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NOTE

Detached tentacles of lion's mane jellyfish *Cyanea capillata* can injure aquaculture fish

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ABSTRACT: Gelatinous zooplankton can cause fish mortalities and economic losses for aquaculture companies. While protective measures against jellyfish blooms are increasingly implemented, free-floating tentacles have not been considered. Tentacles with active cnidocysts, both whole and fragmented, can cause potential damage to fish for an unknown duration after the jellyfish bloom has passed. In this pilot study, we measured for how long detached tentacles of the lion's mane jellyfish *Cyanea capillata* can cause injuries/catch zooplankton prey. Controlled experiments were conducted in late summer 2007 using *in situ* collected specimens from northern Iceland. Jellyfish tentacles maintained their full ability to capture brine shrimps *Artemia salina* for 24 d. However, no prey could be immobilised from Day 26 onwards. To our knowledge, this is the first experimental evidence showing how long cnidocysts in tentacles can catch prey and thus potentially harm aquaculture fish after detachment (about 3.5 wk); this information should be considered when making any hypothetical risk assessment.

KEY WORDS: Cnidaria · Experimental biology · Farmed fish · Gelatinous zooplankton · Mariculture

1. INTRODUCTION

Gelatinous zooplankton, cnidarian jellyfish, and siphonophores in particular, can cause high mortality in farmed fish and hence significant economic losses for the aquaculture companies. Given the negative impacts of jellyfish blooms (Purcell 2012), monitoring of these blooms has become increasingly important. However, as recently highlighted by Halsband et al. (2018), information on jellyfish in high-latitude Atlantic coastal systems is scarce, which makes it difficult to predict bloom events. This includes mariculture in Iceland. Negative interactions between gelatinous zooplankton blooms and aquaculture have been reported from around the globe (Hellberg et al. 2003, Emelianov 2011, Rodger et al. 2011, Halsband et al. 2018). Stinging of the fish skin and gills by cnidocysts of medusae may be the most obvious risk; this applies both to species small enough to pass through the mesh of the cages and to fragments of larger jellyfish (Baxter et al. 2011, Lucas et al. 2014, Mianzan et al. 2014, Pitt et al. 2024). Wounds from jellyfish stings may subsequently become infected by bacterial pathogens and cause changes in blood chemistry (Marcos-López et al. 2016, Powell & Dale 2018). Problems may even arise when the jellyfish are not harm-

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ful, as they can clog pen meshes and fish gills if in sufficient numbers, preventing oxygenation and water exchange between the cage and the surrounding water, leading to hypoxia, stress behaviour, and suffocation of the fish (Rodger et al. 2011, Lucas et al. 2014, Pitt et al. 2024). While the described impacts can result from hydrozoan and scyphozoan blooms, we focus here on large scyphozoans.

In Iceland, scyphozoans are not species rich. Typically, the common jellyfish *Aurelia aurita* and the lion's mane jellyfish *Cyanea capillata* dominate (Sigurdsson et al. 2021, Lüskow et al. 2023). *C. capillata* grows up to 40 cm in diameter in Icelandic coastal waters (Lüskow et al. 2023). The tentacles of the lion's mane jellyfish are generally 100 times longer than its umbrella width (J. Javidpour pers. comm.), and can potentially reach lengths in the order of 40 m. The lion's mane jellyfish has approximately 1600 tentacles, and tentacles are, on average, 300 µm wide (Colin & Costello 2007). Except for extraordinarily high volume-specific ephyra numbers in spring, *C. capillata* abundances are ca. 1 ind. 1000 m^{-3} in nearshore waters in summer and autumn (Lüskow et al. 2023). Aquaculture of salmonids, mainly Atlantic salmon *Salmo salar*, is an emerging industry in Iceland. Jellyfish blooms have previously caused extensive damage to salmon farms in East Icelandic fjords (between 2001 and 2006). This damage was particularly serious in 2006 when ca. 1000 t of salmon were killed or had to be slaughtered due to injuries from *C. capillata* tentacles (Gunnarsson & Gunnarsson 2007). *C. capillata*, which often grows bigger than 50 cm in diameter, has also caused mortality events of farmed fish in Ireland and Scotland (Lucas et al. 2014). Strong winds coupled with tidal currents can cause jellyfish blooms to hit the sea pens, fragment on contact, and small pieces and tentacles can then be washed into the aquaculture cages, where they can cause skin and gill wounds and even instant death. These tentacles, both whole and fragmented, have active cnidocysts which potentially cause damage long after the jellyfish bloom has passed. While experiments in the past used only fresh *C. capillata* tentacles (e.g. Colin & Costello 2007, Helmholz et al. 2007), the longevity of their cnidocysts is not well-studied.

The objective of this investigation was to estimate for how long detached tentacles of *C. capillata* can cause potential injuries using an experimental setup. The damage potential of tentacles was evaluated based on the ability of cnidocysts in tentacles to catch zooplankton prey (*Artemia salina*).

2. MATERIALS AND METHODS

Several adult *Cyanea capillata* of around 40 cm in diameter were collected with a Bongo net just below the surface (~1 m depth) north of the island Hrísey in Eyjafjörður (66.0° N, 18.4° W), northern Iceland, in August 2007. They were kept individually in 20 l buckets filled with seawater and transported to a research station in Sandgerði (SW Iceland), which took approximately 5 h. The jellyfish were then transferred to and kept in 500 l tanks designed for aquaculture, with recirculating seawater at 6°C and a salinity of 35, similar to the conditions at the collection site. Approximately 5 jellyfish were held in each tank, and they were kept for 2 d until tentacle cutting.

