


Further Loss of Intertidal Mussel Stands on the Nova Scotia Coast (Canada) after the Passage of Cyclone Lee

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Abstract: Intertidal mussel stands are common on temperate rocky seashores and host many small invertebrates, so they are important biodiversity reservoirs. Their integrity, however, is being increasingly affected by environmental extremes. An unusual cold snap in Nova Scotia (Canada) in February 2023 was followed by the mass disappearance of mussel stands at mid-to-high elevations in rocky intertidal habitats. The present article presents evidence of significant losses at middle intertidal elevations following the passage of cyclone Lee in September 2023, which created severe surf conditions. The increasing occurrence of successive environmental extremes might challenge the persistence of these important biological systems.

Keywords: disturbance; foundation species; hurricane; wave action

In rocky intertidal habitats on temperate marine shores, mussels often form dense stands that cover large extents of the substrate. As these stands host many small species of invertebrates, they are important biodiversity reservoirs [1,2]. In recent decades, however, the abundance of intertidal mussels has been decreasing on some shores due to anthropogenic factors, which is concerning because of the ecological implications [3,4]. Particularly abrupt losses have occurred in Pacific Canada following a summer heat wave in 2021 [5,6] and in Atlantic Canada following a winter cold snap in 2023 [7].

In Atlantic Canada, unusually low air temperatures during low tides in February 2023 (when intertidal organisms were exposed to the air) were followed by the mass disappearance of mussel stands (*Mytilus edulis* and *M. trossulus* [8]) at mid-to-high intertidal elevations in southeastern Nova Scotia. These losses were documented in April 2023 [7]. This cold snap was also followed by massive bleaching in intertidal red algae (*Chondrus crispus* and *Corallina officinalis*), which suffered considerable biomass losses afterwards [9].

At lower intertidal elevations, dense mussel stands did remain on the substrate after the February 2023 cold snap, likely because those elevations are less exposed to the air as a consequence of tide dynamics. However, in late summer, another extreme environmental event took place. On 16 September 2023, post-tropical cyclone Lee made landfall in southern Nova Scotia. Hurricane-force winds extended as far as 220 km from Lee's center, and tropical storm-force winds extended as far as 630 km from the center [10]. As a result, wave action was unusually intense on the southeastern coast of Nova Scotia [11,12]. For instance, maximum wave height measured hourly at an oceanographic buoy near the coast (H1 buoy, 44.4933, -63.5094) was higher than 10 m for three hourly intervals on 16 September 2023 (peaking at 11.8 m between 13:18 and 14:18) and, overall for that day, higher than 8 m for 14 consecutive hours. In contrast, maximum wave height remained below 7 m during the preceding summer days and the spring, actually surpassing 5 m only in five hourly intervals and averaging only 1.6 m overall [13].

On 29 September 2023, a field survey was done at Western Head (43.9896, -64.6607), which is a representative rocky headland where regular monitoring has been conducted to study ecological change. At middle elevations in wave-exposed rocky intertidal habitats, dense mussel stands that appeared normal before Lee's arrival were no longer present



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(Figure 1). The loss of mussels was extensive, as the substrate showed only byssal threads, indicating the recent removal of entire mussel stands (Figure 2). Some seaweeds that were abundant at middle elevations before Lee's arrival had also experienced significant losses (Figure 1). These biological disturbances thus seem to have been caused by the wave action generated by cyclone Lee, as is the case when severe hydrodynamic stress is inflicted upon intertidal organisms [14].

With the ongoing climate change, ecosystems are subjected to an increasing variety of environmental extremes that can affect their integrity [15]. Intertidal mussel stands have traditionally been common on the southeastern Nova Scotia coast [16]; however, in 2023, a winter cold snap was followed by great losses at mid-to-high elevations, while a late-summer cyclone was followed by losses at middle elevations. As extremes in temperature [15,17], wave action [18,19], and cyclonic activity [15,20,21] are predicted to be more common with climate change, these intertidal ecosystems may experience significant changes in the upcoming decades. For example, besides being important as a food source for predators, these mussel stands can host at least 36 invertebrate species [22]. Thus, unless active mussel recolonization takes place after these disturbances, the progressive disappearance of these stands might considerably affect intertidal biodiversity and food web integrity. Long-term monitoring of this system will therefore clarify this possibility.

