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Barnacle recruitment on ice-scoured shores in eastern Canada

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*Previous observations in the St Lawrence Estuary (eastern Canada) suggested that larvae of intertidal barnacles (*Semibalanus balanoides*) would settle almost exclusively inside crevices on shores that are scoured by sea ice every winter. It was suggested that the strong ice scour in winter on that coast (which removes organisms outside of crevices) would select for such a larval behaviour. We tested the generality of this pattern by sampling other ice-scoured shores within the Gulf of St Lawrence system. In particular, we surveyed a shore in Nova Scotia where exposed habitats (subjected to strong ice scour in winter) are interspersed with sheltered habitats (which suffer milder ice scour). Such a topographical complexity might allow for the coastal larval pool to contain a proportion of larvae that have no particular settlement preference for crevices, as selective pressures for such a behaviour would be minimal in ice-sheltered habitats. Consistently with this notion, barnacle recruits (which appear after the winter ice melts) occurred abundantly both inside and outside of crevices across the shore in the spring seasons of 2005 and 2006. Average recruit density on rocky surfaces ranged between 337 and 588 recruits dm^{-2}, depending on the habitat. It is therefore possible that barnacle recruitment patterns on ice-scoured shores may be affected indirectly by the structural complexity of the coast.*

Keywords: barnacle, ice scour, intertidal, recruitment

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Recruitment, or the addition of young individuals to a population, is one of the major components of population dynamics (Underwood & Keough, 2001). In intertidal barnacle populations from the St Lawrence Estuary, in eastern Canada, adult organisms are restricted to crevices (Bergeron & Bourget, 1986). Such a characteristic spatial pattern is related to ice scour, which results from the widespread formation of sea ice across the entire Gulf of St Lawrence system every winter (Saucier *et al.*, 2003). Crevices act as refuges for barnacles against the physical effects of moving ice. The recruitment period for this barnacle species, *Semibalanus balanoides* (Linnaeus, 1766), is limited to a few months on the north-western Atlantic coast, usually earlier in the year in southern locations (Bousfield, 1954; Minchinton & Scheibling, 1991; Pineda *et al.*, 2006). In the St Lawrence Estuary, barnacle larvae settle almost exclusively in crevices (Bergeron & Bourget, 1986), in contrast with the open Atlantic coast (which does not undergo ice scour), where larvae settle extensively across rocky intertidal surfaces (Bourget *et al.*, 1990). It was suggested that selective pressures (intense ice scour outside of crevices) may have determined the larval preference for settlement in crevices in the St Lawrence Estuary (Chabot & Bourget, 1988). To test the generality of this pattern, we investigated barnacle recruitment on other ice-scoured shores within the Gulf of St Lawrence system. In particular, we surveyed topographically complex sections of the coast where areas subjected to intense winter ice scour are interspersed with areas subjected to mild ice scour. We asked the question whether this complex structural pattern on the coast would be associated with a different recruitment pattern than the one described for the St Lawrence Estuary.

We surveyed Sea Spray Shore (45° 46′ N 62° 9′ W), near Arisaig, on the southern coast of the Gulf of St Lawrence, Nova Scotia, Canada. The substrate of this subarctic coast is primarily volcanic bedrock with high rugosity. Surface seawater temperature ranges between monthly averages of -1.4 °C and 18.2 °C in this region, while surface seawater salinity ranges between monthly averages of 28.4‰ and 30.6‰ (Fisheries and Oceans Canada, 2007). Sea ice forms in early winter and melts between late winter and early spring (Saucier *et al.*, 2003), normally late March or April at Sea Spray Shore. On this coast, *Semibalanus balanoides* is the only species of intertidal barnacle. At Sea Spray Shore, habitats directly facing open waters (exposed habitats) are subjected to strong ice scour in winter (see values in Scrosati & Heaven, 2006) and strong wave action during the ice-free period (see values in Scrosati & Heaven, 2007). Habitats protected by outer rocky formations (sheltered habitats) are subjected to significantly lower values of ice scour and wave action (Scrosati & Heaven, 2006, 2007). Barnacle recruits appear on this shore normally in May. On 7–8 June 2005 and 7–10 June 2006, after all sea ice from the preceding winter seasons had completely melted, we measured the density of barnacle adults and recruits in one exposed habitat and one sheltered habitat that were visually representative of the entire coast. Recruits were much smaller than adults at the time of sampling (Figure 1), so both life-history stages could easily be differentiated. In each habitat, we laid a

