



# New strategies for the new environment in Spitsbergen fjords (Arctic). Scattering of the feather star *Heliometra glacialis* (Echinodermata, unstalked crinoid) clinging to a crab

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## Abstract

This publication presents an unusual behavior of a comatulid crinoid that was tentatively attributed to *Heliometria glacialis* (Echinodermata, Crinoidea, Heliometrinae). This unstalked crinoid was observed clinging on *Hyas* sp. crabs in the inner part of the Spitsbergen fjords heavily loaded with suspension runoff. In situ observations were made using a 16-h and 45-min time-lapse sequence showing the decompositions of Atlantic cod. During the exposure, apart from typical organisms such as carrion crustaceans, crabs, and starfish, three individuals of crinoids were observed. One of the crinoids was clinging to the edge of the platform for most of the exposure. The remaining two individuals were observed attached to the carapace of *Hyas* sp. crabs for 6 h 55 min. It was also found, based on analysis of the video material from 202 locations examined in the summer season between 2015 and 2020 using a drop camera, two additional locations showing comatulid crinoids. Both locations in the Ekmanfjorden and in the interior of the Vannmijenfjorden are areas under the strong influence of a glacier meltwater plum or a glacial river runoff. So far, comatulid crinoids have been found mainly in locations outside of the influence of turbid waters from fjords. We interpret this new behavior within comatulid crinoids as an adaptation that help colonize new regions gradually exposed by the retreating glaciers.

**Keywords** Arctic · Spitsbergen · Fjords · Dispersal strategy · Unstalked Crinoidea · Heliometra

## Introduction

Due to the global warming, the European Arctic is one of the most changing marine ecosystems in the world (IPCC 2022). The retreat of sea ice, and tidal glaciers (de-icing), associated with increased advection of Atlantic waters is especially visible in coastal waters and fjords of the Svalbard archipelago (Søreide et al. 2021). This rapid change creates unique opportunity to observe how organisms adapt to new environment and emerging niches.

Particularly not only interesting, but also difficult to study are areas located in the direct vicinity of a tidewater glacier or a glacial river. Extreme sedimentation rates create exceptionally soft sediment that does not allow the use of traditional drop cameras with triggering by a weight hitting

the bottom. Visibility in such places often reaches 20 cm and less.

Rapidly melting tidal glaciers on Svalbard discharge huge amount of freshwater, fine, and coarse mineral particles in the vicinity of the glacier front (Lydersen et al. 2014). In areas of high mineral sedimentation rates, colonization by the epibenthic fauna requires an adapted behavior to prevent sinking into the sediment, avoid clogging of filtering apparatus, and being buried under massive rain of particles. Typical adaptations are to be mobile (fast swimming crustaceans) or very small and light (minute bivalves)—(Włodarska-Kowalczyk and Pearson 2004) or being able to turn around and shake the sediment off—like colonial bryozoan *Alcyonidium disciformae* (Kukliński and Porter 2004). Other option is to use large dropstones as a platform above the soft substrate or larger mobile species as a vehicle like organisms colonizing hermit crab shells (Balazy et al. 2015).

Our aim was to study newly exposed areas of coastline and seabed and check how these are becoming colonized by fauna (ACCES project—see Søreide et al 2021). Recording time-lapse videos from the deglaciated fjords, we have

