Proceedings of the Nova Scotian Institute of Science (2026)
Volume 54, Part 2, pp. 445-470

SHORE ARMOURING ON THE NORTH SHORE OF MAINLAND NOVA SCOTIA

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Dedicated to Anthony Miller: friend, colleague and avid naturalist

ABSTRACT

Using Google Earth (GE) and ground proofing of selected shorelines, we mapped coastal defense measures (CDMs), along the coast of the Northumberland Strait of Nova Scotia from the New Brunswick border to the Canso Causeway. An initial method used 256 point samples from Tidnish to Cape George at 0.5' of longitude and revealed a 22.8% occurrence of armouring. A second method used GE images and the 'path' tool to trace the lengths of each individual wall along 15 shoreline segments facing the Northumberland Strait and selected bays and estuaries. This identified 218 individual CDMs with the most frequent 51-150 m long and four continuous walls over 1000 m long. Shores had 3% to 74% armouring with enclosed estuaries generally having lower values and the outer, exposed shores having higher values. Short lengths of armouring (i.e., less than 50 m) were generally associated with individual residential properties. The impacts of CDMs are discussed in relation to coastal and vegetation changes on shorelines of northern Nova Scotia. Several case studies including original observations at Northport, Big Island, and Mahoneys Island demonstrate for the first time in eastern Canada how CDMs have modified coastal habitats, specifically sand dune and salt marsh ecosystems.

Keywords: armouring, beaches, climate change, sea-level rise, seashore erosion

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INTRODUCTION

Sea-level rise and consequent seashore erosion are global phenomena. While the ultimate cause is climate change, specific contributors include melting of glaciers on both poles, thermal expansion of water, and runoff from terrestrial systems (Munk 2003, Cazenave and Nerem 2004, IPCC 2023, Houston 2024, Chandanpurkar *et al.* 2025). Recent evidence suggests that the rate of sea-level rise has doubled over the last three decades (Hamlington *et al.* 2024), with a record rise of 5.9 mm globally in 2024 (Hamlington *et al.* 2025). The general impact of sea-level rise has been extensive seashore erosion and coastal flooding that impacts both natural habitats and the built environment (Gracia *et al.* 2018).

This global phenomenon is exacerbated in the southern Gulf of St. Lawrence because of post-glacial subsidence (Grant 1975, Scott *et al.* 1987, Carter *et al.* 1989, 1990, Gehrels *et al.* 2005, Han *et al.* 2015) where recent rates of sea-level rise are at least 3-4 mm per year and may be accelerating (Boon 2012). The gentle slopes of most of the coastline and the associated regional geology in the southern Gulf of St. Lawrence with soft rock (i.e., sandstone) make these shorelines particularly prone to erosion (Finck 2007a, b) relative to shores with steeper slopes and harder bedrock (i.e., granite) along the Atlantic coast of Nova Scotia (Roland 1982, Shaw *et al.* 1998). In addition, the microtidal dynamics of the southern Gulf of St. Lawrence result in lower sediment deposition relative to shores of the upper Bay of Fundy. Together, these features have combined to effect conspicuous shoreline erosion on the north shore of mainland Nova Scotia relative to the rest of the province. Taylor *et al.* (1985) suggested shoreline retreat of 0.7 m y^{-1} along the Northumberland Strait; Forbes *et al.* (2004) determined shoreline retreat of >0.5 m y^{-1} for the north shore of Prince Edward Island. These changes have been recognized as part of climate change risk assessment for Nova Scotia (Anonymous 2025).

The warm summertime water and extensive sandy beaches make the north shore of Nova Scotia attractive for summer residences. Indeed, much of what was historically agricultural land has been transformed in the last century into densely packed cottages, resorts, campgrounds, and golf courses. There are remnant farm and forest landscapes; however, the scattered villages and towns are typically found within the harbours and estuaries that have been formed as drowned river valleys. Given climate change over the last 65 years (Garbary 2018, Garbary and Hill 2021) with its decrease in winter ice (Galbraith *et al.* 2024,

Ollerhead 2024), increase storm activity (Garbary and Hill 2025), and their stochastic nature (Ollerhead 2024), it is not surprising that property owners either alone or in groups have needed to protect their investment by constructing coastal defense measures (CDMs) (Figs 1 and 2; Bernatchez and Fraser 2011). Shore armouring is regulated in part by federal policy under the Fisheries Act (1985) which aims



Fig 1 **Google Earth image from 2024 of shore armouring (53 x 8 m) on residential property at Malignant Cove (Antigonish County; 45°47.10'N, 62°05 50'W); armouring in place since at least 2014. Note increased bank erosion of shoreline to the left of the armouring segment where shore erosion has removed ca. 20 m with no apparent change between July 2023 and 2024 images.**



Fig 2 **Google Earth image portion of continuous shoreline armoring of about 250 m at Matheson Cove (45°52.35'N, 63°38.16); this is part of a 600 m long continuous armouring segment. Portion between yellow arrows built since 2019 with the remainder in place since at least 2012.**

to protect fish and fish habitat. Walls are to be placed above the high tide mark and not impact the biology of the shore. The Nova Scotia Beaches Act (1989), protects beaches and associated sand dune systems.

