Benthic ecosystem dynamics following the Late Triassic mass extinction event: palaeoecology of the Blue Lias Formation, Lyme Regis, UK

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The Blue Lias Formation of southwest UK records the evolution of a marine, shelf ecosystem following the Late Triassic extinction event. In order to investigate responses of the local palaeocommunity to environmental changes during this critical interval in Earth history, a quantitative palaeoecological analysis of the well exposed, fossiliferous and historically important sedimentary succession between Pinhay Bay and Lyme Regis, southern England, was undertaken. Quantitative palaeoecological data were collected from 19 limestone beds of the Rhaetian-Sinemurian Blue Lias Formation. For each sampled bed, all macroinvertebrate fossil remains found within two 50 x 50 cm quadrats placed on the exposed bedding plane surface were counted and identified. Palaeoecological changes were assessed through analyses of diversity, richness, evenness, abundance and occupation of ecospace. There is a general trend from palaeocommunities with low diversity, richness, abundance and evenness around the Triassic/Jurassic boundary to those with higher diversity, richness, abundance and evenness in the late Hettangian, but there are intervals of relative stasis as well as significant shifts within biozones and even between adjacent beds. Most of the Rhaetian-Hettangian palaeocommunities are dominated by low-level, surficial, suspension feeders, but the appearance of higher- and deeper-tier organisms, and an increase in motility and feeding styles, characterise key stages of post-extinction recovery. The earliest Sinemurian assemblages show a return to low diversity, low evenness assemblages, but with high abundance. Where there is a stratigraphic overlap, the palaeoecological changes recorded in this study are comparable to those recorded from other southwest UK sites, despite differences in sampling methodology, and are mirrored by changes in the trace fossil assemblages. Local palaeocommunities were probably responding to local and global environmental and climatic changes, perhaps driven by changes in atmospheric CO_2 through the aftermath of the Late Triassic extinction event.

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Introduction

The Late Triassic mass extinction is considered to be the fourth largest such event of the Phanerozoic (Hallam, 1990), and resulted in the final disappearance of taxa such as the ceratite ammonites and important bivalve and brachiopod groups, and the overall loss of 24.3% of marine families (Benton, 1995). In terms of its ecological impact, the extinction is ranked as the third most important of the Phanerozoic (Sheehan, 1996; McGhee *et al.*, 2013), and is the most significant event to have impacted post-Palaeozoic marine ecosystems. Previous hypotheses of an extraterrestrial cause (e.g. Olsen *et al.*, 1987; Ward *et al.*, 2001) have been rejected following revised dating of proposed impact craters and ejecta (Walkden *et al.*, 2002), and environmental and climatic changes resulting from massive volcanism in the Central Atlantic Magmatic Province (CAMP) are now considered the most likely causes of the extinction (Marzoli *et al.*, 1999, 2004; Wignall, 2001a; Pàlfy *et al.*, 2002; Pàlfy, 2003).

The timing of CAMP volcanism and the Late Triassic mass extinction are closely linked (Blackburn *et al.*, 2013), with volcanism being invoked as the cause of major changes in atmospheric conditions during the Late Triassic. The input of significant amounts of carbon dioxide into the atmosphere during outgassing from CAMP may explain the dramatic rise in atmospheric CO_2 levels inferred from palaeobotanical (McElwain *et al.*, 1999; Steinthorsdottir *et al.*, 2011) and palaeosol (Schaller *et al.*, 2011) proxies across the Triassic/Jurassic boundary. Beerling and Berner (2002) estimated that up to ~8,000-9,000 Gt of CO_2 and ~500 Gt of methane may have been released, which would have led to a rapid global warming. Elevated CO_2 and global warming would have had a number of environmental consequences for marine ecosystems, such as sea-level rise, reduced ocean circulation, expanding hypoxia, elevated weathering, runoff, nutrient influx and sedimentation rates, as recorded for other warming-related biotic crises such as the Late Permian mass extinction (Jaraula *et al.*, 2013).

Despite the importance of the Late Triassic event for the early evolution of modern-style ecosystems, relatively few studies have documented in detail the palaeoecological responses of marine ecosystems to this crisis. High resolution palaeoecological studies of the Triassic-Jurassic benthic macrofauna have previously been undertaken in southwest UK