonetes	W74 B7		6.1	8.3			2.3	
Plicochonetes	W74 B7		6.7	9.4			2.9	
Plicochonetes	W74 B7		5.4	7.5			1.6	
Plicochonetes	W74 B7		5.1	8.1			0.9	
Plicochonetes	W74 B7		6.5	7.3			2.4	
Plicochonetes	W74 B7		5.5	8.4			1.5	
Plicochonetes	W74 B7		7.2	9			2.7	
Plicochonetes	W74 B7		5.8	8.2			1.5	
Plicochonetes	W74 B7		7.3	9.9			4.4	
Plicochonetes	M77 30-34"		4.9	7.7				
Plicochonetes	M77 30-34"		5.3	6.5			2.9	
Plicochonetes	M77 30-34"		6.2	7.9			2.2	
Plicochonetes	W75 U2		6.4	8.5			1.8	
Plicochonetes	W75 U2		5.5	7.6			1.5	
Plicochonetes	W75 U2		5.4					
Plicochonetes	W75 U2		4.6	5.8				
Plicochonetes	W75 U2		4.4	7.1			0.8	

Plicochonetes	W75 U2		6.3	9.3			2.4	
Plicochonetes	W75 U2		6.1	7.7			1.7	
Plicochonetes	W75 U2		4.5	6.3				
Plicochonetes	W75 U2		3.9	5.9			1.3	
Plicochonetes	W75 U2		5.2	7.3			1.5	
Rugosochonetes	M37 4.25- 4.75		6.2	9.2				
Rugosochonetes	M37 4.25- 4.75		7.9	12				
Rugosochonetes	M37 4.25- 4.75		3.5	5.3				
Rugosochonetes	M37 4.25- 4.75		6	8.8			1.9	
Rugosochonetes	M37 4.25- 4.75		7.5	12.4			1.5	
Rugosochonetes	M37 4.25- 4.75		6.5	10.3			1.5	
Rugosochonetes	M10.40		7.34	11.4			1.2	
Rugosochonetes	M10.40		6.4	12.1			1.4	
Rugosochonetes	M10.40		5.3	9.4			1.4	
Rugosochonetes	M10.40		5.4	8.8			1.2	
Rugosochonetes	M10.40		6.9	12.2				
Rugosochonetes	M3.28		3.3	5.3				
Rugosochonetes	M3.28		2.8	4				
Rugosochonetes	M3.28		4.1	6.6			0.9	
Rugosochonetes	M3.28		6.5	10.8			1.3	
Rugosochonetes	M3.28		7.9	12.3			1.2	
Rugosochonetes	M3.28		6.7	10.7			1.5	
Rugosochonetes	M3.28		7.2	11.8			1.1	
Rugosochonetes	M3.28		6.7	10.4			0.9	
Rugosochonetes	M3.28		6.7	10.6			1.6	
Rugosochonetes	M3.28		7.2	11.1			0.9	
Rugosochonetes	M3.28		6.3	9.9			1.1	
Rugosochonetes	M3.28		5.3	8.4			1.2	
Rugosochonetes	M3.28		7.7	11.6			1.4	
Rugosochonetes	M3.28		6.8	10.5			1.3	
Rugosochonetes	M3.28		4.9	7.2			0.8	
Rugosochonetes	M3.28		4.8	7.9			1	
Rugosochonetes	M3.28		6.2	10.2			1.1	
Rugosochonetes	M3.28		8.1	12.9			1.8	
Rugosochonetes	M3.28		4.2	5.5				
Rugosochonetes	M3.28		3.3	5.6				
Rugosochonetes	M3.28		4	7.5			0.8	
Rugosochonetes	M3.28		3.7	6.2				
Rugosochonetes	M3.28		3.5	6.1				
Rugosochonetes	M3.28		3.4	5.7				

