First report of skin ulceration disease from temperate waters of the Northwest Atlantic: The case of the sea cucumber *Cucumaria frondosa*

Megan M.F. Scott,[1] Kevin C.K. Ma,* Sophie Wolvin, Jean-François Hamel[2] and Annie Mercier

Abstract

Approximately 60–70 adult individuals of the dendrochirotid sea cucumber *Cucumaria frondosa* –collected in waters off the coast of insular Newfoundland in eastern Canada – presented injuries consistent with skin ulceration disease (SKUD). An examination of 31 individuals that were suspected to be diseased revealed some cases of white-coloured lesions or ulcerations on the body wall, evisceration of internal organs, liquefaction of the dermis, and loss of podia attachment strength. Another 11 diseased individuals were quarantined and, eventually, exhibited liquefaction of the entire body and died. To our knowledge, this is the first time a condition consistent with SKUD has been reported in temperate–subpolar waters of the Northwest Atlantic and, the first time in *C. frondosa*, which is a commercially valuable species.

Keywords: dendrochirotida, health, outbreak, skin disease, SKUD

Introduction

The dendrochirotid sea cucumber *Cucumaria frondosa* (Gunnerus, 1767), commonly known as the orange-footed sea cucumber, occurs in the cold waters of the Arctic and North Atlantic (Mercier et al. 2023). In the northwest Atlantic, this species is commercially fished in the Canadian provinces of Quebec, New Brunswick, Nova Scotia, Newfoundland and Labrador, and in the French territorial waters of Saint-Pierre-et-Miquelon (DFO 2021; Gianasi et al. 2021; Mercier et al. 2023). The species has also been used for generations by some indigenous communities as part of a subsistence fishery in the Canadian Arctic (Mercier et al. 2023; Hamel and Mercier 2024).

There are multiple diseases described in holothuroids such as acute peristome edema disease, viscera ejection syndrome, and off-plate syndrome (Smith et al. 2022). Skin ulceration disease (SKUD), which can also be referred to as skin ulcer syndrome or SUS, has been described in tropical and temperate species (Delroisse et al. 2020). This disease is typically fatal; its common symptoms include anorexia, skin ulcers, swollen oral region, evisceration, general atrophy, and increased mucus secretion (Becker at al. 2004; Delroisse et al. 2020; Smith et al. 2022). Moreover, white spots can appear on the dermis, the dermis and connective tissue can be destroyed (i.e. liquefaction), and ulcers can enlarge over time, perforating the body wall (Delroisse et al. 2020).

SKUD was described in several species, all of which are commercially exploited: *Holothuria scabra* in the Indo-Pacific (Delroisse et al. 2020), *H. arguinensis* in the northeast Atlantic (Cánovas et al. 2019), and *Apostichopus japonicus* in the temperate western Pacific (Deng et al. 2009; Shao et al. 2013). Moreover, the disease was described in captive and cultivated sea cucumbers and, in some instances, wild sea cucumbers in Portugal (Cánovas et al. 2019; Delroisse et al. 2020).

This skin disease was first detected in juveniles of *A. japonicus* and was originally thought to be linked with elevated temperatures and high stock densities (Zhang and Liu 1998). Many factors induce the disease including bacteria, viruses, and parasites (Delroisse et al. 2020; Smith et al. 2022). Specifically, *Vibrio sp., Shewanella sp.,* and *Pseudoaltermonas sp.* are bacterial pathogens that have been put forward as causative agents of SKUD in sea cucumbers (Shao et al. 2013; Cánovas et al. 2019; Smith et al. 2022). Some suspected causative agents may be species specific; for example, certain types of bacteria or a diet containing high levels of animal organic matter (i.e. an inappropriate diet; Delroisse et al. 2020). Environmental and physiological stressors, such as high stocking density or thermal stress, may also be a proxy for SKUD outbreaks, as Zhang and Liu (1998) found the disease in *A. japonicus* under high stocking conditions and Delroisse et al. (2020) found it in *H. scabra* after prolonged exposure to low temperatures.

