Section 35 Risk Assessment for Oceans Act Marine Protected Areas: Musquash Scallop Dragging in Zone 3

Chantal Audet, Bryden Bone

Marine Planning and Conservation
Aquatic Ecosystems Branch
Fisheries and Oceans Canada
Maritimes Region
Bedford Institute of Oceanography
PO Box 1006
Dartmouth, NS
B2Y 4A2

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Bedford Institute of Oceanography
PO Box 1006
Dartmouth, NS
B2Y 4A2

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Canada's Marine Protected Areas (MPA) Protection Standard was created to increase consistency and clarity on prohibited activities across all MPAs and helps to protect portions of Canada's oceans from the potential negative effects of industrial activities. Based on a recommendation by the National Advisory Panel on MPA Standards, the standards and guidelines of the International Union for the Conservation of Nature were adopted, thereby prohibiting four industrial activities, including bottom-trawl gear fisheries, from occurring in all federal MPAs established after 2019. The Protection Standard indicates that all MPAs established before 2019 should review the compatibility of activities included in the Protection Standard against the MPA's conservation objectives as part of their regular management review cycle. Musquash Estuary MPA is located in the outer Bay of Fundy and covers 7.4 km^2. It was established through the *Oceans Act* in 2006, and at that time, an exception was provided for scallop dragging in the outer estuary (Zone 3) to allow for the continuation of fishers' traditional access to the estuary. As part of Musquash MPA management cycle, an ecological risk assessment was undertaken to assess the compatibility of the scallop drag fishery in Zone 3 with the site's conservation objectives. Ecological risk was determined by evaluating the Impact Risk and Recovery Lag of selected conservation priorities under the scallop drag fishery's current level of intensity, following the national Marine Conservation Ecological Risk Process Guidance developed by Fisheries and Oceans Canada (DFO). The results of this ecological risk assessment will help to inform the Protection Standard compatibility review for the scallop drag fishery in Musquash MPA.

Résumé

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La norme de protection des aires marines protégées (AMP) a l'objectif d'offrir davantage de cohérence et de clarté à-propos des activités interdites dans les AMP fédérales et de contribuer à sauvegarder ces zones de nos océans des effets potentiellement nocifs des activités industrielles. Basée sur une recommandation du Comité de conseil national sur les normes concernant les AMP, les normes et les lignes directrices de l'Union internationale pour la conservation de la nature ont été adoptées, interdisant quatre activités industrielles, incluant les engins mobiles de chalutage ou de dragage en contact avec le fond, dans toutes les AMP fédérales établies après 2019. Toutes les AMP établies avant 2019 devraient évaluer la compatibilité des activités visées par la norme de protection avec les objectifs de conservation de l'AMP dans le cadre de leur cycle de gestion régulier. La zone de protection marine (ZMP) de l'estuaire de la Musquash est située dans l'extérieur de la baie de Fundy et occupe une région de 7,4 km^2. Elle a été créée en 2006 en vertu de la Loi sur les océans. À l'époque, une exception a été accordée pour autoriser la drague à pétoncles dans la partie extérieure de l'estuaire (zone 3) afin de permettre un accès traditionnel continu. Dans le cadre du cycle d'examen de la gestion de Musquash, une évaluation des risques écologiques a été effectuée afin d'évaluer la compatibilité de la drague à pétoncles dans la zone 3 avec les objectifs de conservation de la ZPM. Suivant le processus national d'évaluation des risques écologiques liés à la conservation marine élaboré par Pêches et Océans Canada, les niveaux de risque ont été déterminés en évaluant à la fois l'ampleur et les conséquences de l'exposition de certains objectifs de conservation face à la drague à pétoncles. Le temps nécessaire à la récupération a ensuite été déterminé en classant la persistance de la pression dans l'environnement en fonction des facteurs qui influent sur la résilience globale des objectifs de conservation. Les résultats de cette évaluation des risques aideront à déterminer s'il convient ou non d'autoriser la poursuite de la drague à pétoncles dans la zone 3 de la ZPM.

SECTION 35 RISK ASSESSMENT FOR *OCEANS ACT* MARINE PROTECTED AREAS: MUSQUASH SCALLOP DRAGGING IN ZONE 3

1.0 INTRODUCTION

1.1 Background

The Marine Protected Areas (MPA) Protection Standard was developed to provide greater consistency and clarity on prohibited activities in federal MPAs, and helps in protecting and conserving productivity and biodiversity in Canada's oceans from potential negative effects of industrial activities (DFO 2023a). The National Advisory Panel on MPA Standards recommended the adoption of the International Union for the Conservation of Nature standards and guidelines for all MPAs. Therefore, the Protection Standard prohibits four industrial activities from occurring in all federal MPAs established after 2019: oil and gas exploration, development and production, seabed mining, dumping and the use of bottom trawl fishing gears. Bottom trawl gears include bottom trawls, hydraulic dredges and scallop drags as well as midwater trawls that have been modified to make contact with the seafloor.

