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Evidence for the bioerosion of deep-water corals by echinoids in the Northeast Atlantic

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ABSTRACT

In situ video observations of echinoids interacting with deep-sea coral are common in the deep-sea, but paradoxically the deep-sea literature is devoid of reports of bioerosion by extant echinoids. Here we present evidence of contemporary bioerosion of cold-water coral by four species of deep-sea echinoids, *Gracilechinus elegans*, *Gracilechinus alexandri*, *Cidaris cidaris*, and *Araeosoma fenestratum*, showing that they actively predate on the living framework of reef building corals, *Lophelia pertusa* and *Madrepora oculata*, in the NE Atlantic. Echinoid specimens were collected in six canyons located in the Bay of Biscay, France and two canyons on the north side of the Porcupine Bank and Goban Spur, Ireland. A total of 44 live specimens from the four taxa (9 of *G. elegans*, 4 of *G. alexandri*, 21 of *C. cidaris* and 10 of *A. fenestratum*) showed recent ingestion of the coral infrastructure. Upon dissection, live coral skeleton was observed encased in a thick mucus layer within the gastrointestinal tract of *G. elegans* and *G. alexandri* while both live and dead coral fragments were found in *C. cidaris* and *A. fenestratum*. Echinoid bioerosion limits the growth of shallow-water reefs. Our observations suggest that echinoids may also play an important role in the ecology of deep-water coral reefs.

1. Introduction

Bioerosion is an essential process regulating the degradation of carbonate skeletal material in marine habitats and an important aspect of reef ecology that is often overlooked (Wisshak et al., 2005). In deep-sea coral reefs, bioerosion has received little attention despite a wealth of recent studies carried out in an effort to gather evidence supporting conservation strategies for these environments (*e.g.*, Bromley, 2005; Mah et al., 2010). Cold-water coral habitats constitute refuge for a host of mega- and macroinvertebrates, but interactions, trophic or otherwise, between them and the host are not fully understood. Research conducted on *Lophelia* skeleton bioerosion to date has largely focused on endolithic (boring and encrusting) forms, such as the sponges *Alectona millari* and *Aka labyrinthica*; the foraminifer *Hyrrokkin sarcophaga*; the fungus *Dodgella*; and the sabellid worm *Perkinsiana socialis* (Rogers, 2004; Beuck and Freiwald, 2005; Bromley, 2005; Wisshak et al., 2005; Beuck et al., 2007).

Among known extant epilithic bioeroders, asteroids, such as the Hippasterinae, are accepted as the main predators of deep-sea coral (Krieger and Wing, 2002). These echinoderms are known to erode gorgonians, alcyonaceans, antipatharians and other deep-sea cnidarians (Krieger and Wing, 2002; Mah et al., 2010). Other predators of the alcyonacean *Primnoa* include nudibranchs and snails (Krieger and Wing, 2002). The rare gastropods, "*Coralliophila*" *richardi* and *Babelomurex sentix* (Coralliophilinae), are known bioeroders of *Lophelia* and *Madrepora* in Mediterranean deep-waters (Taviani et al., 2009). *In situ* video and image observations of echinoids interacting with deep-sea coral are common (see p. 34 in Reed and Ross, 2005; p. 70 in Freiwald et al., 2009; p. 22 in Munoz et al., 2012) and some figure captions suggest that they are 'grazing' on the coral (see Freiwald et al., 2009). However, further reports and discussion about the bioerosion behaviour is absent from the deep-sea literature.

In shallow-water habitats, echinoids have long been known to play a crucial role in tropical coral reef development and stability. The echinoid genera *Diadema*, *Echinometra*, *Echinostrephus* and *Eucidaris* have been described as the major bioeroders in shallow-water habitats (Bak, 1994; Glynn, 1997). Their role effectively modulates the balance between reef accretion and destruction, hence playing a crucial function in tropical coral reef stability (Bromley, 1978; Glynn et al., 1979; Bak, 1994). Yet in deep-sea habitats this position of echinoids as ecosystem engineers has largely been overlooked. Tooth scratches by regular echinoids, *Gnathichnus pentax*, have been documented on *Lophelia* material from the Pleistocene (*e.g.* Bromley, 2005), but no other accounts of contemporary echinoid bioerosion have been reported in the deep-sea literature.

Here, we report 44 gut content observations of the echinoids *Gracilechinus elegans* (formerly known as *Echinus elegans*), *Gracilechinus alexandri*, *Cidaris cidaris*, and *Araeosoma fenestratum*

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collected in six canyons in the Bay of Biscay, France, as well as two canyons on the north side of the Porcupine Bank and on the Goban Spur, Ireland. This evidence is complemented by *in situ* video observations suggesting active predation on the living framework of reef building coral, *Lophelia pertusa* and *Madrepora oculata*. The study describes and discusses this previously unreported bioerosion activity by deep-sea echinoids.

2. Materials and methods

2.1. Study area

All echinoid specimens used in this study were collected during three cruises (BOBECO with the '*Pourquoi pas*?'; CE10004 and CE11006 with the '*Celtic Explorer*') in the Northeast Atlantic, within French and Irish waters (Fig. 1): eight sites in the Bay of Biscay, in six different canyons (one site within the Croizic, Guilvinec, Crozon, and Morgat Douarnez canyons and two sites in the Lampaul and the Petit Sole canyon); five sites on the Irish continental shelf (two sites on the Goban Spur and two in canyons on the north side of the Porcupine Bank). Reef building coral was present at all sites where specimens were collected.

