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Abrasion-induced holes in the bivalve shells from the Baltic Sea: Implications for palaeontological studies

Abstract

Drill holes made by predators on shells are considered direct evidence of predator–prey interactions. However, some authors recently suggested that some holes in shells may be also formed *via* abrasion. Actually, criteria for recognizing holes made by drilling predators and abiotic-environmental factors are still in dispute. Holes in shells of *Parvicardium hauniense* (Petersen & Russell) from the Baltic Sea are reported. This preliminary set of data strongly confirms that various holes in shells were set by abrasion. Therefore, caution needs to be taken when considering holes in the fossil isolated shells in the scope of appropriately interpreting the role of predator–prey interactions in the evolution of shelly organisms.

Streszczenie

Otwory wydrążone w muszlach uznaje się za bezpośredni dowód interakcji pomiędzy drapieżnikiem a jego ofiarą. W ostatnim czasie niektórzy autorzy zasugerowali, że część z nich może powstawać także w wyniku abrazji. Obecne kryteria rozpoznawania otworów produkowanych przez drapieżniki i tych powodowanych przez czynniki środowiskowe są nadal sporne. Obecnie opisano otwory w muszlach *Parvicardium hauniense* (Petersen & Russell) pochodzące z Morza Bałtyckiego. Wstępne dane potwierdzają, że różnorodne otwory w muszlach mogą być wytwarzane na drodze abrazji. Należy zatem zachować ostrożność, obserwując otwory obecne na wyizolowanych muszlach kopalnych, aby móc dokonywać poprawnych interpretacji roli interakcji pomiędzy drapieżnikami a ich ofiarami w ewolucji organizmów oskorupionych.

Keywords: drill holes, abrasion, predation, mollusks, bivalves, Baltic Sea

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Introduction

Understanding the evolution of organisms in both modern and past ecosystems requires examining the key factors (biotic and abiotic) shaping it (e.g., Vermeij 1977; Vermeij 1987). Predation is considered an important, though controversial, agent in evolution. Numerous trends have been interpreted in the light of predator–prey interactions, including those that characterized Palaeozoic and Mesozoic mollusks (Harper and Skelton 1993; Kowalewski et al. 1998; Harper 2003; Salamon et al. 2012; Salamon et al. in press). However, evaluating the role of predation in recent ecosystems is a tough issue and an even tougher one in the fossil record.

Drill holes made by predators on shells are considered a direct evidence of predator–prey interactions (Kowalewski 2002; Dietl and Kelley 2006), but some reports suggested that various holes may also be formed *via* abiotic processes (e.g. Lescinsky and Benninger 1994; Gorzelak et al. 2013; Chojnacki and Leighton 2013). Actually, criteria of distinguishing holes made by drilling or boring predators from those set by abiotic-environmental factors are still controversial. This may lead to potential pitfalls in further interpretation of the predator–prey interactions.

It has been argued that the distinction between biotic- and abiotic-made holes is only possible when non-morphological criteria (evaluation of holes for non-random distribution) and morphometric studies (quantification of the drill-hole shape) are considered (Kowalewski 1993; Kowalewski et al. 1998; Urrutia and Navarro 2001; Grey et al. 2005). For example, it has been long assumed that circular or oval holes are commonly produced by drilling gastropods, whereas irregular holes are mostly generated by abiotic-environmental processes (Kowalewski 1993; Kowalewski et al. 1998, Chojnacki and Leighton 2013). Nevertheless, some studies demonstrated that modern drilling gastropods may also produce holes displaying irregular shapes and outlines (compare Figure 4 in Urrutia and Navarro 2001). Furthermore, Gorzelak et al. (2013) suggested that oval holes might not be necessarily formed by the action of drilling predators. In particular, their tumbling experiments, which simulated shell degradation under seawater-agitated conditions, revealed that abrasion may leave holes resembling those produced by drilling gastropods. Nevertheless, whether tumbling experiments imitate accurately the mechanical conditions experienced by shells in the surf zone has been the source of confusion and uncertainty (Chave 1964; Driscoll 1967; Cintra-Buenrostro et al. 2005). Therefore, testing this issue in a natural ecosystem devoid of drilling gastropods is the core issue at stake here: the Baltic Sea is such an ideal system. This preliminary report introduces seminal data on the occurrence of abrasion-induced holes in the bivalve shells from the Baltic Sea.