The National Framework for Establishing and Managing Marine Protected Areas recommends periodic reviews of MPA management plans to ensure that the site's objectives are being met (DFO 1999), and the Protection Standard indicates that all MPAs established before 2019 will re-evaluate the compatibility of activities included in the Protection Standard with the site's conservation objectives during said review. In addition, this re-evaluation should include consultation with partners and stakeholders, as cooperation with affected parties is key for the successful management of an MPA.

Section 35.1 of the *Oceans Act* states that MPAs may be designated to conserve and protect areas of high biodiversity and productivity, fisheries resources, threatened or endangered species and their habitats, unique habitats, as well as "any other marine resource or habitat as is necessary to fulfill the mandate of the Minister".

Musquash Estuary MPA (hereafter known as Musquash MPA) was established under the *Oceans Act* in 2006, and an exception was provided for scallop dragging in Zone 3 to allow for the continuation of fishers' traditional access to the estuary. The exception for the commercial scallop fishery was central to the community and environmental non-governmental organization (eNGO)-led nomination of this MPA and an important site design element that helped to gain support within the fishing industry for the proposal as a whole.

1.2 Risk Assessment Overview and Objective

An ecological risk assessment is a process that tries to account for interactions between human activities and ecological components (DFO 2025a). DFO staff working on MPA establishment and management apply the national *Marine Conservation Ecological Risk Process* when examining anthropogenic stressors. The risk assessment methodology begins by characterizing all human activities – or in certain cases, activity of interest – and associated pressures taking place in an area along with the site's priority species and habitats. Risk events (i.e. activity-pressure combinations that *may* pose a risk to the site's conservation priorities) are then identified and analyzed using existing literature to assess the level of risk posed by the activity to the conservation priority. As Musquash MPA is an established site with conservation objectives, conservation priority species and habitats were selected to be representative of the site's conservation objectives. These conservation priority species and habitats are referred to as "conservation priorities" (CP) throughout the rest of this document.

The risk assessment methodology involves analyzing the Impact Risk and the Recovery Lag which are determined by five separate parameters (Figure 1; DFO 2025a). The Impact Risk score is determined by combining the likelihood of an interaction (spatial and temporal exposure) with the consequences to the conservation priority if an interaction occurs (severity). The Recovery Lag (time needed for recovery) is determined by categorizing the persistence of the pressure in the environment with characteristics representative of the CP's overall resilience (e.g. COSEWIC status, fecundity, age at maturity, etc.).

Combined, these two scores (Impact Risk and Recovery Lag) allow us to assign one of three risk levels (acceptable, may be tolerable or intolerable) which represents the risk the activity-pressure poses to the conservation priority (DFO 2025a). Any time the risk level falls into the may be tolerable or intolerable categories, mitigation measures must be considered—and in cases of intolerable—implemented to decrease the risk to at least a may be tolerable score.

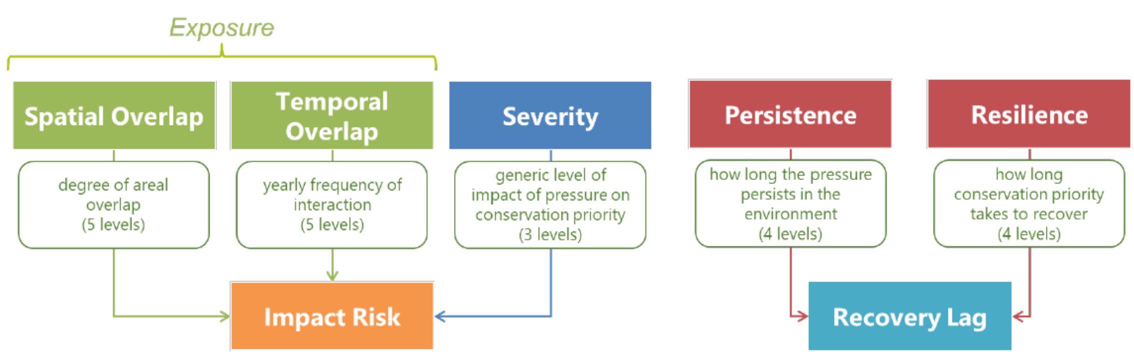

Figure 1. The five risk analysis parameters taken from DFO (2025a) which was adapted from Robinson et al. 2014.

The objective of this risk assessment is to evaluate the compatibility of the scallop drag fishery with Musquash MPA's conservation objectives. The results will help to inform the decision on whether or not to continue allowing scallop dragging in Zone 3 of the MPA. The specific scoping rationale is described in Section 1.5.

