

Size differences of the post-anoxia, biotic recovery brachiopod, *Dyoros* sp., in Hughes Creek Shale (Carboniferous), Richardson County, Nebraska.

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Abstract. Two localities of the Carboniferous Hughes Creek Shale in southeastern Nebraska contain both fossiliferous limestones and shales, as well as black shales interpreted as being deposited under anoxic conditions in ancient oceans. Fossils within strata above the anoxic layers represent life that had recovered from a local killing event. Examining the killing/recovery patterns on expanded, regional scales is made difficult due to the relative lack of good exposures between outcrops. Previous miscorrelations have occurred for the Hughes Creek Shale in two established collecting localities separated by only a few kilometers. Specimens of the brachiopod fossil, *Dyoros* sp., abundant at both localities were compared using the size frequency distributions of their length measurements. Null hypotheses of the equality of the medians and equality of the overall distributions were not able to be rejected, adding support to the current accepted interpretation of correlation for the two localities, allowing for future use of both for examining killing/recovery of life on expanded geographic scale.

Introduction

The Hughes Creek Shale of southeastern Nebraska is a Carboniferous Period (~350-290 million years ago) rock unit that has been interpreted to contain evidence of several intervals of anoxia, or low/no oxygen in the oceans in which they were originally deposited. The anoxic episodes are shown as black-colored shales that are devoid of fossil remains. For the Hughes Creek Shale the anoxic episodes were regional in scale probably covering only several 100km². Even so, they are a good, small-scale model for the larger (global?) existence of anoxia during mass extinction events, such as at the end of the Permian Period (~250 million years ago), while the “normal” limestones and shales deposited above them (and containing fossils) indicate how life and environments recover afterwards.

Before testing any hypotheses of mass extinction and recovery, it is necessary to show that rocks in geographically separated locations can be correlated, or shown to be coeval. Locality 5 of Pabian and Diffendal (2003) is assumed to be correlative to their Locality 10, but they correctly note that it was only a few years before thought to be from a different formation, and several million years younger (Holterhoff and Pabian, 1990). Correlative rock units in this study are assumed to contain fossils with the same size characteristics. In order to test a hypothesis that Localities 5 and 10 are correlative, the size frequency distributions of one of the most distinctive and well-preserved species, the brachiopod *Dyoros* sp., were statistically compared.

Significance for Astrobiology

Anoxic events as preserved in the stratigraphic record on Earth are related to space science via the interdisciplinary sciences of Astrobiology and Exobiology. The current guidelines for NASA-supported studies of this type are the Astrobiology Roadmap (Des Marais et al., 2008). This paper addresses GOAL4 – “Understand how life on Earth and its planetary environment have co-evolved through geological time. Investigate the evolving relationships between Earth and its biota by integrating evidence from the geosciences and biosciences that shows how life evolved, responded to environmental change, and modified environmental conditions on a planetary scale.” Objective 4.3 within GOAL 4 is to investigate the effects of extraterrestrial and terrestrial events upon the biosphere, with research based on the fossil record of life and its activities. Evidence of the timeliness of such studies is the fact that a complete session, entitled, “Oxygen and Evolution: Looking to the Past” was devoted to anoxic black rocks and their associated fossils in the most recent Astrobiology Science Conference 2012 (NASA, 2012).

Location

Carboniferous age rocks are sporadically exposed in road and stream cuts throughout southeastern Nebraska. Localities 5 and 10 (Figure 1) are both road cut exposures of the Carboniferous rocks in Richardson County, Nebraska, separated by approximately 10 miles of geographic distance. The land cover between the two localities is mostly agricultural, making exact correlations, and even formation identification, difficult.

