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ORIGINAL PAPER

Northernmost record of *Crypthelia medioatlantica* (Hydrozoa: Stylasteridae) in Icelandic deep waters

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Abstract

The stylasterid coral *Crypthelia medioatlantica* Zibrowius & Cairns, 1992, previously reported only from the Mid-Atlantic Ridge (~23–37° N), is newly documented from Icelandic waters based on material collected by the BIOICE programme. Six dry, subfossil skeletal fragments were recovered at 1539 m depth west of Iceland in 1996, extending the known range of the species by ~28° latitude into sub-Arctic environments and representing its northernmost record. Detailed morphological analysis of coenosteal texture and cyclosystem structure confirms the identification. This discovery adds a fifth stylasterid coral species to the high-latitude North Atlantic fauna and demonstrates that *C. medioatlantica* has occurred in deep sub-Arctic benthic communities at least historically. It also highlights overlooked stylasterid diversity in under-explored regions and the value of historical collections. Combining re-examination of archived material with targeted, molecularly suitable collections will be essential to clarify the biogeographic history and conservation status of *C. medioatlantica* in the North Atlantic and to determine whether the Icelandic fragments represent an extant but unsampled population or the remnants of a past local population.

Keywords Historical collections · Taxonomy · Marine biodiversity · BIOICE programme · Biogeography · Deep-sea fauna

Introduction

The family Stylasteridae Gray, 1847 (Hydrozoa: Anthoathecata) is commonly referred to as lace corals and includes predominantly cold- and deep-water taxa (Cairns 2015). Within this family, the genus *Crypthelia* Milne Edwards & Haime, 1849 is characterized by small, delicate, often uniplanar colonies bearing cyclosystems, each partially covered by a fixed

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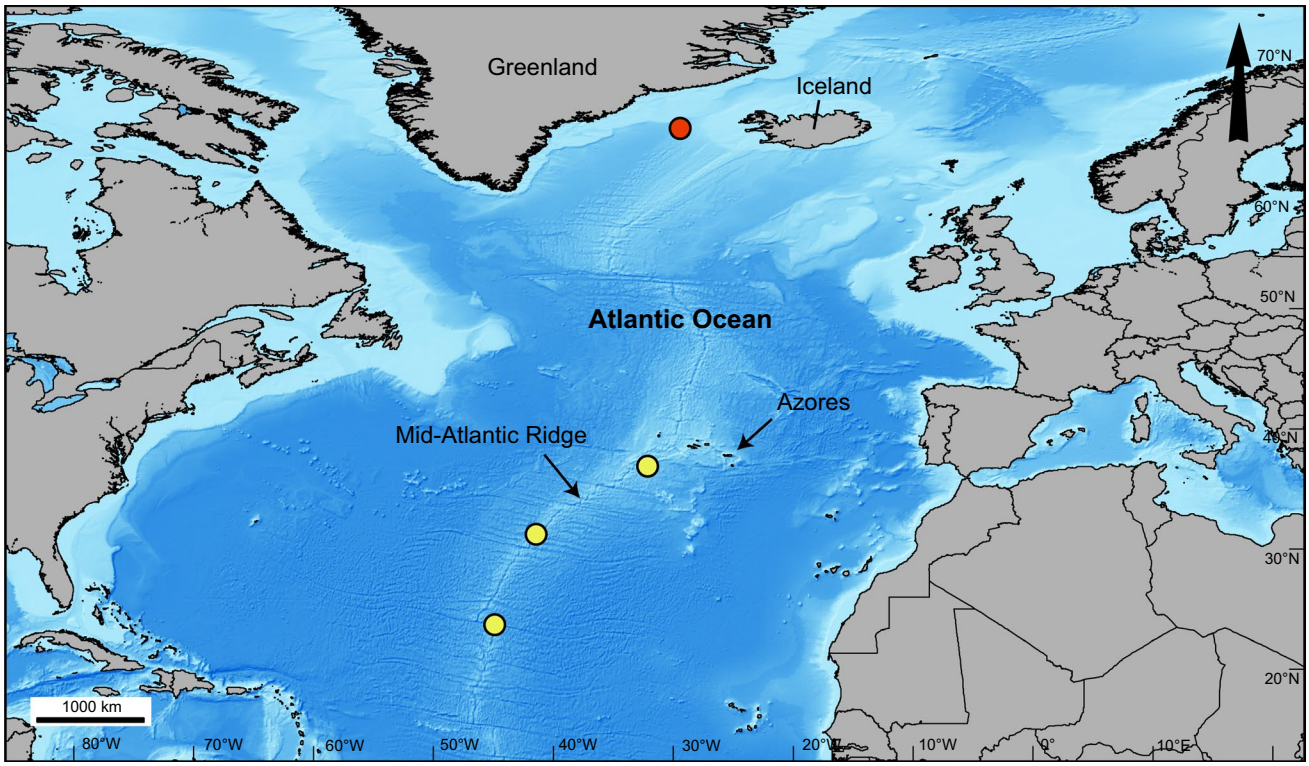