1.3 Ecology of Musquash Estuary Marine Protected Area

Musquash MPA is a 7.4 km^2 protected estuary located in the Bay of Fundy (DFO 2017a). The MPA is a partially enclosed area on the coast where freshwater from the Musquash River mixes with saltwater from the Bay of Fundy and contains nine different habitat types. The MPA includes the subtidal portion of the lower Musquash River and the Musquash Estuary. Although not a part of the MPA, management of 4 km^2 of the estuary's intertidal area, known as the

Administered Intertidal Area (AIA), was transferred from the Government of New Brunswick to the federal government in 2006 and is managed in the spirit of the MPA (Figure 2).

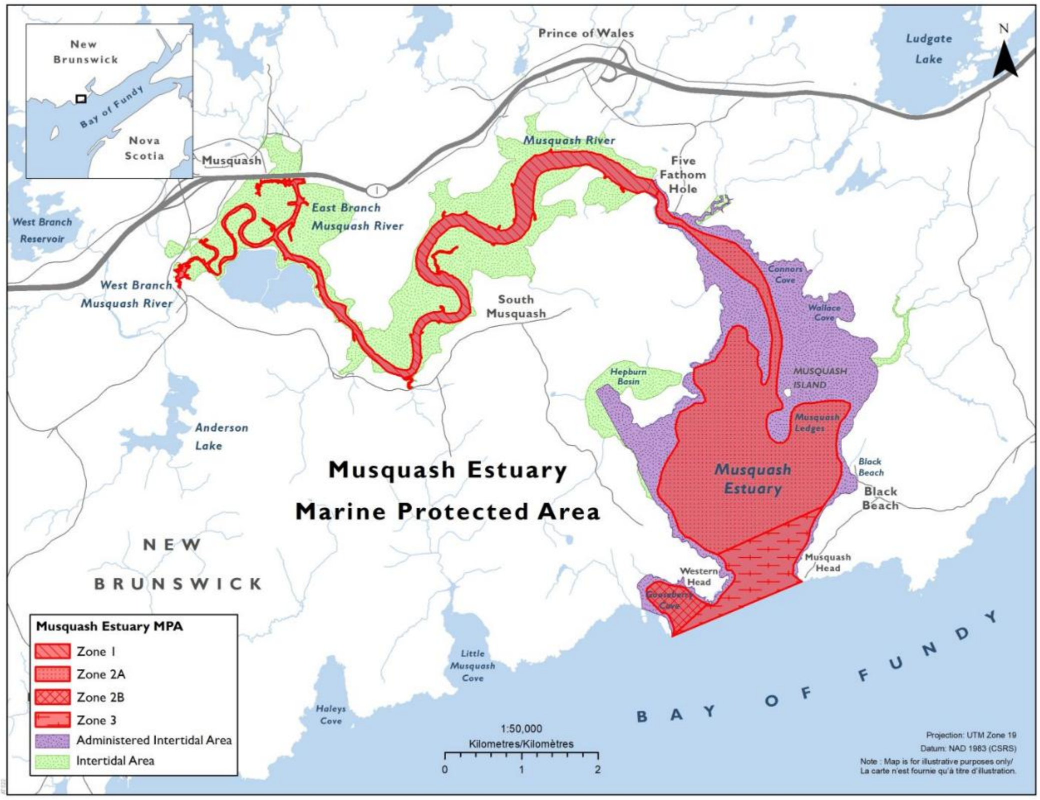

Figure 2. Management Zones of the Musquash Estuary Marine Protected Area (MPA).

The MPA is separated into four distinct management zones, each with its own restrictions that offer unique levels of protection (DFO 2017a). The MPA zones are as follows:

- Zone 1: subtidal portion of the upper Musquash River
- Zone 2A: subtidal portion of the lower Musquash River and the upper Musquash Estuary
- Zone 2B: subtidal portion of Gooseberry Cove
- Zone 3: subtidal portion of the estuary's mouth between Western Head and Musquash Head

All four zones are unique in their habitat composition. Based on an interpretation of sonar data, the estuary's substrate is primarily composed of a sediment mixture that is dominated by silt and clay with some sand (Figure 3) (DFO, unpublished data; Coastal Environmental Baseline Program (Maritimes Region) 2021). There are also rocky areas present along the shore and throughout the AIA as well as interspersed areas of mixed gravel sediment across the MPA (DFO 2017a; Coastal Environmental Baseline Program (Maritimes Region) 2021). The rocky areas and associated rockweed provide valuable shelter for fish residing in the estuary (DFO

2017a). Zone 3 is unique in its substrate composition in that it also possesses large areas of sediment that are dominated by sand (Coastal Environmental Baseline Program (Maritimes Region) 2021).