In this paper, we map shoreline armouring on the marine and brackish shores of Nova Scotia facing the Gulf of St. Lawrence and selected estuaries. Case studies of several sites are used to demonstrate impacts on biological communities including sand dunes and salt marshes.

METHODS

Free Google Earth Pro software was used to identify and measure armouring along the shores of the Northumberland Strait and selected estuaries of mainland Nova Scotia facing the Gulf of St. Lawrence (Fig 3). While ground proofing was conducted at many locations, it is possible

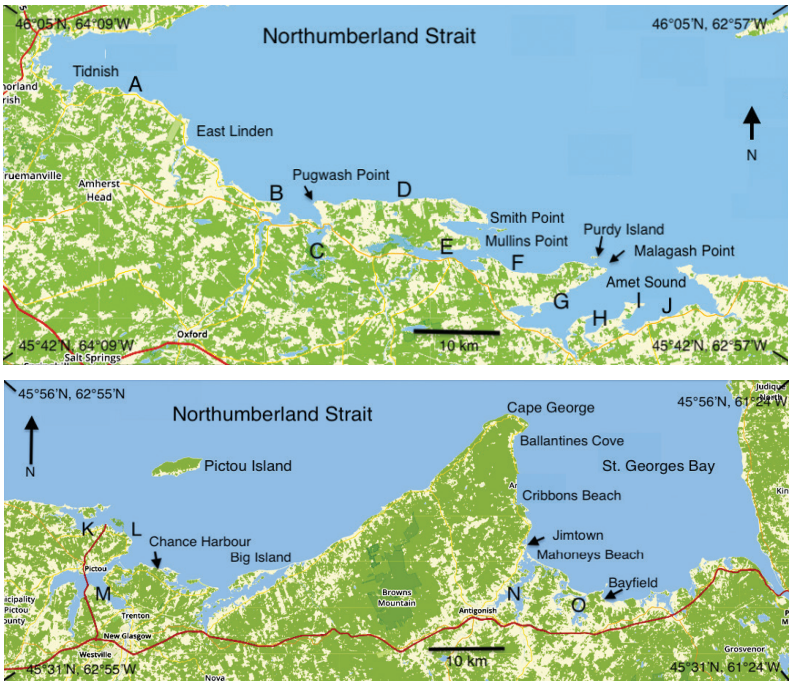


Fig 3 **The North Shore of Nova Scotia indicating western (upper panel) and eastern (lower panel) portions of the Northumberland Strait from the border of New Brunswick (Tidnish) to St. Georges Bay indicating geographic features mentioned in the text and sites A-J where armouring was quantified over transects ca. 4-50 km; see Tables 1-2 for locations and site details.**

that some armouring was missed because of poor Google Earth (GE) images and it is possible that some natural rock formations were mistaken for armour walls. Collapsed CDMs, such as those described by Finck (2007a) from the Amherst Shore would be difficult to resolve with GE. Recent ground surveys showed extensions of CDMs added even after the most recent GE imagery. At the western end of Chance Harbour (45°40.601'N, 62°35.035'W), and the tombolo associated with Big Island (45°41.05'N, 62°20.44'W), rock walls were built and then covered with sand, likely through wave action. To the extent that this is more widespread, it would not have been detected in the GE analysis. Regardless, even low-profile walls with a single row of armour stones, such as at the tombolo at Mitchells Island, can be conspicuous in GE (Figs 4-5). Thus, while some CDMs might have been overlooked, we consider that we have captured the primary extent of shore armouring in the region.

In an initial GE survey, spot samples (254 samples) every 0.5' minutes of longitude (=650 m intervals) from Tidnish to Cape George identified 58 occurrences (22.8% of total) These were plotted in groups of 20 (i.e., 10' of longitude) to show changing frequency of armouring from west to east. We then used GE 'Historical Imagery' under the pulldown menu 'View' to visualize changes in armouring with GE images. This was informative back to ca. 2010 and facilitated a historical perspective for some shores where multiple images were available. This helped overcome constraints of poor lighting, cloud cover, and poor image quality.

We followed the initial overview with a more detailed mapping of 15 selected shores with conspicuous armouring (Tables 1-2). These shores were considered in three categories: Type 1, open coast; Type 2 semi-enclosed bays and harbours, and Type 3, estuaries with well-defined barrier beaches. In GE, the 'Ruler' tool with its 'Path' function was used to measure the length of individual CDMs and the gaps between them. This facilitated quantifying the length frequency distribution of the CDM.