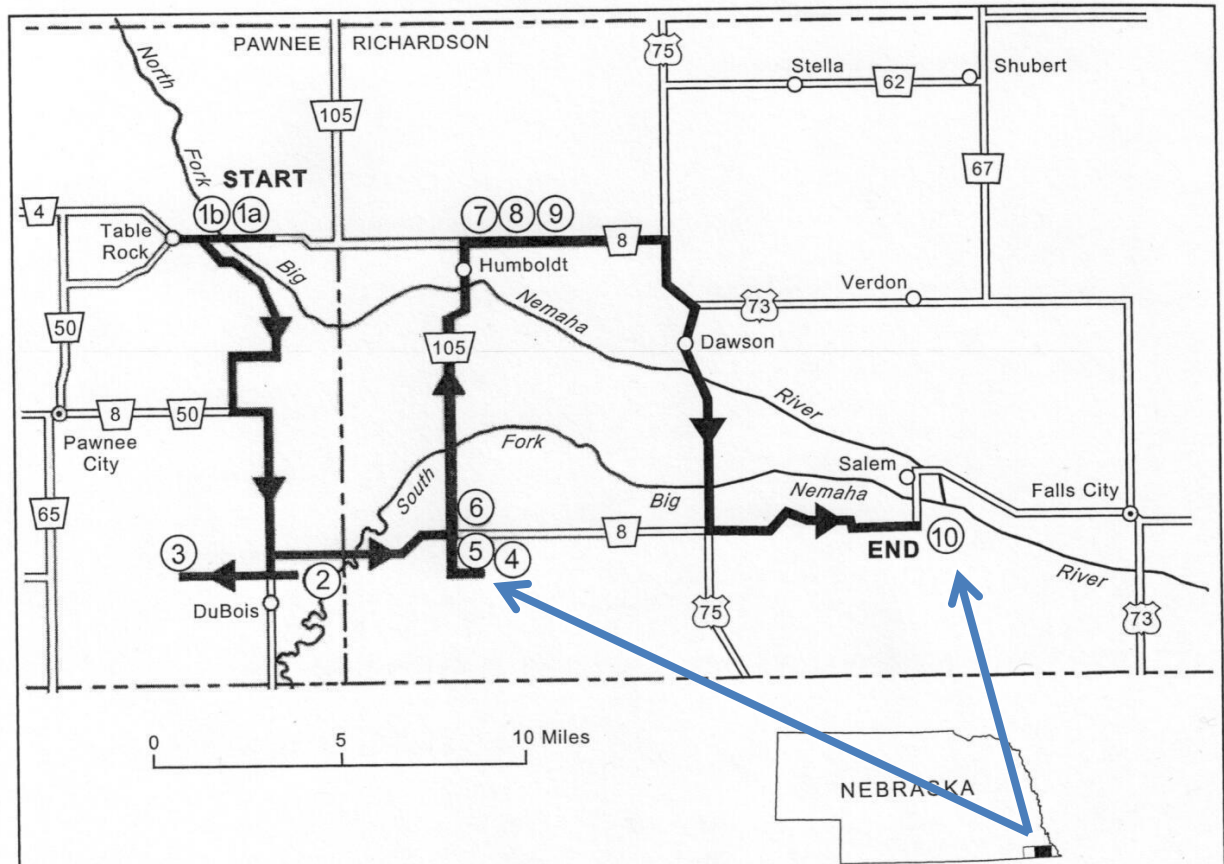


Figure 1 – Locality map of Carboniferous localities in southeastern Nebraska (adapted from Pabian and Diffendal, 2003). Localities 5 and 10 are indicated with arrows.

Methods

Specimens of *Dyoros* sp. were collected in the field using both surface collection and bulk sampling methods. These have been shown previously to be an efficient method of maximizing species richness and biomass values. Both localities (5 and 10 of Pabian and Diffendal, 2003) were sampled for equal duration over relatively equal surface areas. In addition, the field collections were supplemented by previously collected specimens from the same sampling localities now deposited in the University of Wisconsin-Whitewater Invertebrate Paleontology collections. All *Dyoros* sp. specimens (N=103 from Loc. 5; N=257 from Loc. 10) were identified, sorted from the other taxa, counted, and measured for length and width (Figure 2) using digital calipers.