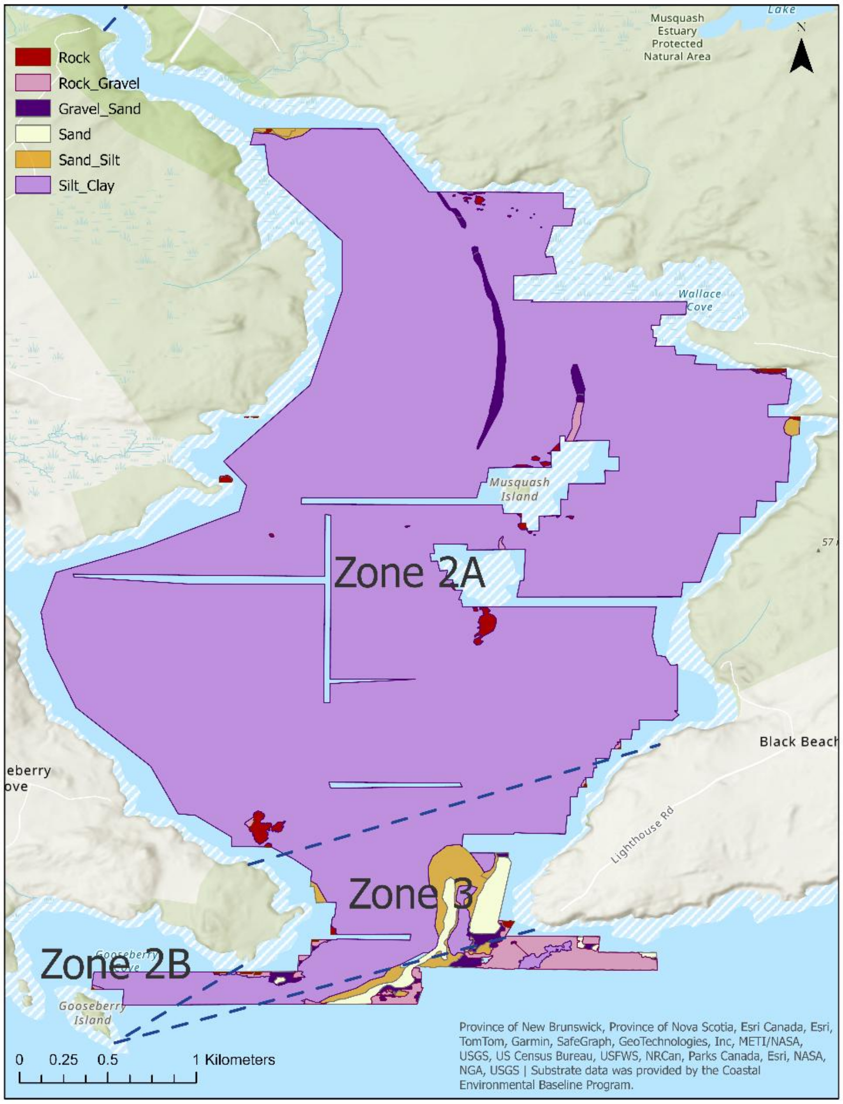

Figure 3. Substrate composition of the different management zones in the Musquash Estuary Marine Protected Area (MPA). Data provided by the Coastal Environmental Baseline Program (Maritimes Region) 2021.

The predominant infaunal species of Musquash MPA include polychaetes, nematodes and oligochaetes (Figure 4; Cooper and Blanchard 2023). Zone 2A has a large copepod population whereas small bivalves are numerous in Zones 2B and 3 (Cooper and Blanchard 2023). Juvenile Winter Flounder (*Pseudopleuronectes americanus*) and Atlantic Cod (*Gadus morhua*), adult Silverside (*Menidia menidia*), Atlantic Herring (*Clupea harengus*), Atlantic Rock Crabs (*Cancer irroratus*) and Jonah Crabs (*C. borealis*) have all been repeatedly sampled in Zones 2A and 2B

(Figure 5; Eastern Charlotte Waterways Inc. (ECW) 2022). Due to the challenging environment for diving and visual surveys, nekton have not been sampled by optical means in Zone 3; however, environmental DNA (eDNA) sampling in Zone 3 between 2022 and 2024 has detected several species including Menhaden (*Brevoortia tyrannus*), Atlantic Herring, Mummichog (*Fundulus heteroclitus*), Red Hake (*Urophycis chuss*), Tomcod (*Microgadus tomcod*), Blueback Herring (*Alosa aestivalis*), Alewife (*Alosa pseudoharengus*), Silverside, Cunner (*Tautogolabrus adspersus*) and Winter Flounder (Cooper et al., unpublished data).