The mapping described above was followed by ground proofing at selected sites to confirm the identification of the CDMs or undertaken as part of field work associated with salt marsh and sand dune ecology beginning in 2012 and 2022 by DG and AT, respectively.

RESULTS

Shore armouring

The Coastal Defense Mechanisms (CDMs, or armouring) consisted mostly of large boulders placed against the shoreline bank, walls up to five metres high, or rows of stacked boulders placed directly on the upper beach surface (Figs 1-2, 4-5). In some cases, wooden pilings were used alone or as supplements to rock walls. Some rock walls had vertical pieces of lumber attached (Fig 6). Finck (2007a) provided an excellent account of the variety of CDMs and their durability used in the region. Many CDMs were within the intertidal zone, and



Fig 4 **Rock wall on beach at margin of sand dune vegetation at Mitchells Island (45°53.59'N, 63°47.73'W) looking northwest along the beach to the island. (Photo DG, June 2025).**



Fig 5 **Google Earth image (2023) of road across dune to Mitchells Island with row or armour stones on beach and portion of salt marsh on opposite side of road.**

Table 1 **Sites used for analysis of coastal armouring on the North Shore of mainland Nova Scotia; sites listed from west to east. Shores were considered as: Type 1 – open coast of Northumberland Strait; Type 2 – semi-enclosed bays and inlets; Type 3 – enclosed estuaries typically with barrier beaches. See Fig 3 for general location of sites.**

Site	Shore type	Start of transect	End of transect
A Tidnish to East Linden	1	45°59.67'N, 64°02.30'W	45°54.00'N, 63°48.82'W
B Heather Beach to Toney Creek	1-2	45°52.50'N, 63°45.01'W	45°51.79'N, 63°44.76'W
C Pugwash Harbour	3	Entire estuary	
D Pugwash Point to Smith Point	1	45°52.28'N, 63°40.74'W	45°51.03'N, 63°24.80'W
E Wallace Harbour bridge to Mullins Point	2	45°49.36'N, 63°29.01'W	45°50.04'N, 63°25.68'W
F Cambra sands to Purdy Island	1	45°48.87'N, 63°24.42'W	45°48.36'N, 63°14.85'W
Amet Sound:			
G Emerys Island to Malagash Point	2	45°45.90'N, 63°19.95'W	45°47.17'N, 63°13.98'W
H Brule Shore	2	45°45.04'N, 63°15.90'W	45°45.04'N, 63°12.93'W
I Brule Point	2	45°45.04'N, 63°12.93'W	45°44.90'N, 63°12.93'W
J Semple Creek to River John	2	45°44.22'N, 63°11.58'W	45°45.10'N, 63°03.52'W
Caribou Harbour:			
K Three Brooks to ferry terminal	3	45°43.99'N, 63°44.73'W	45°44.21'N, 62°41.43'W
L Caribou and Munroe's Island Park east towards Pictou	1	45°43.45'N, 62°39.00'N	45°41.70'N, 62°39.61'W
Pictou Harbour:			
M Abercrombie Point to Trenton Connector	3	45°39.41'N, 62°43.00'W	45°37.42', 62°39.09'N
N Antigonish Harbour	3	Entire estuary	
O Pomquet Harbour	3	Entire estuary	

at high tide the water lapped on rock walls or the bases of timbers with populations of seaweed (mostly *Fucus vesiculosus*, and filamentous and ulvoid green algae). Barnacles were often present. During spring tides and especially during storms, wave action impacts the CDMs. CDMs occasionally comprised gabions that were filled with stones, although these could not be resolved using GE.

The 254 point samples for presence of armouring between Tidnish and Cape George Lighthouse (164 km) gave 58 occurrences with armouring (22.8%), with the remaining sites being sandy beaches, gravel shores,



Fig 6 **Three-metre tall rock wall supplemented with wooden beams in high intertidal zone of Amherst Shore. (photo DG, June 2025)**