Rugosochonetes	M3.28		4.4	7.4			0.8	
Rugosochonetes	M3.28		6.2	9.8			1.3	
Rugosochonetes	M50 6- 11"		10.9	17.6			2	
Rugosochonetes	S52 3.75- 4.25		9.4	17.6			2.6	
Rugosochonetes	S52 3.75- 4.25		7.2	9.6				
Rugosochonetes	S52 3.75- 4.25		8.5	11.8			2.6	
Rugosochonetes	S52 3.75- 4.25		17.2	12.1				
Rugosochonetes	S52 3.75- 4.25		6.3	10.7			1.4	
Rugosochonetes	S52 3.75- 4.25		9.4					
Rugosochonetes	S55 4.5-5.25 Q3		8.5	13.7			2.3	
Rugosochonetes	S55 4.5-5.25 Q3		7.6	10.7			1.9	
Rugosochonetes	S55 4.5-5.25 Q3		5.9	9.4			1.2	
Rugosochonetes	S55 4.5-5.25 Q3		7.4	11.7			2.6	
Rugosochonetes	S55 4.5-5.25 Q3		7.6	11.8			2.1	
Rugosochonetes	S55 4.5-5.25 Q3		3.8	7			1.1	
Rugosochonetes	S55 4.5-5.25 Q3		6	9.9			1.6	
Rugosochonetes	S55 4.5-5.25 Q3		3.7	5.7			0.6	
Rugosochonetes	S55 4.5-5.25 Q3		7.5	12.1			3.2	
Rugosochonetes	S55 4.5-5.25 Q3		7.9	12.5			1.3	
Eolissochonetes	K34 4-8"		3.6	5.8			0.5	
Eolissochonetes	K34 4-8"		4.1	7.1			0.6	
Eolissochonetes	K34 4-8"		6.1	9.2			1.6	
Eolissochonetes	K34 4-8"		6.5	9.7			1.8	
Eolissochonetes	K34 4-8"		5.7	8.9			0.9	
Eolissochonetes	K34 4-8"		5.9	9.3			1	
Eolissochonetes	K34 4-8"		5.3	8.5			1.1	
Eolissochonetes	K34 4-8"		4.2	6.9			1.1	
Eolissochonetes	K34 4-8"		4.3	7.6			2.4	
Eolissochonetes	K34 4-8"		1.5	2.7				
Eolissochonetes	K34 4-8"		2.6	4.4				
Eolissochonetes	K34 4-8"		4.9	8.5				
Eolissochonetes	K34 4-8"		5.3	8.2			1.2	
Eolissochonetes	K34 4-8"		4.1	6.4			0.5	

Eolissochonetes	K34 4-8"		2.2	3.6				
Eolissochonetes	K34 4-8"		3.2	5.4			1	
Eolissochonetes	K34 4-8"		3.4	5.2			0.7	
Eolissochonetes	K34 4-8"		2.5	4.2				
Eolissochonetes	K34 4-8"		2.6	3.8				
Eolissochonetes	K66 4.5-5 Q1		5.2	9.5				
Eolissochonetes	K66 4.5-5 Q1		5.3	8.7				
Eolissochonetes	K66 4.5-5 Q1		6.2	9.7				
Eolissochonetes	K66 4.5-5 Q1		4.7	7.1				
Eolissochonetes	K66 4.5-5 Q1		5.9	7.9				
Eolissochonetes	K66 4.5-5 Q1		4.7	6.1				
Eolissochonetes	K66 4.5-5 Q1		5.4	7.5				
Eolissochonetes	K66 4.5-5 Q1		4.7	6.4				
Eolissochonetes	K66 4.5-5 Q1		5.3	8.9				
Eolissochonetes	K66 4.5-5 Q1		3.4	5.2				
Eolissochonetes	K66 4.5-5 Q1		6.7	10			1.5	
Eolissochonetes	K48 1-5"		4.8	7.1			1.1	
Eolissochonetes	K48 1-5"		4.4	6.7			1.1	
Eolissochonetes	K48 1-5"		2.7	6.1				
Eolissochonetes	K48 1-5"		5.5	8.4				
Eolissochonetes	K48 1-5"		3.8	6			1.8	
Eolissochonetes	K48 1-5"		3.1	4.8			1.1	
Schizophoria	S39 2-2.5 Q1		23.7	25.4				
Schizophoria	S39 2-2.5 Q1		15.5	16.7				
Schizophoria	S39 2-2.5 Q1		18.4	22.7				
Schizophoria	S29 0-12" Q1		16.1	15				
Schizophoria	S29 0-12" Q1		17	20.6				
Schizophoria	S39 2-2.5 Q2		17.9	19.1				
Schizophoria	Unknown		16	18.8				
Schizophoria	Unknown		25.9	26.5				
Schizophoria	Unknown		16.2					
Schizophoria	Unknown		12.4					
Schizophoria	M37 21-36" Q2		35.7	32.1				
Schizophoria	M37 21-36" Q2		24.4	25.2				
Schizophoria	M37 21-36" Q2		15.8	15.3				
Schizophoria	M37 21-36" Q2		17.1	19.2				
Schizophoria	M37 21-36" Q2		8.8					
Schizophoria	M37 21-36" Q2			33.1				
Schizophoria	M37 21-36" Q2		15.2	12				
Schizophoria	M37 21-36" Q2		12.2					