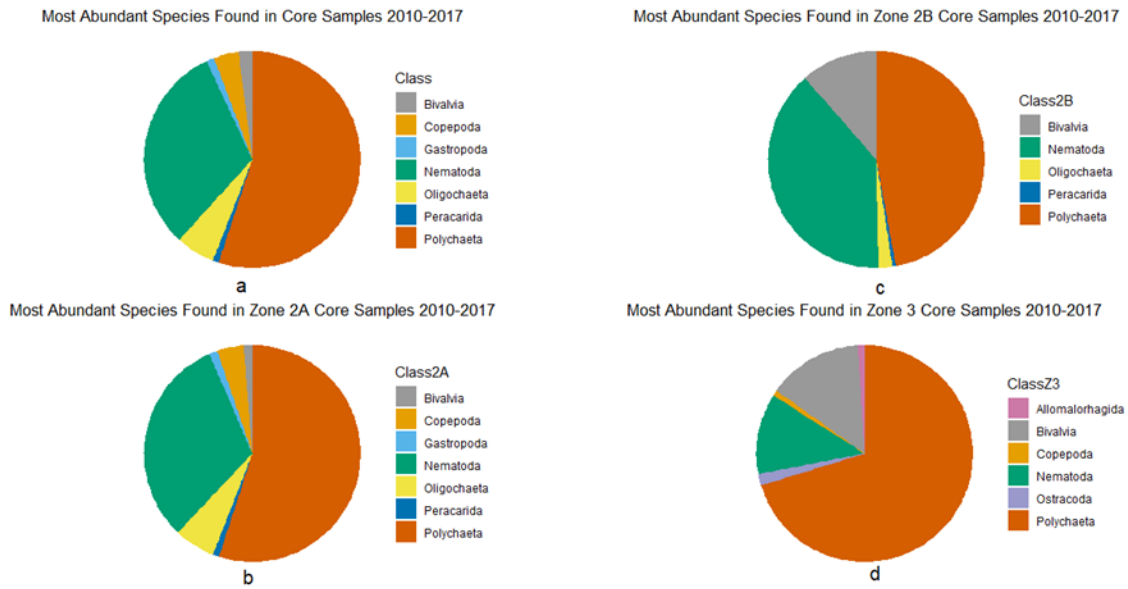

Figure 4. The most abundant taxa in Musquash Estuary Marine Protected Area (MPA) sediment core samples collected between 2010-2017. Only species that made up >0.5% of the samples' abundance were included in the graphs. A) Entirety of Musquash MPA B) Zone 2A; C) Zone 2B; D) Zone 3.