Fig. 1 Bathymetric map of the North Atlantic showing the new Icelandic deep-water occurrence of *Crypthelia medioatlantica* (red marker) and the three previously known Mid-Atlantic Ridge localities (yellow markers) from Zibrowius and Cairns (1992). Bathymetry from the GEBCO 2023 Grid (General Bathymetric Chart of the Oceans). The Icelandic locality (BIOICE station 2918) represents the northernmost known record of the species

lid. *Crypthelia* currently comprises 56 extant species (Cairns 2024; Schuchert et al. 2025), distributed throughout the Atlantic and Indo-Pacific. Because many species are known from relatively few localities, each new record provides important information on depth range, environmental tolerances, and the contribution of *Crypthelia* colonies to deep-sea habitat complexity alongside other framework-forming corals. Although *Crypthelia* species occur across broad geographic and bathymetric scales, records from high northern latitudes of the Atlantic remain rare, leaving gaps in our understanding of their true distribution and ecological role.

The North Atlantic margin of Iceland and the adjacent Reykjanes Ridge represent a dynamic and complex deep-sea environment, shaped by volcanic topography, sediment plains, and a mosaic of hard substrates such as basalt outcrops and glacial dropstones (Astthorsson et al. 2007). Strong mixing of cold North Atlantic Deep Water and Arctic-derived currents creates stable, oxygen-rich bathyal conditions that support a diverse assemblage of benthic fauna, including deep-water corals. This diversity occurs despite the region's sub-Arctic latitude (Astthorsson et al. 2007; Read 2000; Hansen and Østerhus 2000; Burgos et al. 2020).

Within this region, the BIOICE (Benthic Invertebrates of Icelandic Waters) programme conducted a comprehensive national inventory of benthic diversity between 1991 and 2004, with sampling depths from 20 to 3000 m (Steingrímsson et al. 2020; Guðmundsson 2023). BIOICE was coordinated primarily by the Marine Research Institute and the Icelandic Institute of Natural History and has produced extensive collections of deep-sea invertebrates from around Iceland.

Here, we report the first record of *Crypthelia medioatlantica* Zibrowius & Cairns, 1992 from west Iceland, based on BIOICE material (Fig. 1). Previously, the species was known only from a few localities on the Mid-Atlantic Ridge between ~ 23° and 37° N (Zibrowius and Cairns 1992). This new record at ~ 65°N represents the northernmost known occurrence of the species, highlights hidden stylasterid diversity in the North Atlantic, and demonstrates the value of re-examining historical deep-sea collections for refining stylasterid biogeography.