In this report, we document suspected cases of SKUD among individuals of a laboratory-held population of *C. frondosa* by comparing disease-associated symptoms with those previously described in the literature, and exploring potential co-incident causative factors. Also, we discuss the possible progressive deterioration of infected individuals, starting with the appearance of exposed collagenous connective tissue, then perforation on the body wall leading to evisceration, and ultimately liquefaction of the entire body wall.

[1] Department of Ocean Sciences, Memorial University, St. John's, Newfoundland and Labrador, Canada
[2] Society for the Exploration and Valuing of the Environment, St. Philips, Newfoundland and Labrador, Canada
* Corresponding author: kevin.ma@mun.ca; kevinckma@gmail.com

Methodology

More than 600 adult individuals of the sea cucumber *Cucumaria frondosa* were collected by hand via scuba at depths of ~10–15 m in Tors Cove, Newfoundland and Labrador, Canada (N47°12'44"; W52°50'39") between 2022 and 2023 for various fundamental and applied studies. In the laboratory (Ocean Sciences Centre, Memorial University), the collected individuals were transferred to independent flow-through tanks supplied with unfiltered ambient seawater. These sea cucumbers experienced the natural photoperiod through large windows and, as suspension feeders, they had access to ambient levels of food particles. Throughout the study period – from the beginning of March to the end of November 2023 – seawater temperatures in flow-through tanks were recorded using a temperature logger (HOBO Pendant Temperature/Light 64K Data Logger UA-002-64).

In the laboratory, *C. frondosa* were maintained at densities between 20 and 30 individuals per square metre and monitored regularly for mortality. These conditions would be typical in nature, with densities upwards of 50 individuals per square metre recorded in eastern Canada (Hamel and Mercier 1996; So et al. 2010; Gianasi et al. 2021; Hamel et al. 2023). Water flow and seawater temperature were monitored regularly.

All individuals showing signs of body-wall damage or signs of disease were taken out of the holding tank (~60–70 individuals over the study). A subset of these individuals (n = 31) was photographed and preserved in 70% ethanol. Another subset (n = 11) was quarantined in a separate holding tank to examine the disease (degradation) progression. The whole wet weight of some of these individuals (n = 24) was determined using a digital balance (Optima OPD-A).

Results and discussion

All unhealthy individuals of *Cucumaria frondosa* that were isolated and examined (i.e. those showing signs of abnormal body-wall conditions) lost podia attachment strength, and some exhibited swelling of the oral region (specifically the introvert, the collar of flexible tissue behind the buccal tentacles and associated structures that can be pulled into the body cavity by retractor muscles; see Mercier et al. 2023). For comparison, a healthy unaffected individual exhibited an unblemished body wall and tended to retract its introvert when disturbed (Fig. 1A). An external examination of the subset of 31 unhealthy individuals revealed that 84% (n = 26) presented white-coloured lesions or ulcers on the dermis (Fig. 1B–C). Fifty-four percent of individuals (n = 17) eviscerated internal organs (e.g. the digestive tract, gonads, respiratory tree) through a perforation of their body wall (Fig. 1D). Moreover, 10% (n = 3) exhibited liquefaction of the dermis (Fig. 1E–F). These dermal injuries tended to expose the white-coloured collagenous connective tissue underneath the dermis (Fig. 1B–F). These symptoms – white-coloured lesions and a swollen oral region – were consistent with those previously described in SKUD-affected individuals of other holothuroid species (Delroisse et al. 2020; Smith et al. 2022).