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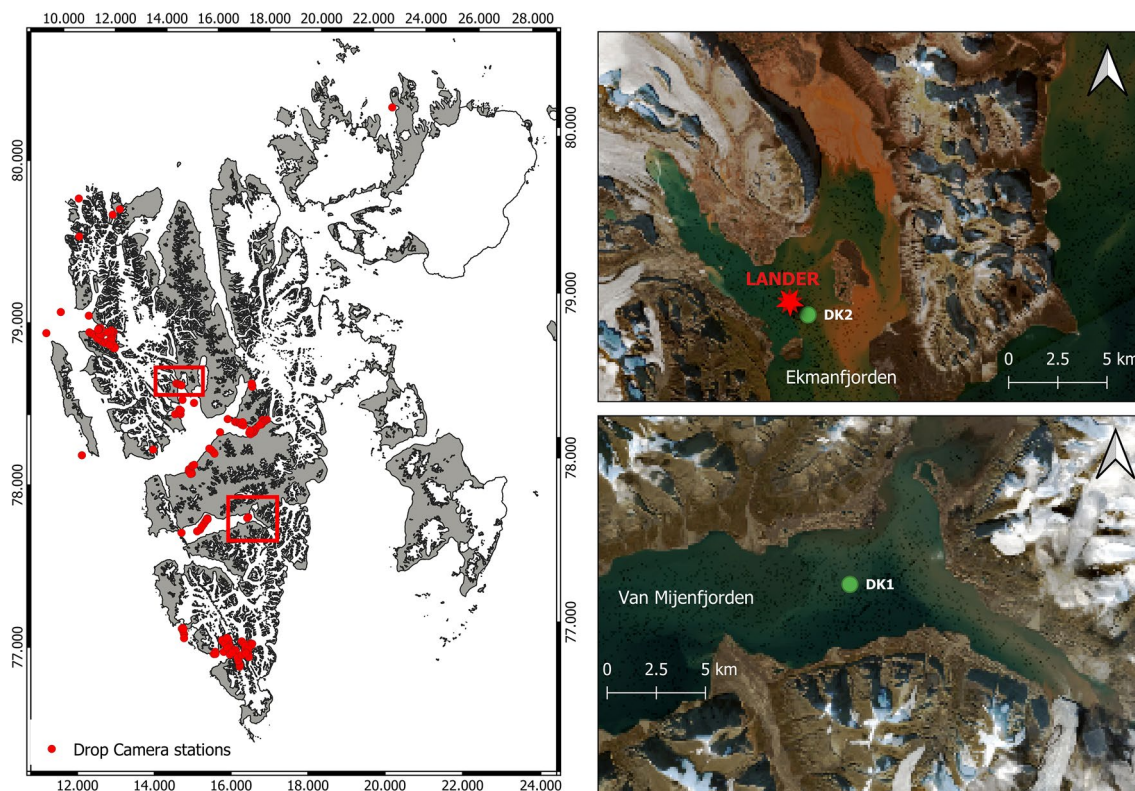
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observed an unusual behavior of the filter feeder crinoid in the turbid coastal environment, which is a new observation of the presumed adaptation helping the colonization of new regions.

There are two species of unstalked crinoids known from Spitsbergen coast (Clark 1970); however, only one, *Heliometra glacialis*, is regarded as relatively common and widely distributed on the outer shelf of Barents and Greenland seas—(Dyer et al. 1984; Graeve et al. 1997; Schander et al. 2010). The most typical bottom for this species is gravel mixed with mud and sand, but it has also been found only on sand, silt, and loose stones (Clark and Clark McGown 1967). Present records of this species typically placed it on mixed to hard bottom out of the fjords turbid waters, so occurrence of *Heliometra glacialis* within inner fjord basin comes as a surprise.

## Research area (environmental setting and location)

The research area is the western fjords of Spitsbergen. The Ekmanfjorden is the northern branch of the large centrally located Isfjorden fjord system (Fig. 1). It ends with two bays. One of them is Brevika, ends with a glacier flowing directly into the water, while the other is Mudderbukta ends with a river delta that drains water from glaciers ending on land. The place is heavily loaded with suspension runoff at least periodically since June–August (Fig. 1). This is visible on the water surface in the form of brick-red plumes, which is the result of the erosion of Devonian sandstones lying in the area (Hjelle 1993; Kavan et al. 2022). Median size of suspended particle near glacier area is much bigger than in inner and outer parts of the fjords (Sagan and Darecki 2018). The median size of suspended particles increases in water column due to sedimentation and flocculation processes (Szcuciński and Zajączkowski 2013; Moskalik et al. 2018). In winter, the fjord freezes and the ice recedes at the beginning of June (Kavan et al. 2022). Van Mijenfjord is a medium-sized fjord located south of Isfjord. The station