Materials and methods

The specimens were collected in 1996 using a detritus sledge ("Sneli") west of Iceland during the BIOICE programme and are deposited in the collections of the Nature Research Institute of Iceland (NRII). The sampling site (station 2918) is

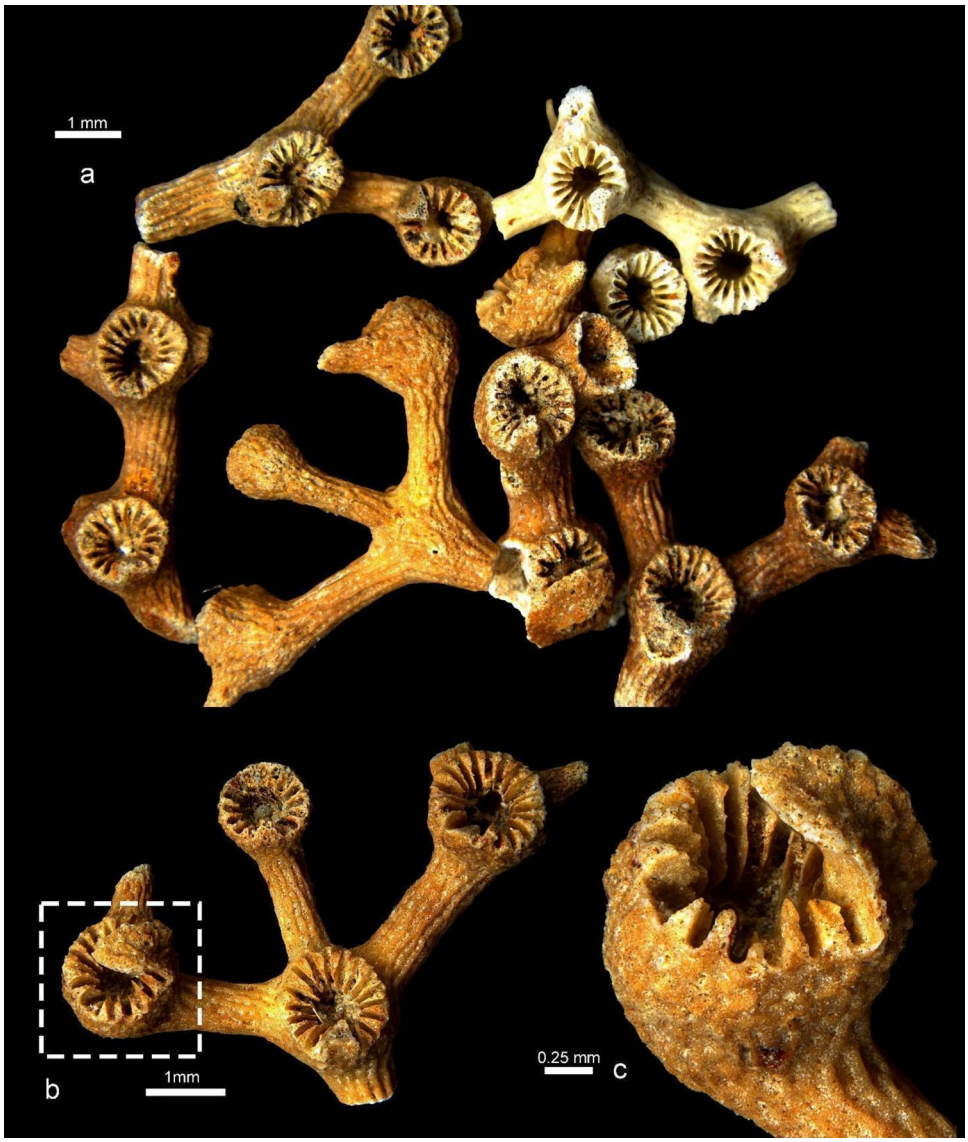

Fig. 2 Fragments of *Crypthelia medioatlantica* Zibrowius & Cairns, 1992 (NRII cat. no. 43546); **a** branch segment with cyclosystems, most with broken lids; **b** male cyclosystem with ampullae; **c** magnified view of cyclosystem with lid and male ampullae

located in the Denmark Strait (Fig. 1), close to a major route of southward-flowing deep-water currents from the Nordic Seas (Jochumsen et al. 2016, 2017), which provide cold, dense waters typical of stylasterid habitats. At this station, the detritus sledge sampled a depth of 1539 m on 26 August 1996; associated environmental data (bottom temperature 3.2 °C, salinity 34.9‰) were recorded during sampling. The material consists of six small, dry, dead branch fragments lacking soft tissue. The fragments show subfossil preservation (surface patination, localized smoothing) (Fig. 2).