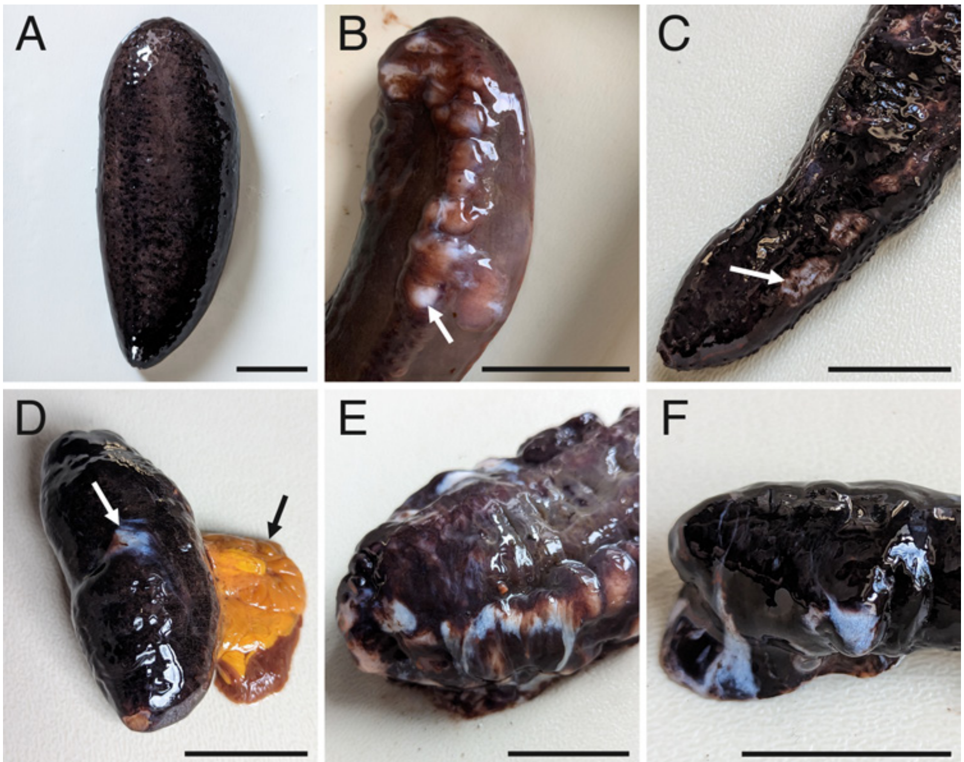

Figure 1. (A) A healthy unaffected *Cucumaria frondosa* individual; (B–C) individuals displaying white-coloured lesions or ulcers (white arrows), exposing the collagenous connective tissue underneath; (D) a case of evisceration through a perforation of the body wall (black arrow) and early signs of liquefaction of the dermis (white arrow); and (E–F) liquefaction of the dermis. Scale bars represent 3 cm.

In the laboratory, affected *C. frondosa* individuals tended to be observed from the same tanks, such that multiple independent tanks were affected. One characteristic aligning with previously described SKUD symptoms in sea cucumbers was the initial appearance of lesions or ulcers near the cloaca and the oral region, later spreading to the rest of the body (Delroisse et al. 2020). Among the 26 individuals with lesions or ulcers on the dermis, 42% (n = 11) had lesions near the oral region, 12% (n = 3) had lesions near the cloaca, 12% (n = 3) had lesions only around the mid-body section, 8% (n = 2) had lesions on both ends, and 27% (n = 7) had lesions all over the body. However, the sequence of events related to the appearance and spread of lesions and ulcers was not observed in the present study.

Affected individuals of *C. frondosa* tended to be smaller in size, with an average wet weight (± standard deviation) of 112 ± 60 g (n = 24), compared to the average size of sea cucumbers in the laboratory (wet weight of ~180 g). SKUD was found to affect smaller individuals (juveniles) of both *Holothuria scabra* (Becker et al. 2004) and *Apostichopus japonicus* (Zhang and Liu 1998), although small adult individuals of *C. frondosa* discussed here were substantially larger than those juveniles.

Individuals with only lesions or ulcers responded sluggishly to haptic stimulation, suggesting that this may be the initial phase of disease. Eviscerated individuals usually had some damage to the body wall, which could be a combination of white-coloured lesions or ulcers, perforation through the body wall, or early signs of liquefaction of the dermis. Individuals with near-complete liquefaction of the dermis were not responsive to haptic stimulation, indicating that this could be a late phase of disease. Delroisse et al. (2020) described SKUD in stages (I–IV), which is comparable to the progression seen in the present study. Quarantined individuals of C. frondosa (n = 11) eventually exhibited liquefaction of the entire body, death and decomposition over time (with an associated putrid smell). None of the infected individuals in quarantine survived, and less than three to four weeks elapsed between the first symptoms and mortality. Mortality was also the usual outcome for sea cucumbers affected by SKUD in previously studied species (Delroisse et al. 2020, Smith et al. 2022).