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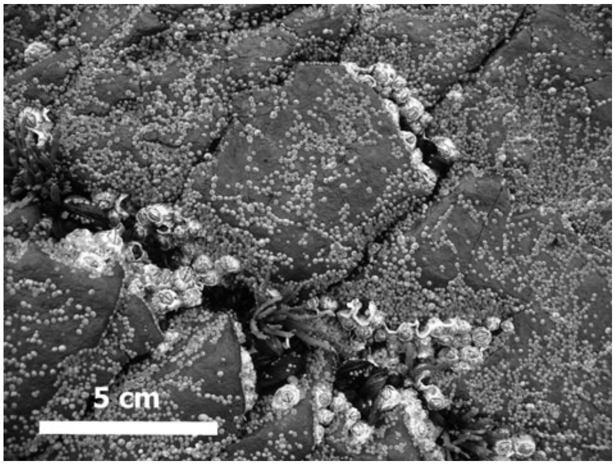

Fig. 1. Intertidal zone of an exposed habitat at Sea Spray Shore viewed in the spring (June), showing adult barnacles restricted to crevices and barnacle recruits occurring extensively across the rocky substrate, both inside and outside of crevices. Note the pronounced size difference between adults and recruits. Photograph by R. Scrosati.

20 m transect line across the mid–high intertidal zone and counted the number of barnacle adults and recruits in 30, 100 cm^2 random quadrats.

We found that barnacle recruits occurred abundantly throughout the rocky substrate, both inside and outside of crevices (Figure 1). Recruits were significantly more abundant than adults in sheltered and exposed habitats in both years (Student's *t*-tests, $P < 0.05$; Figure 2). In each year, the density of recruits was similar between exposed and sheltered habitats (Student's *t*-tests, $P > 0.05$; Figure 2). Barnacle adults were restricted to crevices in the exposed habitat, whereas they occurred both inside and outside of crevices in the sheltered habitat, apparently as a result of the milder ice scour that occurs in winter there.

The massive barnacle recruitment occurring everywhere on rocky surfaces on the outer Gulf of St Lawrence stands in sharp contrast with the spatially selective recruitment in crevices in the St Lawrence Estuary. What might explain this regional difference along the same ice-scoured coastline? A long-term history of strong ice scour might indeed determine microhabitat selectivity in larvae through natural selection, as suggested by Chabot & Bourget (1988) to explain their findings in the St Lawrence Estuary. However, in habitats where ice scour is relatively mild, settlement inside crevices is less critical for population persistence, as several organisms settling outside of crevices will also reach adult size. Thus, on topographically complex shores where sheltered habitats are interspersed with exposed habitats, the coastal larval pool (a mixture from various shore areas) would include many larvae without a particular spatial preference for settlement. Sea Spray Shore includes alternating areas subjected to strong and mild ice scour (Scrosati & Heaven, 2006), and larvae indeed settle both inside and outside of crevices everywhere on the shore, as we found. The selective potential of environmental factors on larval settlement behaviour in marine invertebrates has been investigated by a number of researchers (Todd, 1998; Morgan, 2001). Our study suggests that ice scour, a rarely considered factor in terms of larval ecology (Barnes & Conlan, 2007), might also affect the evolution of settlement behaviour in barnacles. Experimental studies on this topic should therefore improve our understanding of barnacle population dynamics in polar and subpolar shores.

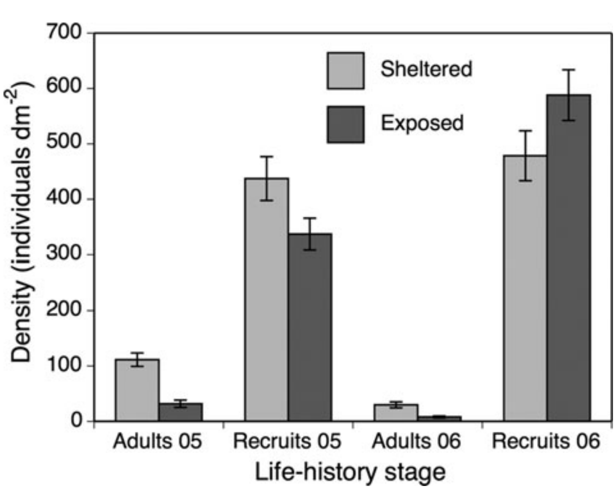

Fig. 2. Density (individuals dm^{-2}; means $\pm$ SE) of barnacle adults and recruits in exposed and sheltered habitats at Sea Spray Shore in the spring (June) of 2005 and 2006 (N = 30 quadrats for each case).

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