For the experiment, a few hundred tentacles were cut off from the medusae with scissors at the start of the experiment and placed in 5 jars (1 l) filled with clean seawater and kept in a refrigerator at 6°C. The seawater was exchanged once a day. To test whether jellyfish tentacles were active, 5 tentacles, randomly chosen from each jar, were placed in individual Petri dishes with seawater. One growing or adult brine shrimp *Artemia salina* was then added to each Petri dish. The tentacles were considered active if the tentacle was able to catch the brine shrimp. At first, cnidocyst activity was monitored every 1 h, but after the first 48 h, the monitoring was changed to daily checks with new tentacles tested each day. The experiment continued for 28 d. Data were visualised using R (R Core Team 2023) version 4.3.2.

3. RESULTS

Tentacles of *Cyanea capillata* maintained their full ability to capture brine shrimps for 24 d. The tentacles were mostly passive, but managed to catch the brine shrimp when it made contact. Over time, tentacles decreased in length and volume, becoming approximately 50% shorter and narrower over the duration of the experiment (G. M. Sigurdsson pers. obs.). Despite this, cnidocysts were able to capture brine shrimps until Day 25 (3 out of 5 tentacles were unresponsive) and on Days 26, 27, and 28, none of the cnidocysts in the 5 tentacles immobilised a brine shrimp (Fig. 1).

4. DISCUSSION

The common jellyfish *Aurelia aurita* and the lion's mane jellyfish *Cyanea capillata* dominate Icelandic coastal waters (Sigurdsson et al. 2021, Lüskow et al.

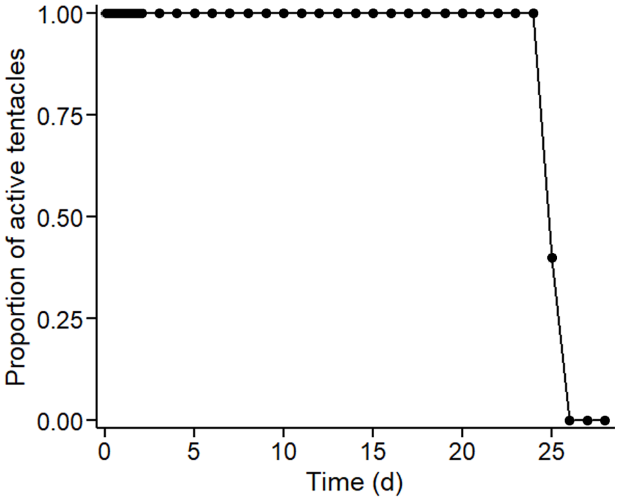

Fig. 1. Activity level of freshly cut tentacles of the lion's mane jellyfish *Cyanea capillata*. The ability of tentacles (n = 5, randomly chosen from each experimental jar) to immobilise brine shrimp *Artemia salina* is shown over the experimental period of 28 d

2023). Results of our simple experiment suggest that pieces of jellyfish, e.g. tentacles, can potentially harm aquaculture fish long after the jellyfish themselves have disappeared or have been mechanically removed. The results have implications for protective fences, bubble curtains, or nets used to defend against jellyfish blooms, as those might stop the actual jellyfish yet not redirect tentacles. There is a need to assess whether the protective measures may facilitate the breaking of tentacles, as this may increase their number as opposed to natural shedding. Jellyfish blooms are typically observed for a few days or a week. However, tentacles might break off and have the capacity to potentially damage the fish for several weeks afterwards. Whether farmers should leave protective fences and bubble curtains in place after a jellyfish bloom disappears, or whether this may increase the risk of the tentacle potentially breaking, is yet to be explored. It would be relevant to know the tentacle-shedding rate of jellyfish, but this has not yet been investigated. We suggest that tentacle shedding be explored when modelling the impacts of jellyfish blooms on aquaculture. To our knowledge, this is the first experimental proof showing for how long cnidocysts in tentacles are active and thus can potentially harm aquaculture fish after detachment (about 3.5 wk). As stated earlier, exposure to jellyfish can be potentially harmful for fish. For instance, when the blood of Atlantic salmon *Salmo salar* was exposed to *C. capillata* venom, immediate haemolysis occurred (Headlam 2020) and blood electrolytes and CO_2 concentration increased (Powell & Dale 2018), illustrating potential post-bloom risks.

It should also be noted that tentacles with active cnidocysts may not just stay on the net (where they would be an unlikely threat as fish do not often come into contact with the net) but could break further and enter the water inside the cage. Volume- rather than area-specific tentacle occurrence could be a more interesting way to estimate how many cnidocysts will potentially come into contact with a given number of fish when one or more jellyfish hit an aquaculture cage, and this could be considered in any risk modelling efforts. In addition to documenting potential risks from jellyfish tentacles and broken pieces of jellyfish, our results are also relevant for evaluating the effect of fouling communities including hydroids that are common on aquaculture nets. These can be released during *in situ* net pen cleaning and the 'cleaning waste' might drift to neighbouring pens and potentially neighbouring farms where sustained cnidocyst activity may cause potential injury. As both scyphozoans, *A. aurita* and *C. capillata* (besides siphonophores like *Apolemia* sp.), are expected to change phenology and horizontal distribution in northern temperate waters as a result of climate change, spatiotemporal overlap with finfish aquaculture will likely increase (Pitt et al. 2024). These first results on the duration of jellyfish tentacle activity should be examined in more detail and considered when designing and implementing protective measures for maricultures.

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