Materials and methods

The bivalve shells were collected on the beach near Międzyzdroje (a seaside resort in northwestern Poland on the Wolin Island off the Baltic coast) and Ahlbeck (a part of Heringsdorf, a seaside resort in Germany on the Usedom Island in the Baltic Sea; Fig. 1).

Ten kilograms of sands in total from the surf zone were collected and sieved and 59 isolated bivalve valves were retrieved.

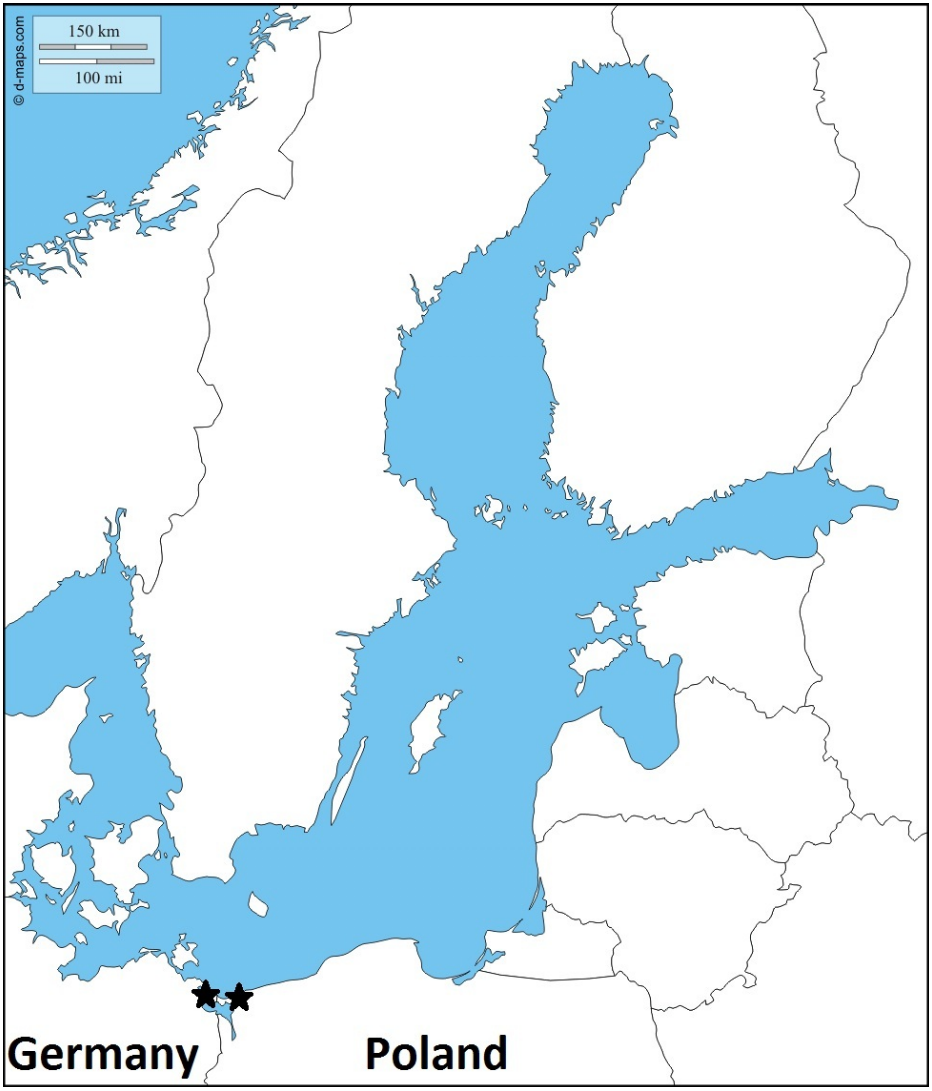

Figure 1. Schematic map of Baltic Sea with described localities shown as stars

Results

The bivalve shells belong to *Parvicardium hauniense* (Petersen & Russell). This bivalve species has a thin and small (up to about 10 mm) shell. Valves are rather equally formed and inequilateral. In ligament, the heterodont hinge has two small wedge-shaped cardinal teeth set in the middle part near the umbones and two elongated lateral teeth on the anterior and posterior margins on both sides. The outer shell morphology displays 22 to 28 ribs radiating to the crenulata margin. The ribs are rather low, almost flat with equal spaces between them.