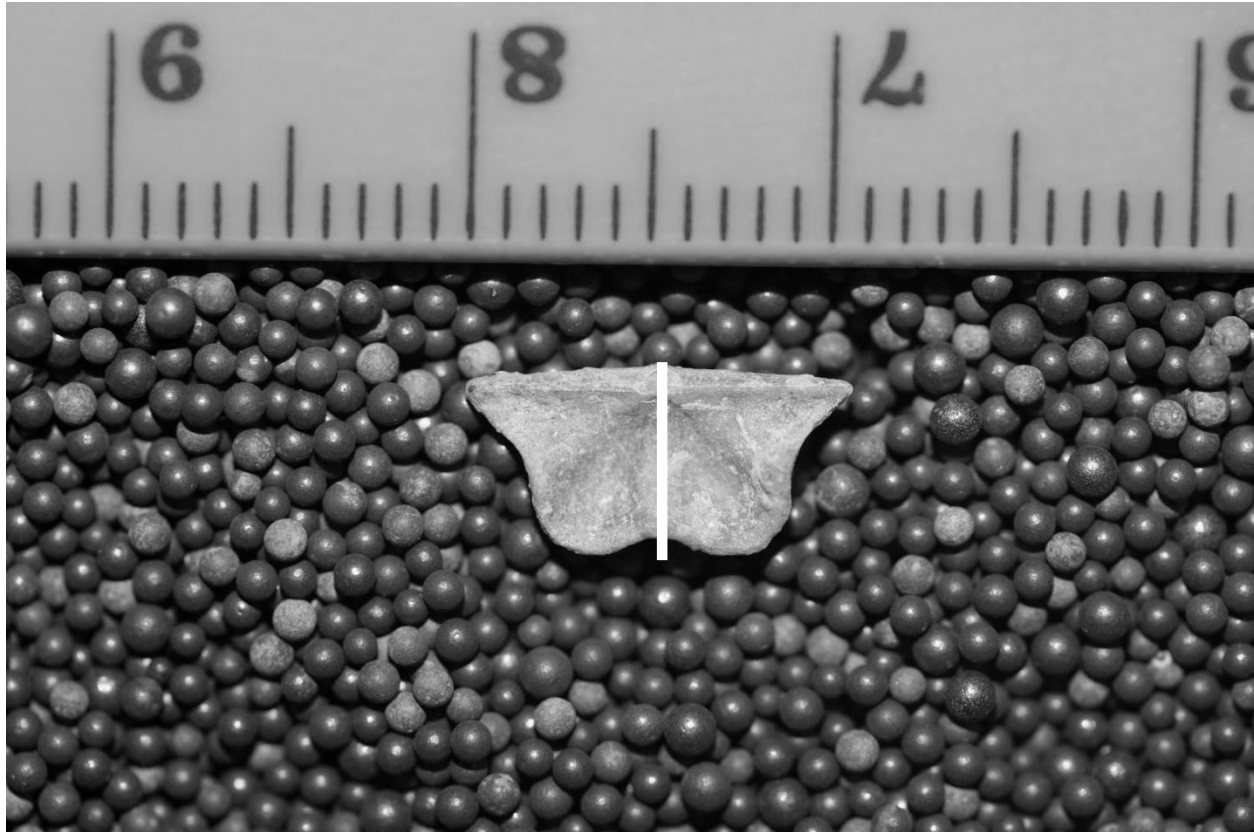


Figure 2 – Ventral view of *Dyoros* sp. from the Hughes Creek Shale. White bar indicates the standardized length measurement for all individuals. For the individual shown, length = 12.73mm.

All statistical analyses were performed using the software package, PAST (Hammer et al., 2001). Measurements of the length of unbroken specimens were log-transformed as is standard in biometric analyses (Zelditch et al., 2012) and tested for normality using the Shapiro-Wilk test. The Mann-Whitney U and Kruskal-Wallis tests were used to test hypotheses of equality of medians, and the Kolmogorov-Smirnov test was used to test a hypothesis of equality of distributions for the two sampling localities.

Results

Though both the distributions for Localities 5 and 10 appear normally distributed (Figure 3), Shapiro-Wilk tests for their normal distribution are rejected for Locality 5, $p(\text{normal}) = 3.009 \times 10^{-5}$; but not for Locality 10, $p(\text{normal}) = 0.06558$. Since at least one of the distributions is not normal, non-parametric statistical tests were used for further testing.