**Fig. 1** General map of Spitsbergen (at left) with locations of the drop camera stations and detailed satellite views figured at right. Red dots: drop camera stations, green dots: stations in which the presence of unstalked crinoids was recorded (DK1 and DK2), red aster-

isk: Lander station. The satellite images were taken two days after the Lander experiment and show plumes of sediment reaching the station areas

where the presence of unstalked crinoids was confirmed is situated in the inner part of the fjord between Rindersbukta with a glacier still actively flowing into the bay and Sveabukta, where suspension from the great glacial river Kjellstromdalen is discharged. The innermost part of the fjord usually freezes in winter. The image material was collected in the middle of the ablation season (Holmes et al. 2019) when the sedimentation rate is very high. In Kongsfjorden, the sedimentation rate reaches  $20,000 \text{ g m}^{-2} \text{ year}^{-1}$  in the area of the ice front (Svendsen et al. 2002). During the rest of the year the activity of the glacier and therefore the sedimentation rate is much lower. On the basis of research in Adolfbukta, it was found that in the autumn, the particulate matter flux to the bottom decreases by an order of magnitude compared to summer while the concentration of suspended particulate matter (SPM) decreases only twice. The authors explain this phenomenon with less effective flocculation (Szczuciński and Zajączkowski 2013).

## Materials and methods

Time-lapse cameras with lighting according to Balazy et al. (2018) were mounted on an adapted Lander structure previously used to take underwater vertical photos. The device was lowered to the seabed from the RV Oceania at the selected location (Fig. 1) at a depth of 35 m. The ship then sailed to another position minimizing its impact. Lander is a construction made of stainless steel, weighted with lead to minimize tipping when lowering to the bottom. Modification of the Lander consisted mainly in building special clamps for two sets of cameras and adding a platform at the height of 30 cm for attaching the bait. Due to the often very hydrated and soft sediment in the inner parts of the Spitsbergen fjords, the heavy lander was sinking into the sediment, and as a result, the bait platform was at the bottom level. Classical benthic gear (box cores) use to sink in the sediment as well. A drop camera with a preview or specially prepared time-lapse video equipment left for a short time up to several days (buried by sediment) will work best. One of the cameras was mounted at an angle, the other directly above the bait. The bait was half Atlantic cod. The exposure time was 16 h 45 min. The camera mounted at an angle worked with an interval of 5 min, which allowed to obtain 205 photos. The vertically mounted camera worked with an interval of 15 min, which allowed to obtain 67 photos. The vertical camera images had a defect due to a trapped air bubble in front of the lens but were still usable. The material was recorded in both JPG and RAW format, which allowed to easily and without loss of quality improve the exposure of photos. From the captured material, a time-lapse movie (15 fps—frame per second) was made showing the course of the entire experiment. Drop camera photos were taken according

to the methodology described by Deja et al. 2019 in the summer season between 2015 and 2020 from the research vessel RV Oceania. In total, material was collected from 202 locations. The bottom was filmed with a camera for 10 min. In the studied locations, CTD (Conductivity–Temperature–Depth) profiles were also made to check the temperature and salinity in the bottom layer.

