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NOTE

Field technique to quantify intensity of scouring by sea ice in rocky intertidal habitats

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ABSTRACT: Scouring by sea ice is an important abiotic factor affecting intertidal communities in polar and subpolar rocky shores. Traditionally, measurement of the intensity of scouring by sea ice has been done at rather coarse spatial scales, thus limiting the understanding of the role that this factor has in determining local-scale ecological variability, particularly when scouring intensity varies locally due to shore topography. We hereby present a technique to quantify the local-scale intensity of scouring by sea ice in rocky intertidal habitats. This technique is inexpensive and easy to apply and measure. We provide an example of its potential usefulness using local-scale data on intertidal species richness.

KEY WORDS: Community ecology · Field technique · Ice scouring · Sea ice · Subpolar intertidal ecology

INTRODUCTION

Sea ice is a common feature of polar and subpolar marine waters. It develops when the temperature falls below the freezing point of seawater and it may cover the sea surface as a relatively continuous layer of variable thickness (Pinet 2003). In intertidal habitats from polar and subpolar regions, sea ice is an important factor structuring the biological communities that live there. This is so because sea ice is not permanently static, but may move with currents, tides, waves and wind. When portions of floating sea ice grind over the surface of rocky shores, benthic organisms are damaged or physically removed as a result (Barnes 1999, Gutt 2001). Thus, understanding spatial patterns in intertidal community structure requires knowledge of spatial patterns in the intensity of scouring by sea ice (ISSI).

Information on coastal sea ice conditions is available for a number of regions worldwide through regional hydrographic services. However, the spatial scale of ecological variability in intertidal communities is generally smaller than the spatial resolution in sea ice data provided by such services. As a result, publicly available sea ice data may not be enough to understand ecological patterns that result from local-scale differences in ISSI arising from shore topography. Some studies have provided estimates of scouring by sea ice based on the percent cover of sea ice in coastal waters and on the number of days during which floating sea ice was visible from the coast (Keats et al. 1985). However, such a method also provides estimates at a coarse spatial scale and is usually only valid for shore areas that are directly exposed to the incoming fragments of sea ice. Other studies have used data on community structure to infer the predominant coastal sea ice regime (Barnes 1999), but community structure is also determined by other abiotic factors (e.g. temperature, irradiance, wave exposure, desiccation and salinity) and by biotic factors (e.g. competition, facilitation, herbivory and predation). Thus, the utility of community data to infer ISSI may be limited for some shores. The best approach is to measure ISSI directly and at the desired level of spatial resolution for a particular shore. Markers have been used to assess damage by icebergs

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in subtidal habitats (Brown et al. 2004), but such markers were relatively large (almost 0.5 kg in mass) and strong (made of concrete). Such size and consistency is likely to be ineffective at detecting differences in ISSI in intertidal habitats, as subtidal damage by icebergs is normally much greater than intertidal damage by sea ice.

The present contribution presents a technique to quantify ISSI in intertidal habitats. This technique is inexpensive and easy to apply and measure, which makes it particularly useful for ecological studies in polar and subpolar rocky shores, as such studies are normally demanding in terms of labour and funds.

MATERIALS AND METHODS

The present study was carried out on the rocky shore around Arisaig (45° 46′ N, 62° 10′ W), on the southern coast of the Gulf of St. Lawrence, Nova Scotia, Canada. Sea ice is highly seasonal in this subarctic region. In early winter every year, fast ice (sensu Barnes 1999) of up to 0.5 m in thickness develops across the surface of the gulf (Saucier et al. 2003), while an ice foot (sensu Barnes 1999) develops on intertidal rocky surfaces. These types of sea ice progressively melt between late winter and early spring in this region, leaving the sea surface and shores free of ice until the following cold season. During the cold season, floating patches of sea ice often drift across the sea surface because of currents and wind. As a result, large sections of sea ice frequently pile up on top of each other when they meet the rocky shore (Fig. 1), causing a high degree of biological disturbance to the rocky surface. Inner areas of the shore are generally sheltered from such large build up of sea ice through protective outer rocky reefs (Fig. 1).

Fig. 1. Arisaig coast (Gulf of St. Lawrence) in winter, showing extent of sea ice. The 2 upper arrows indicate areas where scouring by sea ice was maximal (‘outer’ areas), the 2 lower arrows areas where scouring was less intense (‘inner’ areas). (Photo by R. Scrosati)

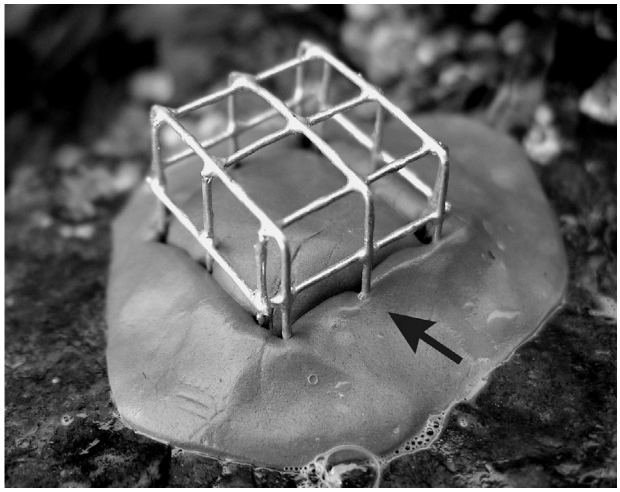

Fig. 2. Cage attached to intertidal rocky surface by marine epoxy glue, before sea ice had formed on shore. Arrow indicates central column at initial angle of 0° from vertical (i.e. no deformation). (Photo by R. Scrosati)