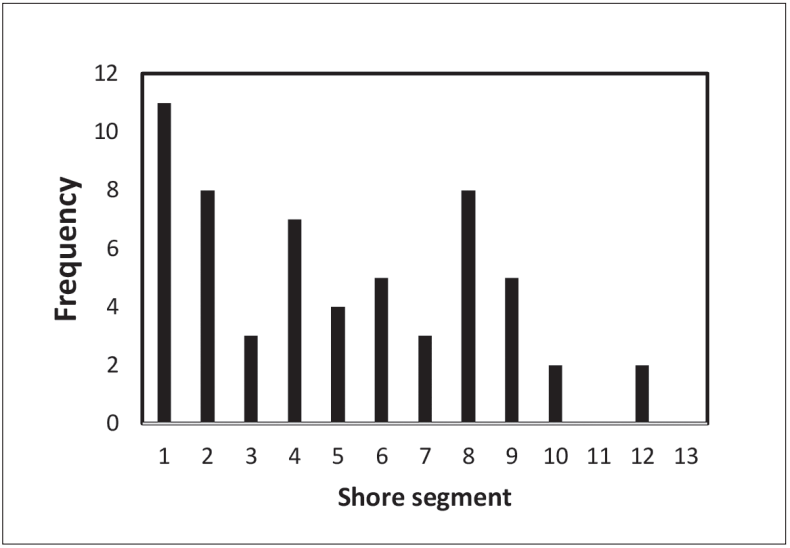


Fig 7 **Frequency of armouring in successive point samples of 20, for each 10' of longitude measured every 0.5' from Tignish (segment 1; 45°59,74, 64°02.50'W) to Cape George (segment 13, 45°53.13'N, 61°64.50'W), Nova Scotia. Segment 8 includes the end of Caribou Island. Note: three of the armouring points in segment 9 are protecting the road to Big Island and not associated with housing.**

Table 2 **Shore armouring at selected sites on North Shore of Nova Scotia including sites directly exposed to Northumberland Strait and in bays and estuaries; data derived from Google Earth images using 'historical imagery' and 'path' tool. See Fig 3 for general location of sites.**

Site	Number of armour walls	Summed length of armouring (m)	Shore length (km)	Shore armouring (%)
A Tidnish to East Linden	44	10350	25.0	40%
B Heather Beach to Toney Creek	6	2676	3.7	74%
C Pugwash Harbour	6	1722	35.5	8% (5%*)
D Pugwash Point to Smith Point	30	6113	24.9	25%
E Wallace Harbour Bridge to Mullins Point	9	2063	6.1	34%
F Cambra sands to Purdy Island	14	1872	13.3	12.5%
Amet Sound:				
G Emerys Island to Malagash Point	29	4064	12.4	33%
H Brule Shore	9	2230	4.6	49%
I Brule Point	9	2744	9.1	30%
J Semple Creek to River John	19	4917	14.1	35%
Caribou Harbour:				
K Three Brooks to ferry terminal	7	718	5.1	14%
L Caribou and Munroe's Island Park east towards Pictou	9	2211	4.6	48%
Pictou Harbour:				
M Abercrombie Point to Trenton Connector Bridge	14	1665	9.1	18%
N Antigonish Harbour	10	1592	50	3%
O Pomquet Harbour	1	1100	40	3%

*Excluding the 900-m causeway across the estuary to the salt mine

steep banks, and salt marshes. Armouring was found to be more frequent at the western end of the study area with 19/40 samples (47.5%) scoring positive than it was found at the eastern end where 2/54 samples were positive (3.7%, Fig 7).

The second method examined 15 sections of shoreline (Table 2; Fig 3, A-O) with lengths ranging from about 5 to 50 km. These were selected based on the occurrence of conspicuous CDMs visualized in GE.

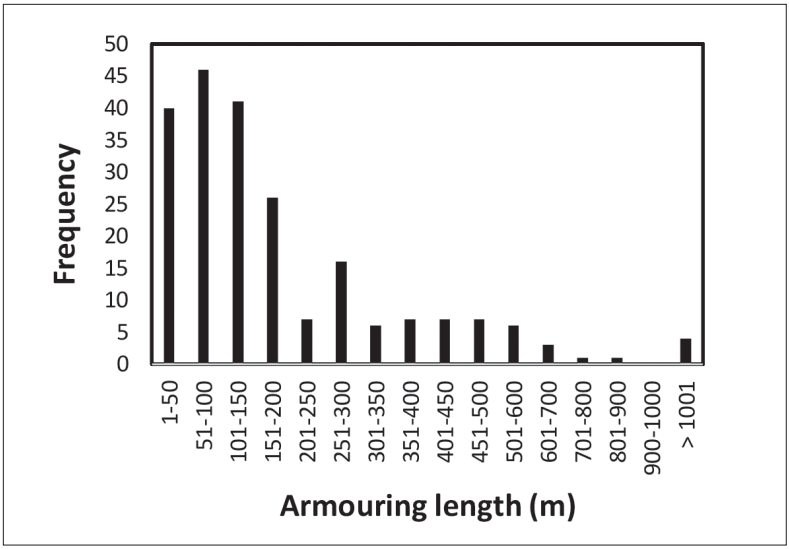


Fig 8 Size-frequency distribution of 218 armour segments from areas listed in Table 1.