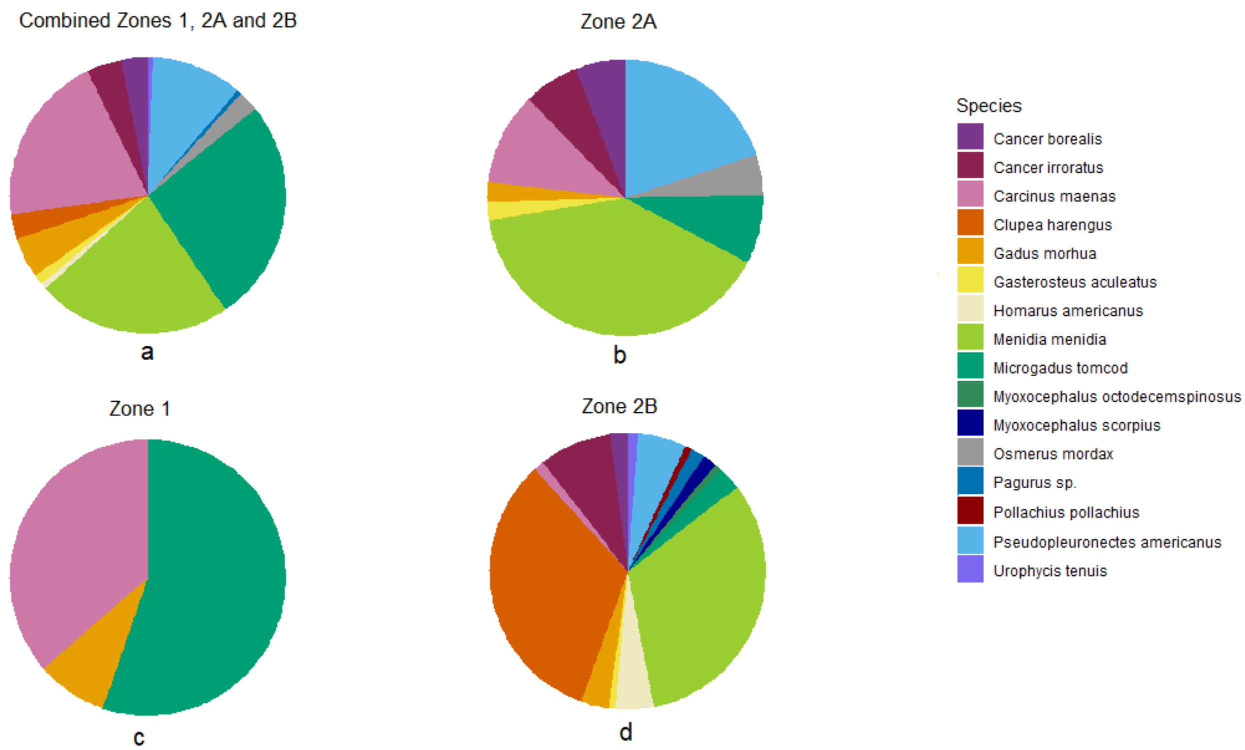

Figure 5. Pie graphs displaying the most abundant taxa in Musquash Estuary Marine Protected Area (MPA) fyke and seine samples collected between 2019-2021 by Eastern Charlotte Waterways Inc. Only species that made up >0.5% of the samples' abundance were included in the graphs. A) Combined Zones 1, 2A, and 2B; B) Zone 2A; C) Zone 1; D) Zone 2B.

The conservation objectives for Musquash MPA (DFO 2017a), are to ensure no unacceptable reduction or human-caused modification to:

A. Productivity so that each component (primary, community, population) is functioning in the ecosystem (e.g., by maintaining the abundance and health of harvested species);
B. Biodiversity by maintaining the diversity of individual species, communities, and populations within the different ecotypes;
C. Habitat in order to safeguard the physical and chemical properties of the ecosystem by maintaining water and sediment quality.

1.3.1 Conservation Priorities

Winter Flounder (juveniles and adults), Atlantic Rock Crabs (adults) and infaunal community habitat were chosen as conservation priority species and habitats for the risk assessment. These priority species and habitats act as proxy for Musquash MPA's conservation objectives.

Large crustaceans, such as Atlantic Rock Crabs, are important components of the ecosystem as predators and prey for many species of fish and invertebrates (Hanson et al. 2014). Atlantic Rock

Crabs are common within the Musquash Estuary (ECW 2022) and are a common bycatch species in the inshore scallop drag fishery (DFO Observer Database, 2000-2024; Sameoto and Glass 2012). In addition, as benthic species, scallop dragging operations directly interact with their habitat. Therefore, Atlantic Rock Crab was chosen as the CP to assess the risks posed by scallop dragging to benthic invertebrates.

Groundfish, such as Winter Flounder, are also important components of the ecosystem as predators and prey for other species of fish and mammals (Pereira et al. 1999). Winter Flounder is reported as bycatch within the inshore scallop drag fishery (DFO Observer Database, 2000-2024) and, as a demersal species, scallop dragging operations directly interact with their habitat. Juvenile Winter Flounder are common within Musquash MPA (ECW 2022), which suggests that the estuary acts as a nursery for the species. Therefore, Winter Flounder was chosen as the conservation priority to assess the risks posed by scallop dragging to groundfish in the MPA. It is important to note, the scallop drag fishery in the MPA (which occurs from January to March) is not expected to temporally overlap with the majority of spawning adult Winter Founder (April and May; Tyler 1971; DeCelles and Cadrin 2011; DFO 2016). Though it is expected that small young-of-the-year would make up the majority of the population in the MPA during the winter (Pereira et al. 2019), it is possible that larger young-of-the-year or older individuals may occupy Zone 3 during the period in which the fishery occurs, as migratory patterns appear to be influenced by a combination of variables, such as bottom water temperature and foraging behaviour (Scott and Scott 1988; Pereira et al. 1999; DFO 2016).

Lastly, the abundant infaunal community residing in the mud habitat of Zone 3 is dominated by polycheates, very small bivalves, nematodes and crustaceans such as Peracarida (Cooper and Blanchard 2023). Polychaetes, nematodes, Peracarida species and bivalves are all important sources of prey for several fish and invertebrates (Pereira et al 1999; Garrison and Link 2000; Pezzack et al. 2011). Therefore, infaunal community habitat was selected to assess the risks associated with scallop dragging on the soft-sediment benthic ecosystem.