Schizophoria	M37 21-36" Q2			12.8				
Schizophoria	M22.5		4.7	6.7			0.9	

Notes on brachiopod measurements: All #s are on ventral valves for *Antiquatonia*; Due to poor preservation, couldn't tell which is which among measured dimensions on *Beecheria* specimen from S31 3.5 Q3.

Overall note: W's in many sample names likely represent Magoffin.

Appendix 4 - Estimations

sp.	AP	LR	DV	Ratios used to impute, if any	Geometric mean	Volume estimate	Max dimension	dry mass estimate	metabolic estimate
Acanthopecten	8.904737	8.506076	2.010695	DV/AP, AP/DV, LR/AP	5.340E+00	7.974E+01	8.905E+00	6.330E-03	1.641E+07
Astartella	11.61143	9.449508	6.627474		8.993E+00	3.808E+02	1.161E+01	1.385E-02	3.178E+07
Aviculopecten	10.44347	10.63544	3.107904		7.015E+00	1.807E+02	1.064E+01	1.069E-02	2.430E+07
Clavicosta	4.45	4.95	2.8		3.951E+00	3.229E+01	4.950E+00	1.120E-03	4.475E+06
Clinopsitha	10.86275	8.016667	4.5		7.318E+00	2.052E+02	1.086E+01	1.138E-02	2.547E+07
Cypricardinia	21.10436	11.42207	7.330061	LR/AP, DV/AP, AP/DV	1.209E+01	9.252E+02	2.110E+01	8.070E-02	1.192E+08
Dunbarella	10.4	8.3	1.434483	LR/AP	4.984E+00	6.483E+01	1.040E+01	1.001E-02	2.313E+07
Edmondia	17.77786	13.43623	7.49994		1.215E+01	9.380E+02	1.778E+01	4.866E-02	7.574E+07
Euchondria	5.872538	5.790909	2.367928		4.318E+00	4.216E+01	5.873E+00	1.854E-03	6.531E+06
Exochorynchus	32.44138	19.2	5.6	AP/DV from treatise	1.517E+01	1.826E+03	3.244E+01	2.869E-01	2.866E+08
Goniophora	11.1	5.4	3.6		5.998E+00	1.130E+02	1.110E+01	1.213E-02	2.671E+07
Leptodesma	6.9	3.6	4.143198		4.686E+00	5.389E+01	6.900E+00	2.983E-03	9.330E+06
Myalinella	7.8	4.2	4.6		5.321E+00	7.890E+01	7.800E+00	4.282E-03	1.224E+07
Nucula and Nuculoidea	3.897143	3.457143	2.324931		3.152E+00	1.640E+01	3.897E+00	5.530E-04	2.636E+06
Nuculopsis	7.823077	5.665461	3.752027		5.499E+00	8.707E+01	7.823E+00	4.320E-03	1.232E+07
Paleolima	5.8	3.687688	4.447553	DV/AP, LR/AP	4.565E+00	4.981E+01	5.800E+00	1.787E-03	6.354E+06
Paleoneilo	10.16092	6.334581	4.637378		6.683E+00	1.563E+02	1.016E+01	9.342E-03	2.197E+07
Paleyoldia	16.1	10.525	5.478555	LR/AP	9.755E+00	4.861E+02	1.610E+01	3.632E-02	6.082E+07
Parallelodon	14.57	7.056667	5.787544		8.411E+00	3.116E+02	1.457E+01	2.705E-02	4.876E+07
Permophorus	20.78599	10.45339	7.026953		1.152E+01	7.995E+02	2.079E+01	7.717E-02	1.153E+08
Phestia	10.88088	5.953333	4.175333		6.467E+00	1.416E+02	1.088E+01	1.143E-02	2.556E+07
Pleurophonella	11.02467	6.78	3.443055	AP/DV, LR/DV	6.361E+00	1.348E+02	1.102E+01	1.188E-02	2.834E+07
Posidonia	9.82	10.61	2.659265		6.519E+00	1.451E+02	1.061E+01	1.061E-02	2.417E+07
Promytilus	12.63274	6.701005	4.112806		7.035E+00	1.823E+02	1.263E+01	1.776E-02	3.556E+07
Schizodus	20.39126	18.24536	11.83281		1.639E+01	2.305E+03	2.039E+01	7.292E-02	1.026E+08
Septomyalina	23.92602	12.38765	10.20359		1.446E+01	1.583E+03	2.393E+01	1.169E-01	1.461E+08
Solemya	15.5	8.533333	4.266667	LR half of DV	8.264E+00	2.955E+02	1.550E+01	3.247E-02	5.592E+07
Wilkingia	22.14116	13.53556	12.56967	AP/DV, DV/AP, LR/DV	1.556E+01	1.972E+03	2.214E+01	9.297E-02	1.231E+08