Morphological examination

Morphological features were examined under a stereomicroscope, focusing on cyclosystem size, coenosteal texture, and ampullar structure. Measurements of branch diameter, cyclosystem diameter, and dactylopore counts were taken using digital calipers from all well-preserved cyclosystems on the six fragments (see Material examined and Diagnosis for sample sizes). Scanning electron microscopy (SEM) was performed at the Naturalis Biodiversity Center (Leiden, The Netherlands) using a JEOL JSM-IT510 SEM operated at 10 kV. Terminology follows Cairns (1983) for the description of stylasterid corals.

Results

Systematic account
Hydrozoa Owen, 1843
Anthoathecata Cornelius, 1992
Stylasteridae Gray, 1847
***Crypthelia* Milne Edwards & Haime, 1849**
***Crypthelia medioatlantica* Zibrowius & Cairns, 1992**

Figures 2 and 3

Crypthelia medioatlantica Zibrowius & Cairns, 1992: 110 (table), 112–114, figs. 36J–M, 38A–H.

Material examined BIOICE station 2918, west of Iceland, 65.21583° N, 29.24867° W, 1539 m depth, detritus sledge ("Sneli"), 26 August 1996, six dry, subfossil fragments, Nature Research Institute of Iceland (NRII), cat. no. 43546.

Taphonomic assessment Macroscopic inspection and SEM indicate subfossil preservation (surface patination; localized smoothing of the coenosteum), but diagnostic micromorphology is intact, allowing confident identification to *C. medioatlantica*.

Diagnosis Subfossil fragments of branches, delicate and small; complete colonies unknown but likely uniplanar. Largest fragment ~ 8 mm long bearing four cyclosystems; subterminal branches slender, 0.45 mm in diameter (Fig. 2a). Coenosteum exclusively linear-imbricate, with slightly convex strips 70–85 µm wide (Fig. 3a–c), densely covered by narrow platelets 4–14 µm wide; nematopores absent. Cyclosystems circular, 1.2–1.4 mm in diameter, each with 14–19 dactylopores (mean 16.1, mode 15). Upper gastropore chamber ~ 0.60 mm in diameter, with ring constriction ~ 0.35 mm; lower chamber ~ 0.65 mm in diameter and ~ 0.10 mm deep. Cyclosystem lid digitiform, inclined upwards, sometimes absent, covering 0–20% of the cyclosystem; ~ 0.30 mm wide. Dactylotomes and pseudosepta ~ 0.10 mm wide; pseudosepta distinctly concave (Fig. 3d). Male ampullae discrete, hemispherical, ~ 0.6 mm in diameter, 1–4 arranged around proximal cyclosystem wall (type C1 *sensu* Cairns 2015: Table 9) (Fig. 2b, c); surface covered with a reticulate system of carinae (~ 60 µm high), extending over the lid. Each ampulla bears an apical depression (~ 0.18 mm wide) with a central raised papilla (~ 0.10 mm diameter) and an apical efferent pore 40 µm in diameter. Measurements are based on all well-preserved cyclosystems on the six fragments ($n = 9$ cyclosystems).

Remarks *Crypthelia medioatlantica* was previously known from only three records included in its original description, all from the Mid-Atlantic Ridge between 23° 31′ N and 36° 50′ N (ca. 23–37° N; the latter off the Azores), at depths ranging from 861 to 2644 m (Zibrowius and Cairns 1992) (Fig. 1). This places it among the deepest stylasterid species known to date, comparable to *Crypthelia affinis* Moseley, 1879, which was collected at 2790 m (Moseley 1879). The present record from west of Iceland represents the northernmost known occurrence of *C. medioatlantica* and extends its known latitudinal range by approximately 28° into sub-Arctic waters. The Icelandic record indicates that the species has occurred in sub-Arctic deep-sea environments, but because the material consists solely of dead skeletal fragments, the current status of local populations and the timing of their occurrence remain uncertain.