1.4 Overview of the Inshore Scallop Fishery

1.4.1 Existing Management Measures

The inshore scallop fishery is managed by an integrated fisheries management plan (DFO n.d.). The Bay of Fundy falls within Scallop Fishing Areas (SFAs) 28A-D as described in the *Atlantic Fishery Regulations, 1985* (*SOR 86-21*) and is further divided into six Scallop Production Areas (SPA) (Figure 6) which are meant to better manage scallop populations and are defined within variation orders and licence conditions (DFO n.d.; DFO 2004). The inshore scallop fishery in Musquash MPA falls within SFA 28B as well as SPA 6C (DFO 2004). The lower and upper reference points defining critical, cautious and healthy stock status zones for SPA 6 are based on commercial biomass (DFO 2024). Catch from the inshore scallop fishery is primarily monitored with dockside monitoring of weight and logbooks to monitor catch (DFO n.d.; DFO 2017b).

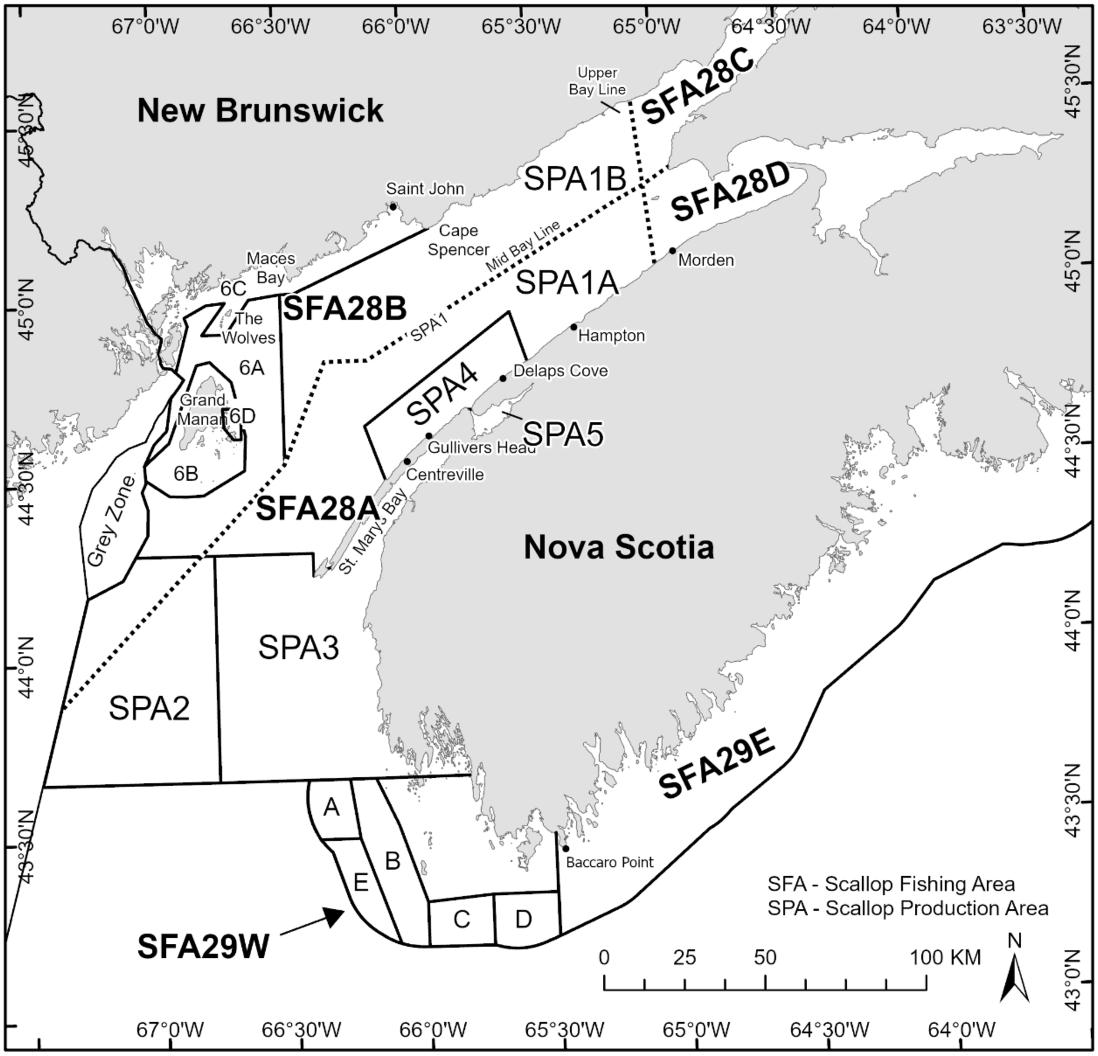

Figure 6. Map of Scallop Fishing Areas (SFA) and Scallop Production Areas (SPA) in the Bay of Fundy and southern Nova Scotia (from DFO 2024).