2.2. Collection and treatment of samples

Echinoids were collected randomly at preselected random points in a quadrat (during the BOBECO cruise with the '*Pourquoi pas*?') and along transects (during the CE10004 and CE11006 cruises with the '*Celtic Explorer*') spanning coral habitat. Actual collection took place during 12 dives, eight with the remotely operated vehicle (ROV) Victor 6000 (during the BOBECO cruise) and four conducted with ROV Holland I (two each during the Irish cruises, CE10004 and CE11006). Echinoids were collected *in situ* with either the mechanical arm or suction hose of the ROVs. Upon recovery, specimens were dissected on board and gut content analyses were performed immediately following dissection. When needed, corallites found in the gut contents were bleached for 1 h with sodium hypochlorite to facilitate observation of the cup and septa for identification of the coral.

3. Results

A total of 78 echinoids belonging to five different species were collected during three cruises. Among this collection, 44 echinoids belonging to four taxa had coral fragments in their gastrointestinal tract (Table 1). Both living and dead coral fragments were found during dissections. A thick layer of mucus accompanied the living coral but were not present when only dead coral was observed in the guts.

In total, nine specimens of *G. elegans* were collected in the NE Atlantic, one in Lampaul Canyon and eight on the north side of the Porcupine Bank. All contained coral fragments encased in a thick mucus layer within their gastrointestinal tract (Fig. 2; Table 1). The presence of live coral in the guts of these echinoids is further supported by polyp tissue found attached to the coral skeleton

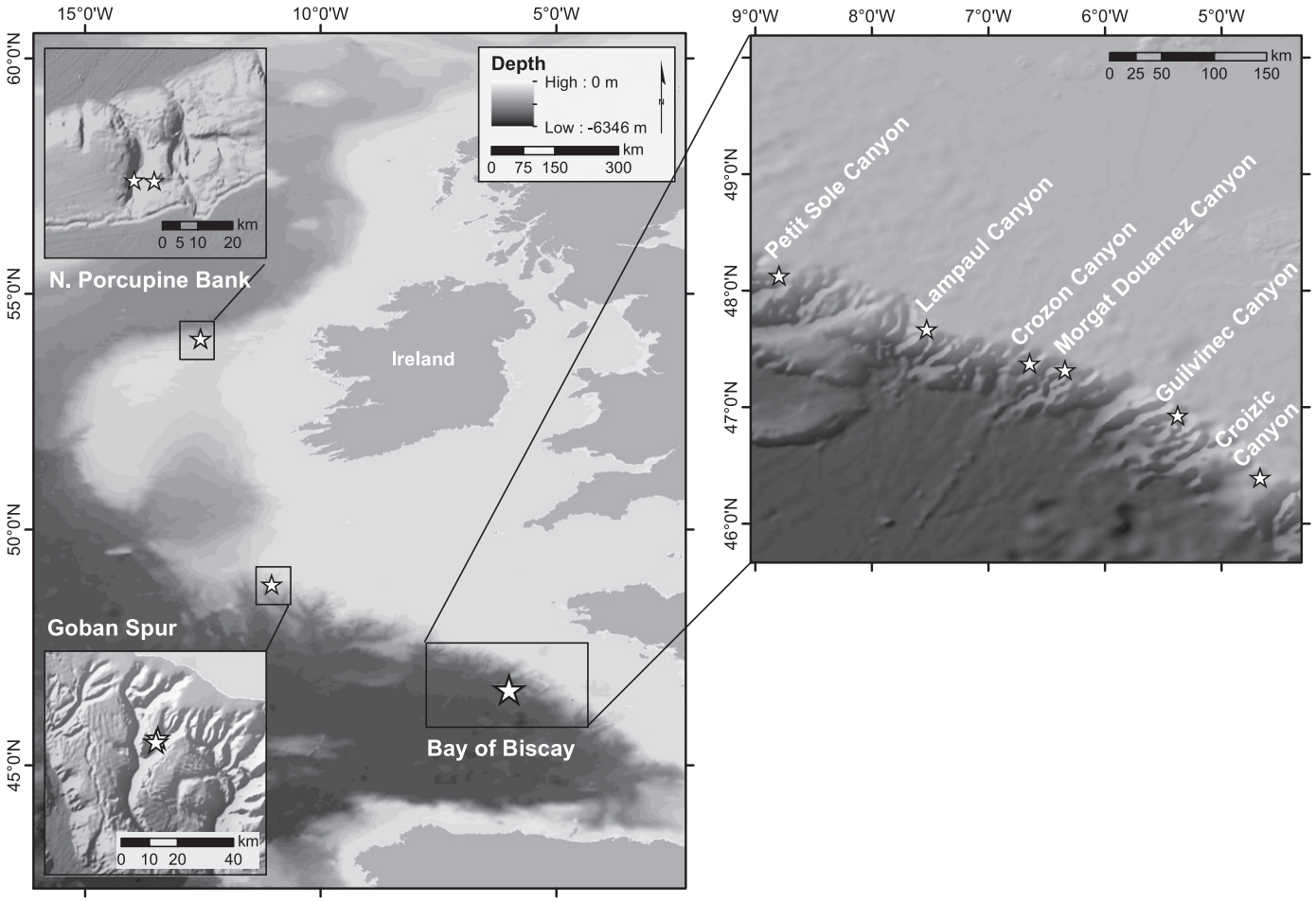

Fig. 1. Location of the study area and sampling stations in canyons on the Irish continental shelf and Bay of Biscay, NE Atlantic Ocean.