Female ampullae are unknown but are inferred to be of B-type *sensu* Cairns (2015: Table 9), based on known reproductive dimorphism in congeners.

The subfossil state indicates that the fragments may predate collection; establishing their age would require direct dating (U–Th or radiocarbon), so this record documents past presence rather than demonstrating a living population at the time of sampling.

Discussion

Biogeographical and ecological significance

Stylasterid corals are frequently under-represented in benthic biodiversity surveys because their small and fragile colonies, including those of the genus *Crypthelia*, are easily damaged or lost during trawl-based sampling. In the North Atlantic, only a few stylasterid species have confirmed high-latitude records: *Stylaster norvegicus* (Gunnerus, 1768), *Pliobothrus symmetricus* Pourtalès, 1868, *Stylaster gemmascens* (Esper, 1794), and *Stylaster erubescens* Pourtalès, 1868. The present record of *C. medioatlantica* from Icelandic waters adds a fifth species to this group, as revealed by historical BIOICE material, and significantly extends the known northern range of the species.

The new Icelandic locality, together with previous records from the Mid-Atlantic Ridge, suggests a broader ecological tolerance for *C. medioatlantica* and raises important questions about population connectivity and evolutionary history. Like many stylasterids, *Crypthelia* is inferred to be a brooder (Cairns 1986, 2011), implying limited larval dispersal and rare colonization events. In the absence of live material or genetic data, however, we cannot distinguish whether the Icelandic record reflects a long-lived local population that persists at depth, a now-extinct relict population, or a rare long-distance dispersal event from more southerly source populations; the available data are too limited to favor any of these scenarios.

The geographic position of BIOICE station 2918 in the Denmark Strait region suggests a plausible dispersal corridor from the Mid-Atlantic Ridge into sub-Arctic bathyal habitats. Southward-flowing overflow waters and deep boundary currents from the Nordic Seas could facilitate rare long-distance transport along ridge and slope hard substrates, consistent with the species' deep distribution (Jochumsen et al. 2016, 2017). The overlap between the species' bathymetric range (861–2644 m) and these overflow/boundary-current pathways in the Denmark Strait makes deep-current mediated dispersal plausible, potentially aided by ridge and slope "stepping-stone" habitats (Jochumsen et al. 2017; Hansen and Østerhus 2000; Etter