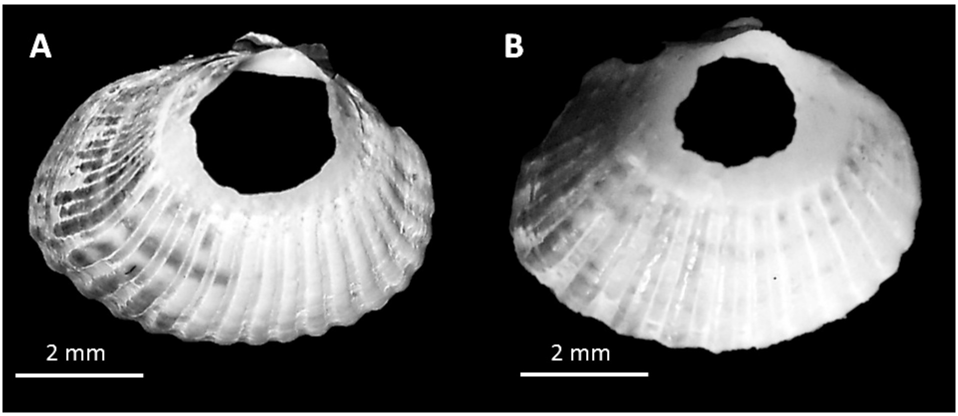

Figure 2. Bivalve species *Parvicardium hauniense* (Petersen & Russell) with a hole in the shell. Scale bar equals 2 mm

Among 59 documented bivalve shells, 9 display holes. They are mostly oval or irregular in outline (Figure 2). These holes completely penetrate the shells. Their vertical cross sections are commonly plane but inclined at different angles with smaller inner hole openings than outer ones (Table 1). Furthermore, the shells display non-randomly distributed holes (Figure 2), i.e., the latter are located dorsally near the umbo.

Table 1. Characteristics of the bivalve shells displaying holes

Investigated taxon	Number of shells	Frequency of holes	Size range of shells with holes (in mm)	Range of maximum outer diameter (in mm)	Range of minimum outer diameter (in mm)	Range of maximum inner diameter (in mm)	Range of ratio of inner to outer diameter (in mm)
Parvicardium hauniense	59	15.3	6.1–7.8	1.9–3.4	1.6–2	1.6–2.6	0.76–0.95

Discussion

Holes produced by drilling snails are commonly recognized as single and "unhealed" perforations perpendicular to the shell surface. They commonly display circular to oval shapes and more or less regular outlines. The ratio of inner to outer diameter in such holes generally exceeds 0.5.

The preliminary data at hand agree with the previous experimental data implying that abrasion may produce similar holes in bivalve shells (Gorzelak et al. 2013). Such holes may be formed *via* the progressive and preferential abrasion experienced by the particular side of the shell leading to its directional thinning. Admittedly, these holes are mostly irregular in outline. Given the ephemeral nature of fossil material subject to diagenetic changes and the fact that recent drilling gastropods may produce irregular holes (compare Figure 4 in Urrutia and Navarro 2001), such abrasion-induced traces can be erroneously treated as holes of predatory origin, inducing an overestimation of predation pressure in the fossil record. Thus, the accurate recognition of drilling predators requires brand new criteria, such as the identification of radular microrasping marks on drill-hole walls (Schiffbauer et al. 2008; Tyler and Schiffbauer 2012).

Future works should focus on larger samples in order to conduct even more reliable morphometric studies, as well as an evaluation of non-random distribution, of abrasion-induced holes in the bivalve shells from high-energy environments lacking drilling predators.

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