The first shore segment examined a portion of the western end of the transect described in the previous paragraph whereas the others were independent lengths of armouring on selected outer shores (Type 1), partially enclosed bays and harbours (Type 2), and estuaries (Type 3). The 218 individual emplacements combined for 37.9 km of armouring and ranged from 19 to 1936 m long (216±245 m, mean±s; 130 m, median; Fig 7). The most frequent armour wall length category was 51-100 m (36 occurrences). These walls were for one or adjoining properties, whereas the longer runs of CDMs included many properties (Fig 2) with the longest continuous walls being for roads and golf courses. The 15 selected shorelines and estuaries (Fig 3, A-O) provided a means to compare armouring on different shore types (Table 1). Both Type 1 and Type 2 shores had extensive CDMs (means of 36% to 40% for sample shorelines) that were not statistically different (Student's t-test, $P>0.05$). These values were at least 60% higher than the method based on the systematic sampling of longitude. This is not surprising, as Type 1 and 2 shores were mostly selected based on occurrence of CDMs, thus making these non-random samples. Type 3 shores had dramatically reduced cover of CDMs, with generally <5% shore cover. Despite the difference in methods, this is dramatically less than the systematic samples of the outer shores of the Northumberland Strait.

This was consistent with other Type 3 sites, e.g., Merigomish and Tracadie Harbours, where formal measurements were not conducted. In addition, in the Type 3 sites much of the armouring was associated with protection of roads and non-residential structures, e.g., the causeway across the harbour to the salt mine. Types 1 and 2 shores were often densely packed with seasonal dwellings that were constructed close to the shore for access to the beach. Small lots also precluded moving buildings away from the shore. Consequently, sea-level rise required construction of CDMs to preserve the property. Buildings on Type 3 shores are typically associated with permanent residences or barns that were constructed away from the water, with landowners more accepting of natural erosional forces.

Case Study: Salt marsh at Trenholm Beach Road, Northport

The shoreline north of Pipes Beach has been extensively armoured to protect the numerous summer residences on the shore (Figs 9-11). There is a small salt marsh facing the open Northumberland Strait (45°56.92'N, 63°52.07'W). Construction of a new dwelling resulted in the recent extension of an existing rock wall. Unfortunately, the extension wall was built across part of the remnant salt marsh and below the high tide mark (Fig 10), causing partial destruction of the salt marsh. In general, the impact of sea-level rise tends to have greater erosional impact on the lower margins of marshes; however, this marsh is being directly and indirectly damaged by the rock wall. This has resulted in a conspicuous 'dead zone' at the upper side of the marsh adjacent to the rock wall where the peat is still intact but there are no living, i.e., emergent shoots of *Sporobolus alterniflorus* (Cord grass, Fig 11). This marsh loss will likely continue along the top of the marsh, eliminating the Cord grass and reducing the area of marsh peat. By limiting exchange from the previous shoreline, sediment transfer is being cut off. While this marsh remnant has been under pressure from sea-level rise, the additional problem of the CDM is hastening its eradication.

Table 3 Summary of armouring amount based on exposure: Type 1, facing the exposed Northumberland Strait; Type 2, in semi-enclosed bays and harbours; Type 3, estuaries with barrier beaches; n = 5.

	Shore type		
	Type 1	Type 2	Type 3
Mean ± s	40 ± 23%	36 ± 8%	9 ± 7%



Fig 9 **Google Earth image from 2019 of 6-m wide rock wall on top of remnant salt marsh at Northport (45°56.91'N, 63°52.08'W).**



Fig 10 **Remnant salt marsh with monoculture of *Sporobolus alterniflorus* at Northport. Note: the same house is visible Fig 9. (photo DG, June 2025)**

Case Study: Big Island Beach, Merigomish, Pictou County

Background: Big Island Beach is a barrier beach tombolo that connects the mainland near Merigomish to Big Island. Big Island Road provides access to the island along the barrier and access to the beach for recreation (Fig 12-13). It is the sole road to the island and is protected by extensive rock armouring at least 2.6 km long in a preservation effort



Fig 11 Upper limit of salt marsh near rock wall at Northport with 'dead' zone, i.e. intact peat mass with no emergent salt marsh flowering plants near rock wall; several rocks have populations of *Fucus vesiculosus*, barnacles and various ulvoid algae. (photo DG, June 2025)

against sea-level rise and storm activity. The road and its armouring have been in place prior to at least the 1960s.

Current status: The rock armouring is alongside the road and follows its contour. As such, at its western extent where the road veers inland, the rock wall is above the high-water mark and back from the seaward limit of the sand dune plant community (mostly *Ammophila beviligulata,* American Beach Grass; *Lathyrus japonicus,* Beach Pea; *Morella pensylvanica,* Bayberry). However, east of this, the seaward position of the road causes a substantial proportion of the rock armouring to be in contact with waves at high tide and during storm surges. There is little dune remaining seaward of the rock wall here and scouring is evident (Fig 12-13). This process is beginning to occur along the intact dune at the western end of the armouring. Sea-level rise is bringing the armouring into contact with the waves causing scouring of the adjacent dune (Fig 12). Big Island demonstrates a fundamental issue with utilizing rock armouring, where armouring is no longer above the high tide mark with rising sea levels. This causes a significant loss of habit, particularly of beach zones.