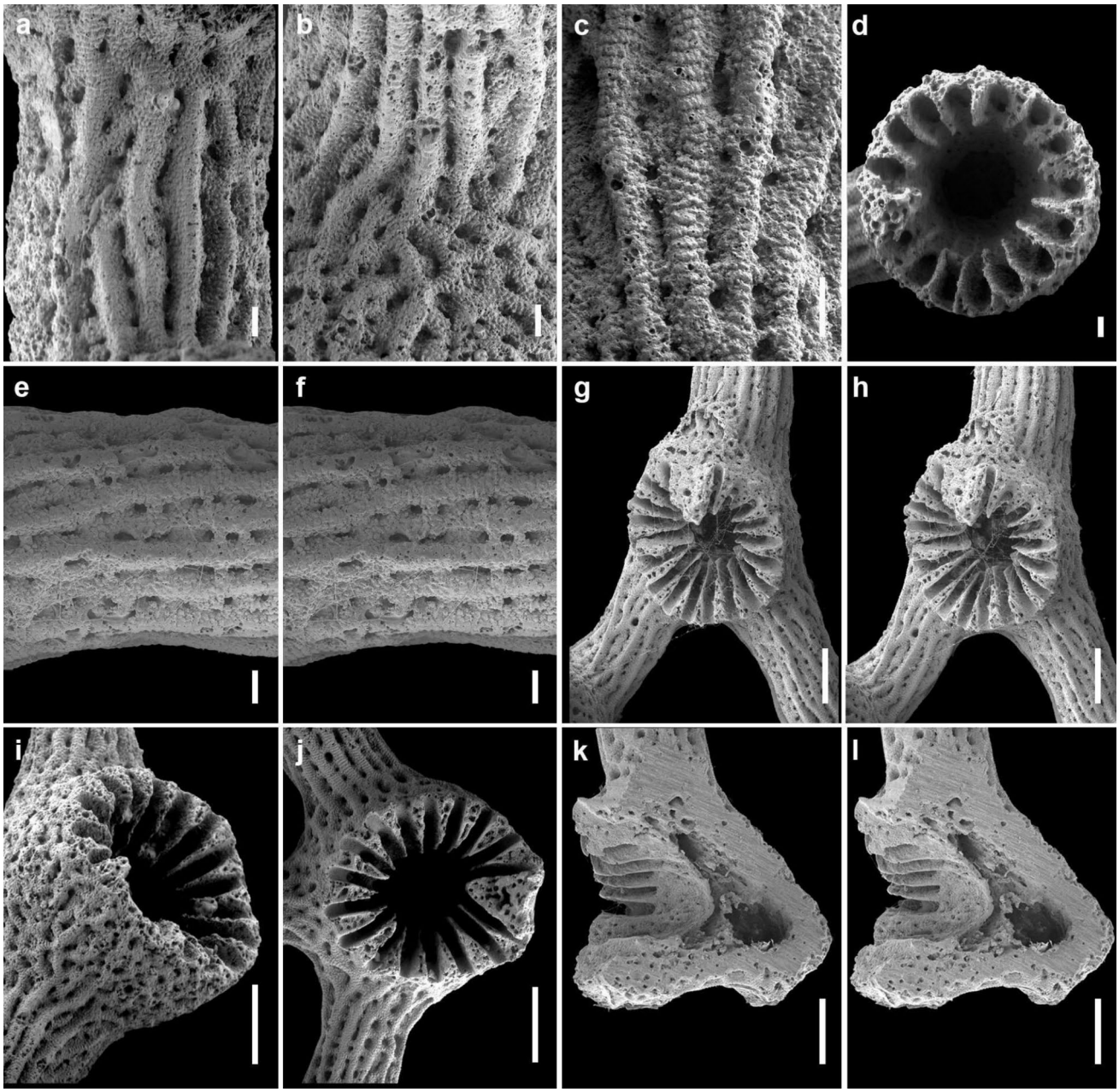

Fig. 3 *Crypthelia medioatlantica* Zibrowius & Cairns, 1992 (NRII cat. no. 43546); **a**–**c** coenosteal texture; **d** concave pseudosepta; **e**, **f** stereo pair of coenosteal texture; **g**, **h**, stereo pair of cyclosystem partially surrounded by male ampullae with visible efferent pores; **i**, **j** cyclosystem partially surrounded by male ampullae (lid broken in **i**); **k**, **l** longitudinal section of cyclosystem showing gastropore chambers (stereo pair) (scale bars: a–f = 0.1 mm; g–l = 0.5 mm)

and Bower 2015; Breusing et al. 2016), and mesoscale or topographically steered circulation events (Spall and Price 1998; Koszalka et al. 2017).

Given its depth range, *C. medioatlantica* is likely adapted to environments that remained relatively thermally stable during Pleistocene glacial–interglacial cycles (Rex et al. 2006; Thistle 2003). Such stability may have facilitated the persistence of cold-adapted stylasterids while glaciation reshaped shallow-water habitats, but this hypothesis remains to be tested. However, Schuchert (2000) reported a sharp decline in hydrozoan diversity below 200 m in Icelandic waters during the BIOICE survey, with no stylasterids documented at all, emphasizing that this depth zone remains severely under-sampled for stylasterids.