## Results

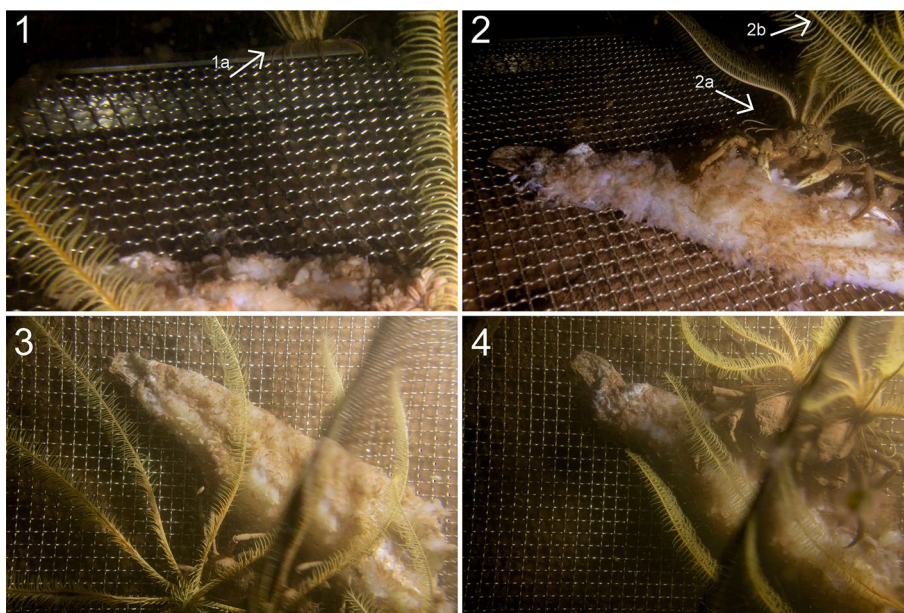
After 55 min, the first carrion crustaceans appeared on the bait. Mainly *Onisimus* sp. and *Orchomenella minuta*. At the same time, they constituted the main part of the attracted invertebrates. After two hours and 55 min, the first representative of crabs attributed to *Hyas* sp. was recorded. Several large scavenger crustaceans *Anonyx nugax* were also attracted, but in very small numbers (only a few individuals). The bait was also visited once by a starfish, probably *Urasterias lincki*. After 4 h and 35 min from the beginning of the time-lapse sequence, one unstalked crinoid from the Comatulida order attributed to *Heliometra glacialis* was recorded. After the analysis of subsequent frames, it can be seen that the this unstalked crinoid was clinging to the platform edge (Fig. 2) and remained in this position until the Lander was pulled out, i.e., over 12 h. In the eighth hour of exposure, a second specimen of *Heliometra glacialis* was registered. It was clinging to the carapace of a crab *Hyas* sp. For the next hours, this *Hyas* sp. crab with a crinoid attached remained visible in the camera field, and at 14 h a second *Hyas* sp. crab also with a crinoid on its carapace appears (Fig. 2). Until Lander was brought to the surface, the crabs with attached crinoids were feeding on the exposed bait. For a total of 6 h 55 min (131 frames), the assemblage crabs/crinoid or only crinoid arms were recorded in the field of view (which meant that the crab was feeding out of frame on an invisible fragment of the bait).

The analysis of the video material from the drop camera showed that comatulid crinoid was also recorded in two additional locations out of the 202 surveyed places. Both locations (DK1, DK2) are located in the inner part of the fjords and are similar in terms of hydrological conditions (Fig. 1). Temperature and salinity in the bottom layer for station DK1 (72 m depth) are ( $-1.45 \text{ }^{\circ}\text{C}$ ; 34.27) and those for station DK2 (42 m depth) are ( $2.7 \text{ }^{\circ}\text{C}$ ; 33.7), respectively. On the surface layer, temperature varies from  $4.59 \text{ }^{\circ}\text{C}$  on DK1 station to  $8.03$  on DK2, and salinity varies from 28.49 to 16.21 respectively. However, none of the comatulid crinoid observed in these additional locations was seen clinging on a crab.