Future concerns: The forced static position of the barrier beach created by the road and armouring will cause waves to reach higher on the beach with rising sea levels. The waves will come into greater



Fig 12 Rock wall at Big Island covering previous sand dune with the sand dune beach community eroded away. (Photo AT, May 2024)



Fig 13 Portion of rock wall at Big Island. (Photo AT, July 2025.)

contact with the rock wall, increasing loss of the seaward dune and causing further habitat loss. The probability of waves overtopping the road and barrier beach will also increase with sea-level rise, risking further damage to the beach system. Long term projection would be the barrier breaking up or drowning as a direct result of the armouring.

Case study: Mahoneys Beach, Antigonish County

Background: Shoreline changes at Mahoneys Beach in Antigonish County have been attributed to longstanding armouring (mostly prior to 1990 but with annual renewal following winter storms) on the

adjacent shore and continuing northward for about 700 m to Jimtown. The armouring protects residences at Jimtown and road access to residents at Mahoneys Beach (Fig 14). The armouring consists of extensive rock walls and several groins. The armouring ends at the beach access parking lot. In December 2004, a storm formed a new channel into Antigonish Harbour that has remained to the time of this study. The channel prevented both foot and vehicular traffic onto the >1.5 km extent of the barrier beach. Utting and Gallagher (2009) reported on the coastal geomorphology of this part of St. Georges Bay (Jimtown to Pomquet) and described how the opening of the new channel into Antigonish Harbour could be attributed to the armouring on this shoreline. The groins and the CDM restricted sediment accumulation from a longshore current from the north. The accumulated sand deficit resulted in sand removal from the public beach that was deposited into the newly formed sand bar on the interior side of the new opening into the harbour. More recent shoreline changes are described below.

Current status: Since 2012, the shoreline of Mahoneys Beach and changes to the vegetation of the barrier-beach system to the east of the new channel (here referred to as Mahoneys Island) have been monitored. The vegetation has dramatically changed on the remnant dune system adjacent to the parking lot. Only a small fringe of American Beach Grass (*Ammophila breviligulata*) remains along the seaward edge, with scattered clumps of herbaceous dune species interspersed with about 50% bare sand. Over the previous dune surface are numerous small



Fig 14 Google Earth image of Mahoneys Beach (2019) with three groin remnants and gravelized beach; opening into harbour formed in December 2004.

boulders deposited by wave action. The invasive species Crown vetch (*Coronilla varia*) has become a dominant species as described previously for Mahoneys Island (Flynn *et al.* 2013). The beach has become relatively more gravel-rich as finer material has been eroded leaving an extensive boulder field. Many boulders have been wave-tossed onto the remnant sand dune.

There has been extensive retreat of the vegetation on Mahoneys Island where a third of the dune area has been lost since an initial survey by DG in 2012 (Garbary *et al.* 2025; Fig 10). While Hurricane Fiona (September 24, 2022, e.g., Straub 2024) may have enhanced background rates of erosion, annual changes to the system can be attributed to loss of sand from the dune margins and increasing rates of sea-level rise. The disturbance is also associated with the establishment of *Coronilla varia* (Crown vetch) that has become a dominant plant in areas previously dominated by *Ammophila* and *Lathyrus* (Flynn *et al.* 2013). *Picea mariana* (Black spruce) and *Morella* often occur at the dune margin with roots often exposed on the scarped edges. Extensive overwash has pushed sand well into the dune interior and killed or stunted the Black spruce. A 250-m section at the western end of the island has only scattered weedy vegetation; what was previously a dune 1-2 m above the beach during 1980s is now barely elevated above the high tide mark.

Rest of St. Georges Bay to the Canso Causeway

There is little armouring on the western side of St. Georges Bay other than the rock walls protecting harbours (i.e., Ballantynes Cove and Cribbons Harbour, on the west side; Bayfield Harbour on the south; and major transportation infrastructure (e.g., around the Canso Causeway).

There is a 190-m armouring at Cribbons Beach (45°45.967'N, 61°54.503), a 700-m armouring from Jimtown to Mahoneys Beach described above, and scattered smaller walls associated mostly with residential properties within estuaries.