Conservation implications

Stylasterid corals are notable for their fragility, slow growth, and limited dispersal capacity (Zibrowius and Cairns 1992; Cairns 1992, 2011). Stylasterids are listed under CITES Appendix II and are recognized as Vulnerable Marine Ecosystem (VME) indicator taxa (Burgos et al. 2020). The Icelandic record of *C. medioatlantica*, although based on a few subfossil fragments, contributes to the baseline mapping of stylasterid diversity in sub-Arctic North Atlantic waters and highlights the importance of continued deep-sea biodiversity assessments in under-explored regions such as Iceland's deep benthic habitats. Resolving remnant vs. extant status will require targeted modern sampling (ROV/post-trawl fine sorting) and, where feasible, direct dating of stylasterid skeletons (U–Th or radiocarbon) to constrain residence time. Stylasterids are easily overlooked in bulk trawl samples due to their small size, and the absence of soft tissue in dead fragments further complicates identification. Although the negative impacts of trawling on corals are increasingly recognized, conservation measures remain species- and region-specific. Records of deep-water corals, including stylasterids, have contributed to the scientific basis for recent Icelandic fisheries closures, such as the designation of the Coral Conservation Area at Papagrunn slope (Stjórnartíðindi 2023). To improve detection and documentation of cryptic or rarely encountered taxa, targeted sampling strategies, such as fine-scale post-trawl sorting, detailed specimen imaging, and early involvement of taxonomic specialists, are crucial.

In addition to trawling, emerging anthropogenic threats, such as deep-sea mining, oil and gas exploration, and the impacts of climate change, pose new risks to vulnerable coral communities in the North Atlantic (Roberts et al. 2006; Cordes et al. 2016; Levin et al. 2016; Mengerink et al. 2014). Although the specific effects on stylasterid populations are poorly documented, the expansion of industrial activity into deep-sea environments highlights the need for enhanced baseline knowledge and more targeted conservation actions.

The value of historical collections and future directions

The re-examination of archived BIOICE material revealing *C. medioatlantica* highlights the enduring value of historical collections in biodiversity research. As Schuchert (2000) emphasized, the richness of the BIOICE collection continues to reveal previously undocumented hydrozoan diversity, even among well-studied groups. Recent initiatives, such as the 2023 Cold-Water Coral Workshop in Iceland (Sigwart et al. 2025), have further promoted the re-examination of museum holdings and fostered international taxonomic collaboration. Expanding such efforts will be vital for improving future deep-sea assessments and refining our understanding of coral diversity and distribution in the region.

At the same time, this study illustrates the limitations of relying solely on preserved skeletal material, which in this case lacks soft tissue and therefore precludes molecular analyses that could resolve population connectivity, phylogeographic structure, and evolutionary history. Fresh collections of *C. medioatlantica*, ideally including material from Iceland and from intermediate localities along the Mid-Atlantic Ridge, are needed to test whether the Icelandic record represents an isolated occurrence, a now-extinct relict population, or part of a broader sub-Arctic population system. Complementary life-history research, including studies on age, growth, and reproductive strategies, will also be critical for assessing the vulnerability and resilience of *C. medioatlantica* to pressures such as ocean acidification. Targeted integrative surveys that combine detailed morphology, molecular data, and environmental information at sites like BIOICE station 2918 will therefore be key to resolving the biogeographic context of *C. medioatlantica* and informing conservation planning for stylasterid corals in sub-Arctic regions.

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Declarations

Conflict of interest The authors declare no competing interests.

Data availability All data supporting the findings of this study are included in the article. The examined material (NRII catalogue no. 43546) and associated metadata are deposited in the Nature Research Institute of Iceland.

Author contribution KS-N conceptualized the study, conducted observations, curated samples, performed imaging, and wrote the first draft. NB conceptualized the study, conducted observations, and contributed to writing and reviewing the manuscript. GG curated samples and data and contributed to writing and reviewing. IS contributed to writing and reviewing. SDC provided advisory support and contributed to writing and reviewing. All authors read and approved the final version of the manuscript.

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