Although the causative agent for SKUD is unknown, there are some proposed hypotheses regarding what the agent(s) may be, such as pathogens and thermal stress (Zhang and Liu 1998; Delroisse et al. 2020). Although not observed as a causative or potentially correlated stressor in other studies, it should be noted that this outbreak was also co-incident with the physiologically demanding breeding season of *C. frondosa* in insular Newfoundland (i.e. between February and May; Mercier and Hamel 2010), with spawning observed in mid-April 2023 in the laboratory population. The latter outbreak event in the fall was co-incident with temperature changes: a spike to 12.6°C occurred on 22 September (from 4.4°C on 21 September and back down to 2.2°C on 23 September), followed by prolonged warmer temperatures through October (an average of 8.5 ± 1.5°C) compared with cooler temperatures in August (2.8 ± 0.8°C; Fig. 2). However, the thermal regime experienced by the individuals overall was similar to that of every other year, possibly being a bit colder than usual. Unlike experimental cases in which SKUD was induced by thermally shocking juveniles of *H. scabra* (Delroisse et al. 2020), the observed temperatures during the study period were not novel to the cold-temperate *C. frondosa*. Moreover, this species has been kept in the same laboratory for the past two decades, with no occurrence of this disease before the recent cases reported here.

As a response to a possible outbreak, any transfer of organisms or materials (e.g. live rock, kelp, or other décor) between affected and unaffected tanks was halted. Moreover, a protocol of soaking equipment (e.g. waterproof gloves and nets) with a multi-purpose disinfectant (Virkon) was implemented during the middle of the study period to minimise the transfer of the putative pathogen from one tank to another, and all individuals suspected of exhibiting signs of SKUD were quarantined in isolated holding tanks or discarded. These procedures showed no indication of eliminating the disease from the laboratory-held population. The conditions observed in *C. frondosa* included the loss of podia attachment strength, presence of white lesions, swollen oral region, evisceration and liquefaction. These symptoms are similar to those described in SKUD cases in other sea cucumber species (Delroisse et al. 2020; Smith et al. 2022). The population size of *C. frondosa* in the laboratory increased by about 500% with a moderate increase in stocking density (i.e. about 50% increase) around the time of the initial outbreak, which could have been one of the main inducing factors. The second outbreak coincided with a temperature spike (+8.2°C peak occurring over <24 h before returning to normal) followed by a seasonal increase (+5.7°C in October), although the increase was not outside of the normal range experienced by individuals housed in the laboratory. Thermal stress is thought to be an abiotic factor in SKUD onset, as well as stocking density (Delroisse et al. 2020), although their correlation with the outbreak in the current study is tenuous.

Geographically, documented cases of SKUD in *Actinopyga japonicus*, *Holothuria arguinensis* and *H. scabra* were previously reported from the Pacific in China, northeast Atlantic in Portugal, and from the Indo-Pacific in Australia, Indonesia, Madagascar, Malaysia and Vietnam, respectively (Delroisse et al. 2020). The suspected outbreak in *C. frondosa* (this study) represents the first report of SKUD in temperate–subpolar waters of the northwest Atlantic and the first time for this suspension-feeding dendrochirotid sea cucumber.