Erosion in Archibald's Cove in Antigonish Harbour (Fig 15) has been observed since the early 2000s (Garbary and Miller unpubl.). In 2005, an *S. alterniflorus* marsh was present up to 10 m wide with the peat about 50 cm thick. Marsh loss was occurring at 0.5-1.0 m y^{-1}. There was a gap of 19 years of observation, but by 2024 the marsh and its peat had eroded away to the tree line (Garbary unpubl.) with many trees (mostly Poplar, Red maple and Spruce) having collapsed onto the shore or with exposed roots from bank undercutting. Some trees along the shoreline were observed to be leaning into the forest, likely



Fig 15 Google Earth Image (2024) of seashore in Antigonish Harbour; see text for discussion.

resulting from Hurricane Fiona that caused extensive windfall in the surrounding area. The sediment surrounding the exposed upper surface of rocks was extremely soft with a muddy consistency where, when walking, one would often sink ankle deep. On an adjacent property where extensive clearing had been done and a rock wall placed in the upper intertidal zone on the bank in 2019, the sediment was firmer, remnant peat and Cord grass remained, and the CDM provided habitat for periwinkles and filamentous green algae. During spring tides the interstices of the rock wall would provide habitat refuge for small fish. While the intertidal zones in the presence or absence of the CDM had healthy populations of oysters and mud snails, these species were more prominent on the shoreline with the CDM.

DISCUSSION

In a meta-analysis, Sauvé *et al.* (2023) provided a global perspective of the variety of coastal defense measures (CDMs) and their impacts. While the authors were based in Canada, none of the 355 case studies from 301 publications were Canadian examples because they did not meet their selection criteria. This suggests that the relevant observations on CDMs have not been carried out in Canada. Our study meets all the Sauvé *et al.* (2023) criteria including: (1) observations made by the authors, (2) the observations include changes to the coastal system relative to a baseline condition, and (3) concludes that the changes

were caused by the CDM. Accordingly, our assessment of armouring in northern Nova Scotia provides an important study of the extent and impacts of CDMs in eastern Canada.

The north shore of Nova Scotia along with many of its bays and estuaries (Table 1) is now extensively armoured with rock walls placed at the top of the shore typically attached to the property of the landowner (Finck 2007a, b). The largest continuous CDM is associated with a causeway and sand dune-barrier beach system at Big Island protecting the only road to the island. This armouring and road caused major damage to the sand dune system and they have not been effective in preventing blowouts and subsequent damage to the road. Indeed, the armouring has required major repairs seemingly on an annual basis. Dugan *et al.* (2008) showed major reductions in the diversity and abundance of birds on armoured versus unarmoured sections of shoreline in southern California. In the Maritime Provinces, the upper beach of sand dunes is the habitat for the endangered Piping Plover (*Charadrius melodus*; Environment Canada 2012); rock walls in this habitat without restoration of the foreshore, e.g., Mitchells Island and Big Island, would limit habitat availability.

There are three primary plant communities associated with marine shorelines of the Northumberland Strait: salt marshes, sand dunes and seaweeds. These communities would fall under the jurisdiction of the Fisheries Act and the Beaches Act because of their importance as fish habitat, their biodiversity, and importance as communal recreational resources. The establishment of seawalls and the armouring of shorelines are rarely placed so that they directly cover salt marsh habitat although two exceptions have been observed: (1) near Pipes Beach and (2) in Antigonish Harbour. In both cases, the marsh was a remnant of a larger area that had been in decline. It is unclear whether the demise of the marsh remnants (Fig 10, 15) was hastened by shore armouring. Regardless, removing these walls would lead to extensive habitat damage from heavy equipment and shore siltation.

The marsh remnants on shores facing the Northumberland Strait are being lost because of sea-level rise, consistent with observations from New England (Donnelly and Bertness 2001). These patches of dead peat suggest recent mortality that can be related to shore armouring. Regardless of the extent to which this has occurred, it is impacting habitat. Shoreline armouring disrupts the land-sea ecotone and the exchange of materials between them (Heerhartz 2013, Heerhartz *et al.*

2013). Small-scale armouring associated with residential development – the primary form of CDMs in the Northumberland Strait – may impact salt marsh plant diversity where species diversity can be restricted to a single species, *Sporobolus alterniflorus* (Garbary unpubl.). This feature of the remnant marshes was also observed in coastal Georgia, USA (Gehman *et al.* 2018).

While the predominant strategy to adapt to increased coastal erosion due to sea-level rise in northern Nova Scotia has been seashore armouring, little effort has gone into mitigation that could limit the need for armouring. Potential mitigation measures for Mahoneys Beach might include the removal of the six deteriorated groins that are currently restricting sand deposition and building more effective armouring systems to prevent road washouts. Gracia *et al.* (2018) suggested that establishment and restoration of natural ecosystems, e.g., salt marsh and seagrass vegetation, dampens wave action and increases sedimentation, thus, limiting the erosional forces of sea-level rise. Considerable effort has gone into salt marsh restoration in the upper Bay of Fundy (e.g., Bowron *et al.* 2012, Ollerhead *et al.* 2020, Rabinowitz *et al.* 2023); however, this has not been explored in northern Nova Scotia where historical dykes are not relevant to the issue of seashore armouring. A starting point might be the remnant patches of marshes on the Northumberland Strait at Tidnish and Northport where interventions might reverse the current marsh loss even with extensive shore armouring. There is some capacity for the recolonization of increasingly gravel-rich shores by Cord grass following peat loss in estuaries (Garbary unpubl.); however, the long-term viability of these populations needs to be studied.