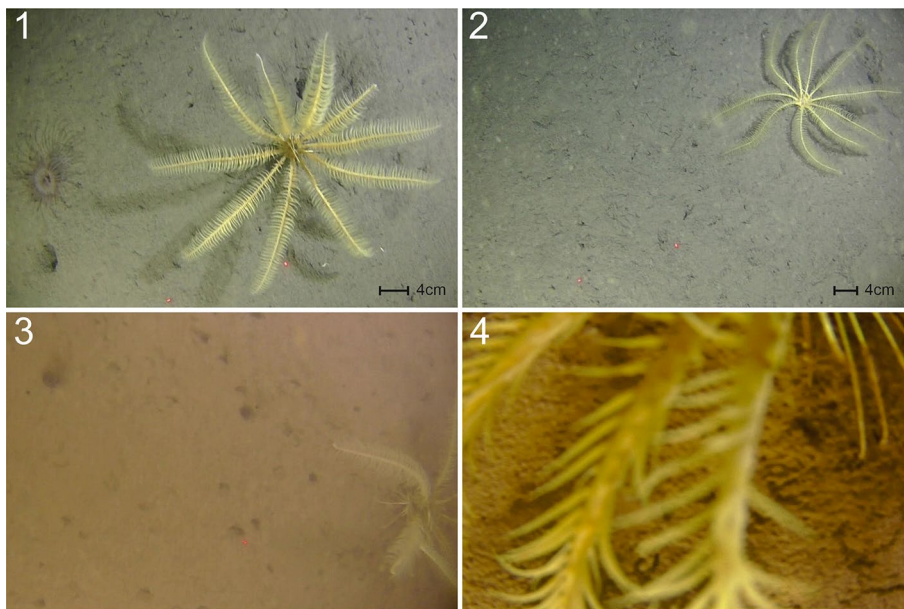
Observations of crinoids in other glacial bays, the innermost parts of the fjords of western Spitsbergen were confirmed using a drop camera (Fig. 3) and other common



**Fig. 2** Photographs showing *Heliometra glacialis* recorded during bait experiment on Lander station. 1a—A crinoid attached with its cirri to the edge of the platform. 2a—Specimen with cirri clinging on *Hyas* sp. carapace. 2b—Arm of a second crinoid also attached to a nearby crab. 3–4—photographs from the horizontal camera, better showing the inter-relationships crinoid/crab



**Fig. 3** Specimens of *Heliometra glacialis* registered in the summer of 2020 in Vanmijenfjorden at DK1 station (1;2) at a 72 m depth and in Ekmanfjorden at DK2 station (3;4) at a 42 m depth. Photographs from Ekmanfjorden are not to scale due to very difficult hydrological conditions (strong currents and high suspension)



echinodermata (starfish and brittle stars) were found in large numbers within the glacier basin and glacier front (Deja unpublished data).

## Discussion

Comatulids and other invertebrate suspension feeders often colonize elevations on the seabed (Meyer 1980; Messing et al. 1990; Messing 1997, 2004; Meyer et al. 2014, 2021; Meyer and Sweetman 2015). At such heights, the flow of current is faster and more laminar, thanks to which these organisms get a feeding advantage (Genin et al. 1986;

Meyer-Kaiser et al. 2021). We observed one crinoid attached to the edge of the platform and the other two attached to the carapace of a crab (Fig. 2, Online Resource—supplementary time-lapse video material). An experiment conducted in the LTER (long-Term Ecological Research) area of HAUSGARTEN, Meyer-Kaiser et al. (2019) showed that on abandoned steel structure the number of comatulid crinoids attributed to *Poliometra prolixa* was significantly higher than at the bottom surface. In Fram Strait where the hard substrate is limited, *P. prolixa* has been frequently observed on stones and as an epibiont on sponges (Meyer et al. 1984, 2014, 2016; Schulz et al. 2010). Bottom currents are essential for benthic organisms to disperse, reproduce, and feed (Eléaume et al.

2011). Dense aggregations of *Heliometra* have been noted on the elevations of sea bed in oceanic ridge—Mohn area in N Atlantic or on the large colonies of sponges (Schander et al. 2010). In the glacial bay, the hard substrate is also very limited, which may explain to some extent the association with crabs, and the attachment of one specimen to the edge of the platform (Fig. 2). To the best of our knowledge, no similar observation has ever been recorded. Crabs from the Majoidea superfamily, which are also represented by the observed *Hyas* sp., are known for decorating the carapace. An association between *Hyas araneus* and *Hyas coarctatus* with the sea anemones *Cribrinopsis similis*, *Hormathia nodosa*, and *Urticina crassicornis* was previously observed in the study area (Balazy et al. 2014). There are only a few reports of epibiont relationships between echinodermata and sea crabs in general (Ng and Jeng 1999; Lee and Ko 2009). Relationships among Pilumnidae, Portunidae are mainly described. Associations with crinoids (*Harrovia albolineata*, *Harrovia japonica*, *Tiaramedon spinosum*) have also been recorded, but none of these observations concern the Arctic regions.