Acknowledgements

Sea cucumbers in this study were collected by the Field Services at the Department of Ocean Sciences, Memorial University. We extend our thanks to Andrea J. Leyte and Sara Jobson for their assistance with data collection. Kevin C.K. Ma was supported by World Wildlife Fund-Canada and Mitacs Accelerate (IT15224 and IT29594), and the

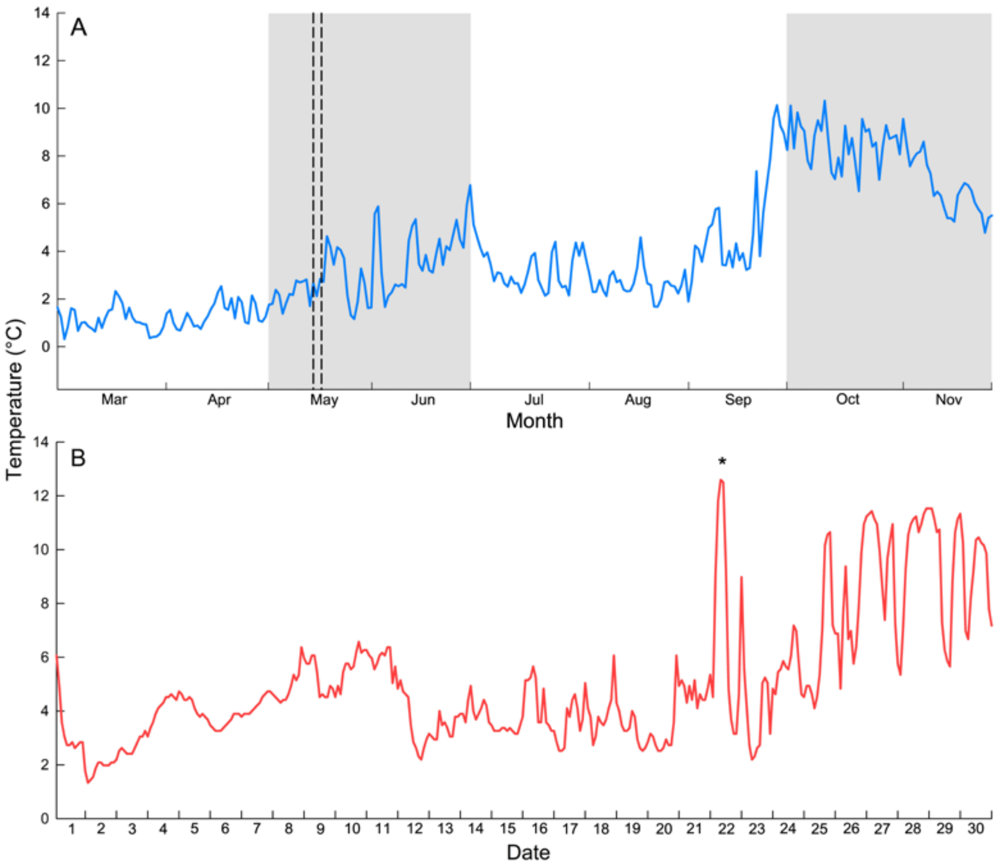

Figure 2. Figure 2. (A) Mean daily temperature from 1 March to 30 November 2023, and (B) temperature recorded every two hours for the month of September 2023. Grey areas in panel A indicate suspected outbreaks of skin ulcerating disease (SKUD) in laboratory-held individuals of *Cucumaria frondosa*; dotted lines in panel A are dates when population size and stocking density was increased; * in panel B indicates the highest temperature measured for the entire study period.

research was partly funded by an National Sciences and Engineering Research Council Discovery Grant awarded to Annie Mercier.

References

Becker P., Gillan D., Lanterbecq D., Jangoux M., Rasolofonirina R., Rakotovao J. and Eeckhaut I. 2004. The skin ulceration disease in cultivated juveniles of *Holothuria scabra* (Holothuroidea, Echinodermata). Aquaculture 242:13–30. https://doi.org/10.1016/j.aquaculture.2003.11.018

Cánovas F., Domínguez-Godino J.A. and González-Wangüemert M. 2019. Epidemiology of skin ulceration disease in wild sea cucumber *Holothuria arguinensis*, a new aquaculture target species. Diseases of Aquatic Organisms 135:77–88. https://doi.org/10.3354/dao03373

Delroisse J., Van Wayneberghe K., Flammang P., Gilian D., Gerbaux P., Opina N., Todinanahary G.G.B. and Eeckhaut I. 2020. Epidemiology of a skin ulceration disease (SKUD) in the sea cucumber *Holothuria scabra* with a review on the SKUDs in Holothuroidea (Echinodermata). Scientific Reports 10:22150. https://doi.org/10.1038/s41598-020-78876-0