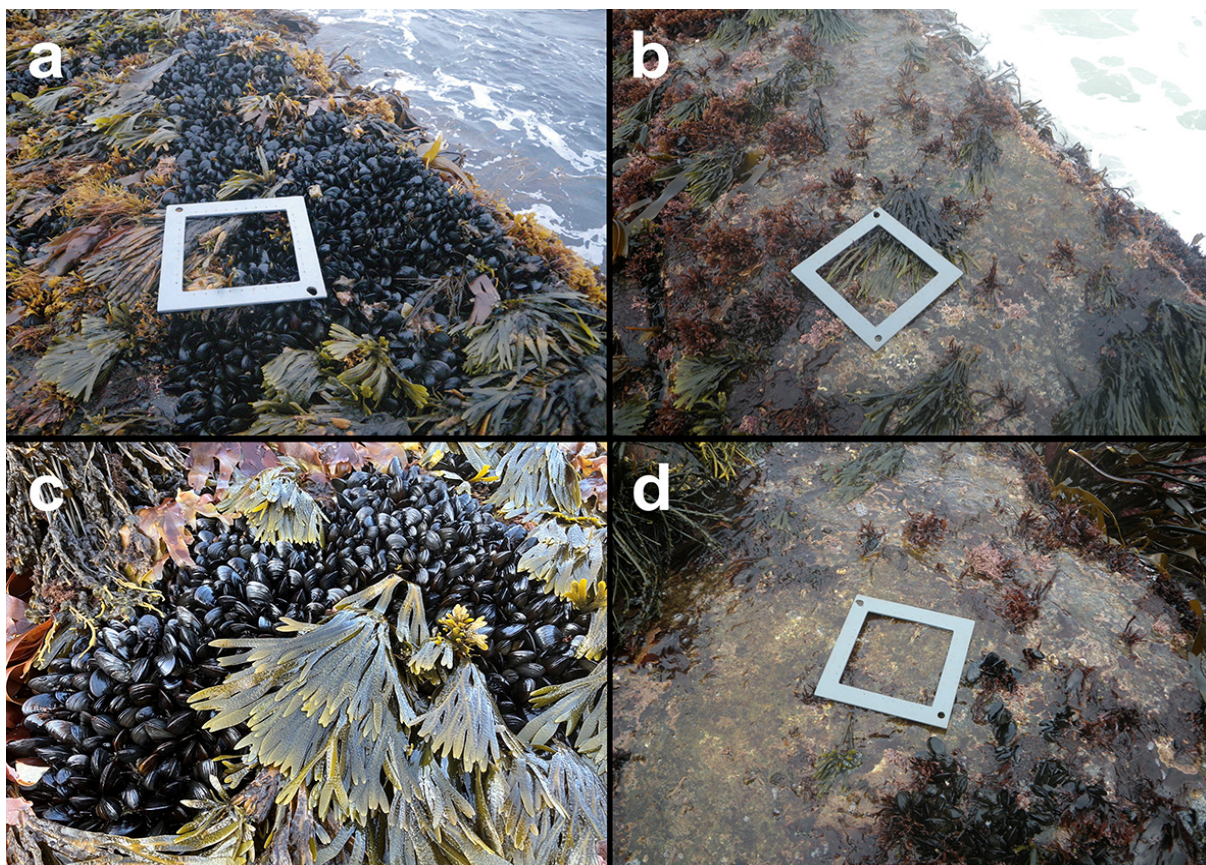


Figure 1. (a) Mussel stand from a wave-exposed habitat at the middle intertidal zone of Western Head (Nova Scotia, Canada) as seen at low tide on 8 July 2023. (b) View of the same area shown in panel (a) but showing the complete loss of mussels on 29 September 2023, days after the passage of cyclone Lee. (c) Another mussel stand from a wave-exposed habitat at the middle intertidal zone of Western Head as seen at low tide on 6 August 2023. (d) View of the same area shown in panel (c) but showing a great loss of mussels on 29 September 2023. The inner frame of the PVC quadrat shown in three of the panels measures 10 cm \times 10 cm.



Figure 2. Close-up view of the mid-intertidal substrate featured in Figure 1b showing numerous byssal threads (examples are indicated by arrows) as the only remains of mussels on 29 September 2023, shortly after the passage of cyclone Lee. The inner frame of the PVC quadrat measures 10 cm × 10 cm.

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