The dropstone melted from the growler will be quickly buried, but the highly mobile large crab gets rid of the suspended matter, while being a convenient substrate for the crinoids. The notion that Echinodermata prefer non-turbid waters often mentioned in the literature is a misleading generalization (Meyer 1980). Many Echinodermata, including crinoids, live in at least periodically cloudy environments (Meyer 1973, 1980). Such a periodically cloudy environment is precisely the glacier bay, the innermost parts of the fjords.

Comatulids in Svalbard were mainly observed in the deep water region (Anisimova and Cochrane 2003; Meyer-Kaiser et al. 2021), the northern Svalbard shelf (Meyer et al. 2015), Wijdefjorden in the northern part (Gulliksen and Svensen 2004). *Heliometra glacialis* generally prefers open waters and has rarely been observed in bays or fjords. However, its presence was found in Gronfjord (small branch in the entrance of Isfjord) (Clark and Clark McGown 1967) and a study conducted over 100 years ago (Hofsten 1915) also found isolated occurrences of *Heliometria glacialis* in Isfjord. The temperature range in which the species was recorded ranges from  $-1.90$  to  $5.80$  °C, while the salinity ranges from 32.2 to 34.9. (Clark and Clark 1967) which is consistent with the temperature and salinity values measured during our study.

The area of the fjords, especially the inner parts, still have much to offer and can significantly expand our knowledge about the behavior, interactions, and functioning of benthic organisms in this changing environment.

The melting tidal glacier forms environment that can offer benefits and not only difficulties. First of all, there is massive rain of marine plankton killed at the surface by the osmotic shock (Węśławski and Legeżyńska 1998; Zajaczkowski and Legeżyńska 2001). This large and predictable food source

sustains rich community of mobile carrion feeders and occasionally also krill that is able to collect phytoplankton food from the sediment (Hirche et al. 2016; Deja et al. 2019). This may be not only a convenient niche for crinoids, but also for the broadly defined megafauna throughout the fjord, also because that large benthic predators such as Atlantic cod avoid such environments (Szczycka et al. 2017).

Crinoids seems to use the uncommon method—crab riding, to avoid the problem with unstable bottom and still use the benefits of glacial front. However, it should be taken into account that crinoids can move on their own, and also might be transported with currents to places behind their usual optimal habitats. There the crab riding might be a useful survival strategy.

## Conclusion

During recording time laps videos, we observed the presence of crinoids in the inner part of deglaciated fjords, under strong influence of turbid water from glacier meltwater. Known records of this species typically place it on mixed to hard bottom out of the fjords turbid waters, so our finding of *Heliometra* within inner fjord basin comes as a surprise. In addition, we have observed two specimens of the comatulid crinoid *Heliometra glacialis* clinging on crabs. We interpret this yet undescribed behavior as an adaptation to colonization of new habitats and in this case to avoid the problem with unstable bottom and still use the benefits of glacial bay.

An alternative interpretation could be: fjords are not optimal habitats for comatulids but some individuals, transported by currents or by chance end up in there, some are lucky enough to find elevated substrate on which to cling, some of these substrates are crabs and this is possible because this crab accepts symbiotic relationships. This interpretation takes into account all of the data available and points at the idea that this is not an “adaptation” (this needs to be defined) but some sort of colonization by chance that is expected in animal populations, especially in populations composed of many individuals such as *Heliometra*.

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s00300-023-03171-3>.

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**Author contributions** KD conducted the experiments, analyzed the data, and designed and wrote the manuscript. KDD wrote and edited the manuscript. JMW reviewed the manuscript. All authors read and approved the final manuscript.

## Declarations

**Competing interests** The authors are required to disclose financial or non-financial interests that are directly or indirectly related to the work submitted for publication. Please refer to “Competing Interests and Funding” below for more information on how to complete this section.

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