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Journal of Experimental Marine Biology and Ecology 334 (2006) 96–108

Journal of EXPERIMENTAL MARINE BIOLOGY AND ECOLOGY

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Effect of rock type on the recruitment and early mortality of the barnacle *Chthamalus montagui*

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Received 10 April 2005; received in revised form 26 November 2005; accepted 18 January 2006

Abstract

Discontinuities in distribution of sessile species due to changes in available habitat have rarely been investigated. In the English Channel, soft sedimentary rocks including chalk could potentially present a barrier to eastward range extension of the southern barnacle *Chthamalus montagui*. To test the effect of rock type on recruitment and mortality, prepared settlement tiles of four calcareous rocks that form important platforms close to existing limits of distribution were fixed to the shore at a site in south-west England, known to have consistently high larval settlement. Prior to fixation, the roughness parameter "R_a" and Potential Settlement Sites (PSS) index was measured. Recruitment was monitored photographically on four occasions during the settlement season and subsequent mortality for 7 months after the settlement season. By the end of the settlement season, recruitment on the hard Kimmeridge Cementstone was significantly less than on the other three rock types and attributed to low surface roughness and fewest Potential Settlement Sites (PSS), yet only 28% of variance could be attributed to PSS. Post-recruitment mortality was more variable, however after 7 months there were significant differences between rock types. Simultaneous surveys of post-recruitment mortality in natural populations showed that although recruitment on chalk can potentially be high, survivorship was relatively low. Thus rock type could be influential in setting species geographical limits.

Keywords: Barnacles; *Chthamalus montagui*; Post-recruitment mortality; Potential settlement sites; Range extension; Recruitment; Rock type; Settlement; Substratum

1. Introduction

Of all possible factors that set geographic limits of marine species, the availability of suitable habitat on which to settle and survive to reproductive maturity is of fundamental importance. This is particularly critical for rocky shore species such as barnacles, where the range of a species depends on the presence of hard substrata. Any range extension prompted by climatic changes requires suitable substratum that is accessible within the life span of pelagic larvae. Yet the specific attributes of the substratum favoured by settling barnacle cyprids and other invertebrate larvae have been shown to be many and varied; rugosity, thermal capacity, colour, surface

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doi:10.1016/j.jembe.2006.01.023

energy and charge and elemental composition (Crisp, 1961, 1974; Crisp and Barnes, 1954; Lewis, 1977; Wethey, 1986; Le Tourneux and Bourget, 1988; Holmes et al., 1997; Berntsson et al., 2000), thickness, composition and age of microbial films (Holmstroem et al., 1992; Wieczorek et al., 1996; Thompson et al., 1998) and presence of conspecifics (Knight-Jones, 1953; Crisp and Meadows, 1962).

The mineral composition of the substrate determines its hardness and resistance to weathering, and can therefore influence surface topography and heterogeneity over a considerable spatial scale. Yet on rocky shores, direct effects of rock type on the pattern of zonation of species are considered to be relatively unimportant compared to its angle and profile, and are unlikely to set species geographical limits (Lewis, 1964). Friable and soft limestones, chalk and sandstones may however be unsuitable for barnacles and large algae compared to harder granite, while pitted limestones could be more beneficial for small littorinids (Lewis, 1964).

The presence of quartz has been shown to have a direct inhibitory effect on animal colonisation in soft-sediments (Cerrano et al., 1999) and highly influential in structuring sublittoral rocky assemblages (Bavestrello et al., 2000; Guidetti and Cattaneo-Vietti, 2002; Guidetti et al., 2004). The term bio-mineralogy has been used to describe the interactions between organisms and minerals (Cerrano et al., 1999) and it has been suggested that mineralogical composition of substrates could influence primary production processes and consumer control in marine habitats (Guidetti et al., 2004). Yet in comparison to the use of artificial substrata in experiments aimed at understanding the role of substrate heterogeneity on recruitment and community development (Wethey, 1986; Bourget et al., 1994; Lemire and Bourget, 1996; Lapointe and Bourget, 1999; Pech et al., 2002) the influence of different naturally weathered rock surfaces upon invertebrate recruitment and community development has received relatively little field investigation and early post-settlement mortality even less attention. Because in nature, larvae are never exposed to single factor dichotomous choices, experiments on settlement should enable larvae to respond to an integrated series of substratum characteristics, which therefore must involve natural weathered substrata (Caffey, 1982; McGuinness, 1989).

Studies undertaken on the effect of rock type on the settlement of barnacle larvae have resulted in somewhat conflicting results. Hatton (1938) found no difference in settlement density of *Semibalanus balanoides* on three types of granite and diabase. In a four-factor experiment with the Australian barnacle species *Tesseropora rosea* on shale, sandstone, mudstone and gabbro, there were no consistent patterns of settlement due to the influence of rock type alone, nor in interaction with factors representing spatial variation at two scales (Caffey, 1982). Significant differences in settlement preferences of *S. balanoides* cyprids were obtained between polished samples of 15 different rock types suspended from a pier at Millport in Scotland and were independent of any potential effect of surface rugosity or colour cues (Holmes et al., 1997). Surface roughness has long been known to be an important parameter influencing *S. balanoides* settlement (Barnes, 1956; Crisp, 1961; Crisp and Barnes, 1954). Settling cyprids of *S. balanoides* prefer small pits (Crisp, 1961, 1976) but also favour changes in surface relief provided by adults where they find refuge bases (Walters and Wethey, 1996). Yet studies on *Balanus improvisus* have indicated that this species may have a preference for relatively smooth surfaces (Berntsson et al., 2000, 2004). Experiments using plastic model casts to test the consistency of responses of settling barnacle larvae to surface contour cues found that cyprids of *Chthamalus fragilis* and *S. balanoides* tended to settle in identical locations (Wethey, 1986). Le Tourneux and Bourget (1988) differentiated roughness parameters on the basis of larval size; substratum heterogeneity below size of settling cyprids is defined as 'surface texture', and above that size 'surface contour' and concluded that the micro-heterogeneity of the surface immediately beneath the larva was most important. A measure of surface complexity, known as the number of Potential Settlement Sites (PSS), scaled to size and behaviour of settling cyprids, was devised by Hills and Thomason (1996). The PSS value is the number of symbolic cyprids that can be packed per horizontal 10 mm of a scaled printout of the surface profile (Hills and Thomason, 1996). Studies on the settlement of *S. balanoides*, aimed at determining the relative importance of surface fractal complexity and the number of Potential Settlement Sites, concluded that larvae responded more clearly to characteristics related to PSS and not to fractal complexity (Hills et al., 1999).

The intertidal species *Chthamalus montagui* Southward occurs abundantly on rocky shores along Atlantic coasts between North Africa and Scotland and in the Mediterranean Sea (Crisp et al., 1981). Close to the species northern limits in south-west England, fluctuations in sea temperature over the past 40 years have caused major changes in the relative abundance of *C. montagui* and the boreal barnacle species *S. balanoides*, with *C. montagui* increasing during warmer periods (Southward, 1967, 1991; Southward et al., 1995). Observations at the species limits in the eastern English Channel suggest recruitment is greater in warmer years (Herbert, 2001). With the prospect of more frequent hot summers and mild