Anthracospirifer	12.36984	17.09048	11.96498	Ventral/AP	1.363E+01	1.324E+03	1.709E+01	1.048E-02	1.198E+07
Antiquatonia	19.5386	24.21228	12.0193		1.785E+01	2.977E+03	2.421E+01	3.356E-02	2.866E+07
Beecheria	7.1	6.1	1.7		4.191E+00	3.855E+01	7.100E+00	5.576E-04	1.326E+06
CHONET	5.419815	8.454349	1.230477		3.834E+00	3.199E+01	4.227E+00	9.865E-05	3.618E+05
Cleiothyridina	8.038095	8.568254	2.496917		5.561E+00	9.004E+01	8.568E+00	1.045E-03	2.124E+06
Composita	17.16797	16.69526	12.14609		1.516E+01	1.823E+03	1.717E+01	1.064E-02	1.211E+07
Crurithyris	4.485001	5.026411	2.3583		3.760E+00	2.784E+01	5.026E+00	1.759E-04	5.583E+05
Derbyia	14.12286	17.26	6.813257		1.184E+01	8.696E+02	1.726E+01	1.083E-02	1.227E+07
Desmoinesia	10.826	13.27	6.03168		9.534E+00	4.537E+02	1.327E+01	4.503E-03	6.354E+06
Hustedia	6.758506	6.728951	4.079269		5.703E+00	9.714E+01	6.759E+00	4.729E-04	1.172E+06
Juresania	18.97426	22.41925	10.06763		1.624E+01	2.242E+03	2.242E+01	2.595E-02	2.363E+07
Kozlowskia	10.7	13.07308	6.911538		9.888E+00	5.062E+02	1.307E+01	4.283E-03	6.120E+06
Lingula	3.082353	2	1	DV/LR	1.834E+00	3.228E+00	3.082E+00	3.435E-05	1.413E+05
Linoproductus	19.27888	22.02131	8.486841		1.533E+01	1.887E+03	2.202E+01	2.444E-02	2.260E+07
Neospirifer	20.00971	31.22979	12.69188		1.994E+01	4.153E+03	3.123E+01	7.851E-02	5.422E+07
Oehlertella	4.82	5.099907	4.485444	LR/AP, DV/AP	4.795E+00	5.773E+01	5.100E+00	1.846E-04	4.988E+05
Orbiculoidea	9.043559	9.045766	6.493841		8.099E+00	2.782E+02	9.046E+00	1.252E-03	2.096E+06
Plicochonetes	5.68125	7.854323	1.834146		4.342E+00	4.285E+01	3.927E+00	7.715E-05	3.009E+05
Punctospirifer	7.943703	12.71822	6.683788		8.773E+00	3.536E+02	1.272E+01	3.907E-03	5.712E+06
Rhipidomella	7.854839	9.593503	2.331791		5.601E+00	9.200E+01	9.594E+00	1.524E-03	2.819E+06
Rhynchopora	7.188889	7.41614	2.193574		4.890E+00	6.123E+01	7.416E+00	6.449E-04	1.479E+06
Schizophoria	17.83153	18.72239	3.414549	AP/LR, LR/AP, Ventral/AP	1.045E+01	5.969E+02	1.872E+01	1.422E-02	1.505E+07
Trigonoglossa	12.33333	14.56667	3.109207	DV/AP	8.236E+00	2.925E+02	1.457E+01	6.148E-03	6.914E+06