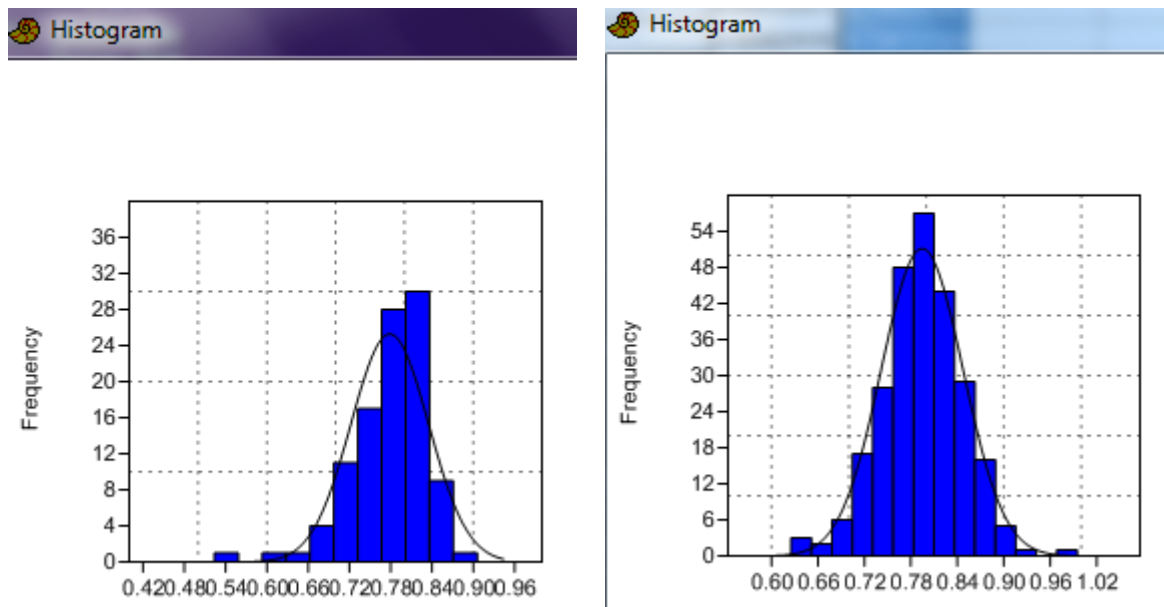


Figure 3 – Size frequency distributions for log-transformed mm length measurements (x-axis) of *Dyoros* sp. at Locality 5 (right) and Locality 10 (left).

Both the Mann-Whitney U and the Kruskal-Wallis are used with non-normal distributions tests for a null hypothesis that two samples are taken from populations with equal medians. Values greater than 0.05 would fail to reject such hypotheses, and thus one could not say that the medians of the two distributions had different medians. Both the Mann-Whitney ($p=0.05217$) and the Kruskal-Wallis ($p=0.0521$) fail to reject the null hypothesis.

The Kolmogorov-Smirnov can test a null hypothesis of equality of overall distributions for non-normal data. For a null hypothesis that the two samples are taken from populations with equal distributions, p values greater than 0.05 will fail to reject, and one could say that the two samples had different distributions. The Kolmogorov-Smirnov ($p=0.1563$) thus fails to reject the null hypothesis.

Discussion and Conclusions

Body size is an important population characteristic for all marine animals, but especially so for suspension feeding organisms, such as the brachiopod *Dyoros* sp., because the size of the body has a direct effect on the availability of food particles moving around an obstructive skeleton (Humphries, 2007). In general, larger body sizes can be viewed as a positive factor in feeding, with increased size meaning increased size of flow (and thus, food) vortices shed around a suspension feeding organism. If the ambient environment were different in the original seas existing at Localities 5 and 10, such as would be expected if the two localities were not coeval,

then the expectation would be that this should be reflected in different body size distributions between localities for populations of the same species, like *Dyoros* sp.

At the community level, body size distribution has proven useful in describing variation both within and between modern (Robson et al., 2005) and ancient (Payne, 2005) communities. The relative body size distributions of any member species may control the species composition and relative abundances, influencing community function. Again, if Localities 5 and 10 were not coeval, then the expected, different body size distributions of suspension feeding species like *Dyoros* sp. would produce cascading effects throughout numerous species of the communities, which are simply not observed for Localities 5 and 10.

The failure to reject null hypotheses of the equality of medians (Mann-Whitney and Kruskal-Wallis tests) and equality of distributions (Kolomogorov-Smirnov test) supports the correlation of Localities 5 and 10 of the Hughes Creek Shale. This then fails to reject an informal hypothesis that the two localities preserve coeval beds of strata. The rejection of the earlier interpretation of Holterhoff and Pabian (1990) by Pabian and Diffendal (2003) is supported by the evidence presented here.

Confident that Localities 5 and 10 are indeed coeval, they can both be used in aggregate to examine the recovery of marine fauna after recovery after a small-scale anoxic event covering at minimum, the ~10 mile distance between them. Both localities are highly fossiliferous, and their summed diversities and body size distributions for all taxa, including *Dyoros* sp., as shown here, add to their robustness as an astrobiologic model for the extinction and recovery of taxa during larger-scale extinctions.

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