ISSI was measured using 1 cm^3 metallic cages (Fig. 2) fixed to the rock surface by marine epoxy glue (A-788 Splash Zone Compound: Z-Spar). A total of 27 such cages were used, of which 12 were placed on outer areas of the shore, directly facing the sea, and 15 on inner areas that were not directly exposed to the sea and, therefore, presumably protected from heavy damage by sea ice. The selected areas are representative of the rocky shores in this region. The length of shoreline surveyed was approximately 200 m. The cages were installed in late autumn 2004, before any sea ice had formed, and were randomly placed at approximately the same elevation across the mid-intertidal zone. This shore was visited again in spring 2005, after all the sea ice had melted, when the shape of each cage was recorded. The angle of departure from the vertical position (i.e. the original shape, with 0° representing the initial angle) was measured for the central column of the same side for each cage (Fig. 2). This method quantifies the cumulative damage caused by sea ice throughout the entire cold season. Periodic measurements during the cold season are not possible, since the cages are then covered by ice, and any attempt to view them by mechanically removing the ice would probably artificially deform them.

RESULTS AND DISCUSSION

At the end of winter, all the ‘outer’ cages were completely flat (Fig. 3A), with a deformation angle of 90°. The ‘inner’ cages were less deformed (Fig. 3B), with an average deformation angle of 46.7° ± 12.1° (mean ± SE).

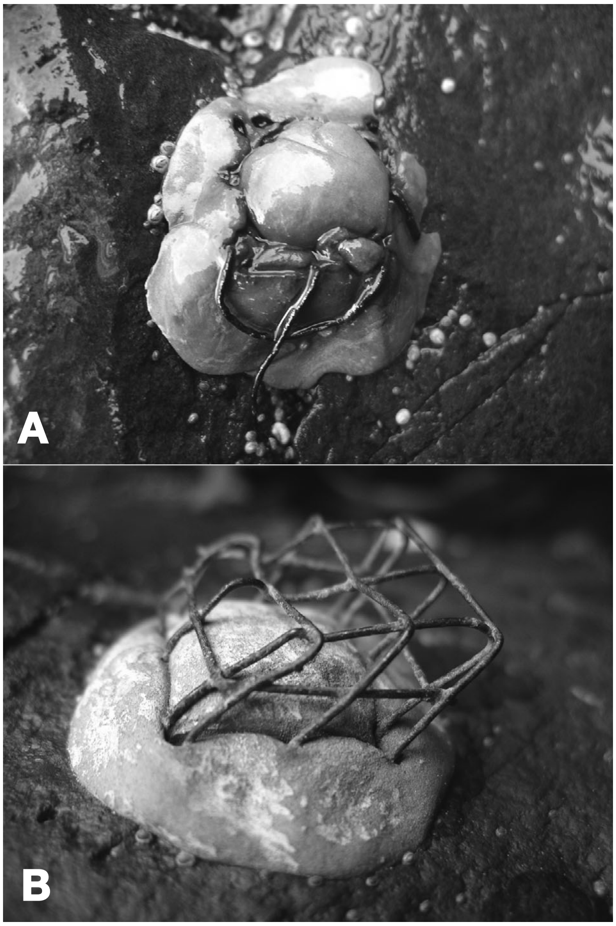

Fig. 3. Cages after winter. (A) Remains of cage from an 'outer' area, with cage completely flattened through strong scouring by sea ice; (B) cage from 'inner' area, where scouring by sea ice was less intense. (Photos by R. Scrosati)

A 1-sample *t*-test (Howell 2002) of the null hypothesis of 90° (deformation angle of the 'outer' cages) indicated that the difference in ISSI between the 2 shore areas was significant ($t = 3.6$, $p < 0.02$), i.e. the outer shore had been subjected to strong scouring by sea ice during the winter and the inner shore to a less intense degree of scouring. In addition to the outer rocky reefs, a more stable ice foot may also have protected the inner shore against heavy damage by moving sea ice, at least when the ice foot was thickest at the winter peak.

The ecological role of scouring by sea ice seems to be important on this shore. In a nearby coastal area, the total number of seaweeds and invertebrates (i.e. species richness) identified in summer 2005 in 25 × 25 cm quadrats across the mid-intertidal zone was significantly higher (2-sample *t*-test, $t = 7.8$, $p < 0.001$) at inner sites (mean ± SE, richness = 13.9 ± 0.6; n = 20 quadrats) than at outer sites (7.9 ± 0.5; n = 20). Such a difference is consistent with the pattern predicted across a gradient of physical disturbance (by sea ice, in the present case) ranging from intermediate to high degrees of disturbance (Bertness 1999). Low disturbance conditions (no sea ice in winter) do not occur in this region.

The possible cause–effect relationship between ISSI and intertidal species richness has yet to be experimentally tested for this shore. The above data on species richness is a simple illustration of the potential usefulness of local-scale ISSI data in attempts to explain community patterns on ice-affected rocky shores. The technique outlined here can be used to monitor sea ice over more than 2 coastal areas, the number of areas depending on the spatial diversity of ISSI patterns and on the ecological research question. Because of the small size of the experimental cages, the spatial scale of study can be as small as tens of centimeters, while almost any larger spatial scale is possible. Thus, this technique seems to be a promising inexpensive, simple tool for microecological and macroecological studies in polar and subpolar rocky intertidal habitats.

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