Property owners have always been able to build armouring structures when these were installed above the high-water mark. Sea-level rise and potential erosion below the armouring structures can subsequently lower their relative position and result in these structures no longer having this setback. Thus, during high tides the water level can be above the base of the armouring structure. This may, in fact, provide a positive impact on marine life by increasing habitat complexity. The rock surfaces can provide substrate for marine algae and barnacles, and the spaces between rocks refuge for small or juvenile fish and shellfish.

Another critical aspect of shore armouring is the impact that a property owner is having on their neighbour or adjacent public shorelines (reviews by Griggs 2005, Sanitwon-Na-Ayutthaya *et al.* 2023).



Fig 16 Google Earth image from 2024 with armoured shoreline (ca. 50 m) in Amet Sound (45°45.26'N, 63°7.72'W) with differential shore erosion on either side of armouring wall. Vegetation retreat on left side was 14 m since 2011.

Once a small stretch of wall is installed, it can impact the adjacent properties by increasing the erosion (Fig 1, 16, 17). Whereas the neighbours might have been accepting of a limited rate of shore retreat, the presence of the CDM will automatically have a negative impact on their property value because of the increasing erosion rate. Surely, this is unethical as it imposes a major expense to expand the wall and limit property loss. Such a situation requires legislation to clarify the rights of property owners to both install shoreline armouring and to be protected from neighbours. In 2024, the Nova Scotia government did not proclaim the passed provincial Coastal Protection Act (Nova Scotia 2019) which was to include regulations that might have remedied this deficiency. Current government policy downloads the responsibility for managing coastlines onto municipalities who can impose local regulations regarding building and setbacks. Sauvé *et al*. (2020, 2022, 2023) proposed approaches to decision making for management of coastal defenses and placed this in a holistic socio-ecologic framework involving stakeholders in participatory decision-making that recognizes local context.

The fate of the barrier beach for Antigonish Harbour, i.e., Mahoneys Island, is an environmental tragedy. Having lost over 30% of the vegetated dune surface in 12 years (2012-2024) with extensive overwash



Fig 17 Google Earth image from 2024 indicating CDM consisting of rock walls at both ends of public beach beside Caribou Island Road (45°45.64'N, 62°44.41'W). Red lines indicate margin of dune vegetation in 2004 and indicate beach retreat of about 10 m on neighbouring property and on public beach.

and dieback of the remaining vegetation at the north end of the island, it has shown greater deterioration than any of the more than 30 beach systems studied in northern Nova Scotia over the same period (Garbary *et al.* 2025, Garbary unpubl.). While Hurricane Fiona also inflicted major erosion on this system, the primary damage predated this storm. Implemented over many years and clearly permitted (or ignored) by authorities, the armouring at Mahoney's Beach has proved both partly ineffective (as shown by the almost annual renewals) and has led to the deterioration of public amenities and ecosystem function. The questions become: (1) Who or what government agencies are responsible for this ongoing deterioration on Mahoneys Beach and Island? and (2) Should those same agencies be responsible for mitigation and restoration?

The questions posed in the previous paragraph were discussed in a general sense in an American context of the 'Public Trust Doctrine' (Liss 2016). Liss concluded that the State is required to protect trust resources, i.e., the natural environment. This concept is less well developed in a Canadian context (Ahmed 2024), although its application could develop into a robust approach for initiating government action regarding mitigation of climate change of which sea-level rise is a key component. Richardson and Wells (2024) emphasized the need for coordinated coastal management in Nova Scotia and the need for the Coastal Protection Act; their discussion is an elaboration of the Public Trust Doctrine. Clancy and Levesque (2025) discussed the limitations of environmental governance of the Gulf of St. Lawrence and concluded (p. 124) that "the pursuit of coastal management remains

in large part aspirational today." To move forward, we need a deeper understanding not only of the ecological impacts of armouring, but also of the economic and social returns that armouring provides. Here we have shown that around 20% of a significant portion of Nova Scotian shores on the Northumberland Strait have been armoured, with many smaller stretches having 40%, or more, with armour walls. Climate change and sea-level rise require both risk assessment (Anonymous 2025) and better management of where and how armouring is to occur.

Acknowledgements We thank landowners who facilitated access to shorelines and for helpful discussion regarding the history of armouring at various sites. This work was funded in part by grants to DJG by NSERC and DFO.

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