Deng H., Chongbo H., Zunchun Z., Liu C., Tan K., Wang N., Jiang B., Gao X. and Liu W. 2009. Isolation and pathogenicity of pathogens from skin ulceration disease and visceral ejection syndrome of the sea cucumber *Apostichopus japonicus*. Aquaculture 287:18–27. https://doi.org/10.1016/j.aquaculture.2008.10.015

DFO (Fisheries and Oceans Canada). 2021. Assessment of the sea cucumber fishery in Quebec's inshore waters in 2020. DFO Canadian Science Advisory Secretariat (CSAS) Science Advisory Report 2021/042.

Gianasi B.L., Hamel J.-F., Montgomery E.M., Sun J. and Mercier A. 2021. Current knowledge on the biology, ecology, and commercial exploitation of the sea cucumber *Cucumaria frondosa*. Reviews in Fisheries Science and Aquaculture 29:582–653. https://doi.org/10.1080/23308249.2020.1839015

Hamel J.-F. and Mercier A. 1996. Early development, settlement, growth and spatial distribution of the sea cucumber *Cucumaria frondosa* (Echinodermata: Holothuroidea). Canadian Journal of Fisheries and Aquatic Sciences 53:253–271. https://doi.org/10.1139/f95-186

Hamel J.-F. and Mercier A. 2024. Perspectives on sea cucumber use and research in the Canadian Arctic with special attention to Sanikiluaq (Qikiqtait, Nunavut). p. 161–170. In: Mercier A., Hamel J.-F., Suhrbier A. and Pearce C. (eds). The World of Sea Cucumbers: Challenges, Advances, and Innovations. London, England: Academic Press.

Hamel J.-F., Morrison R., Jobson S. and Mercier A. 2023. First characterization of a nursery ground of the commercial sea cucumber *Cucumaria frondosa*. Polar Science 37:100963. https://doi.org/10.1016/j.polar.2023.100963

Mercier A. and Hamel J.-F. 2010. Synchronized breeding events in sympatric marine invertebrates: Role of behaviour and fine temporal windows in maintaining reproductive isolation. Behavioral Ecology and Sociobiology 64(11):1749–1765.

Mercier A., Penney H.D., Ma K.C.K., Lovatelli A. and Hamel J.-F. 2023. A guide to northern sea cucumbers: The biology and management of *Cucumaria frondosa*. p. xvii + 92. FAO Fisheries and Aquaculture Technical Paper No. 700. Rome, Italy: Food and Agriculture Organization of the United Nations. https://doi.org/10.4060/cc7928en

Shao Y., Li C., Ou C., Zhang P., Lu Y., Su X., Li Y. and Li T. 2013. Divergent metabolic responses of *Apostichopus japonicus* suffered from skin ulceration syndrome and pathogen challenge. Journal of Agricultural and Food Chemistry 61:10766–10771. https://doi.org/10.1021/jf4038776

Smith L.C., Boettger S.A., Byrne M., Heyland A., Lipscomb D.L., Majeske A.J., Rast J.P., Schuh N.W., Song L., Tafesh-Edwards G., Wang L., Xue Z. and Yu Z. 2022. Echinoderm diseases and pathologies. p. 505–562. In: Rowley A.F., Coates C.J., Whitten MMA (eds.) Invertebrate Pathology. Oxford University Press, Oxford, https://doi.org/10.1093/oso/9780198853756.003.0018

So J.J., Hamel J.-F. and Mercier A. 2010. Habitat utilization, growth and predation of *Cucumaria frondosa*: Implications for an emerging sea cucumber fishery. Fisheries Management and Ecology 17:473–484. https://doi.org/10.1111/j.1365-2400.2010.00747.x

Zhang L. and Liu Y. 1998. Aquaculture techniques of sea cucumber and sea urchin. Qingdao, China: The Press of Ocean, University of Qingdao. 119 p.