Additional management measures include minimum shell height and meat count for retained scallops; Vessel Monitoring Systems (VMS), hail-outs and hail-ins to track the vessels (DFO n.d.). Furthermore, offshore scallop drags are not permitted to be used in inshore areas and the gear is restricted to a maximum 5.5m width with rings of 82mm interior diameter. The scallop fishery within SPA 6C occurs from the second Tuesday in January through March (Roddick and Butler 2002; DFO 2017a).

There are three fleets which have access to the Bay of Fundy: the Full Bay fleet, the Upper Bay fleet, and the Mid Bay fleet (DFO n.d.). The Full Bay fleet is managed through an individual transferable quota whereas both the Upper and Mid Bay fleets have competitive quotas. Only the

Full Bay and Mid Bay fleets are permitted to commercially fish for scallops in SPA 6C (located within Scallop Fishing Area 28B) and share the quota at a respective 15% and 85%.

1.4.2 Inshore Scallop Drag Bycatch Profile

Currently, there is no DFO requirement for at-sea observer coverage in SPAs 1-6 (SFAs 28A and B; Sameoto and Glass 2012); as such bycatch data is scarce. Existing observer records from 2000-2024 were pulled from the Industry Surveys Database (ISDB) and clipped to SFA 28B (Table 1). Data was limited to commercial sets that were witnessed directly by the observer instead of recorded in the captain's logbook, resulting in a total of 554 sets. It is important to note that fishing effort is not equal across all sets, and can range from 1-10 tows per set. As data is recorded at the set level, it is not possible to assess catch composition at the tow level. Therefore, the presence/absence data presented in Table 1 is meant to be used as a high level representation of the bycatch for this fishery and is not representative of a catch per unit of effort (CPUE).

Table 1. Frequency of Interactions between Scallop Drags and Species in Scallop Fishing Area 28B.

Species	Total Catch Weight (kg)	Number of Sets	Percentage of Sets
Sea Scallop	286212	554	100
Stones and Rocks	679589	547	98.74
Foreign Articles, Garbage	61488	539	97.29
Scallop Shells	3623	403	72.74
American Lobster	829	256	46.21
Atlantic Rock Crab	2922	252	45.49
Asteroidea s.c.	4035	145	26.17
Longhorn Sculpin	249	131	23.65
Winter Flounder	254	126	22.74
Sea Urchins	2548	115	20.76
Winter Skate	1020	100	18.05
Jonah Crab	655	99	17.87
Little Skate	643	97	17.51
Monkfish, Goosefish, Angler	346	89	16.06
Thorny Skate	716	78	14.08
Smooth Skate	221	75	13.54
Sea Raven	110	66	11.91
Hermit Crabs, *Pagurus* sp.	263	55	9.93
Lemonweed	7605	54	9.75
American Plaice	121	45	8.12
Brill/windowpane	99	28	5.05
Summer Flounder	88	25	4.51
Witch Flounder	28	25	4.51
Sponges	3546	21	3.79
Mussels (ns)	1197	16	2.89
Brown Seaweeds	6426	15	2.71

Skates (ns)	159	13	2.35
Sea Cucumbers	440	12	2.17
Ocean Pout(common)	16	12	2.17
Haddock	27	11	1.99
Cod(Atlantic)	14	11	1.99
Silver Hake	12	11	1.99
Yellowtail Flounder	10	10	1.81
Sculpins, Sculpin (ns)	32	11	1.99
Round Skate	252	9	1.62
Mud	1238	9	1.62
Canoe Shells	246	8	1.44
White Hake	12	8	1.44
Sand Dollars	237	8	1.44
Shrimps	20	7	1.26
Pagurus politus	8	6	1.08
Common Mussels	42	5	0.90
Pandalus borealis	5	5	0.90
American Eel	6	5	0.90
Acanthocephala p.	4	4	0.72
Crustacea c.	10	4	0.72
Ocean Quahaug	57	3	0.54
Sand	810	3	0.54
Octopus	3	3	0.54
Sea Potato	6	3	0.54
Mucus	18	3	0.54
Green Crab	0	2	0.36
Herring(Atlantic)	2	2	0.36
Cusk	2	2	0.36
Squirrel or Red Hake	2	2	0.36
Brittle Star	6	2	0.36
Wave Whelk, common edible	1	1	0.18
S. droebachiensis	1	1	0.18
Pandalus montagui	1	1	0.18
Arabacia sp.	9	1	0.18
Pontaster sp.	5	1	0.18
Purple Starfish	2	1	0.18
Fourhorn Sculpin	1	1	0.18
Striped Atlantic Wolffish	2	1	0.18
Snails and Slugs	220	1	0.18
Rock Gunnel(eel)	1	1	0.18
Spiny Crab	6	1	0.18
Toad Crab,unident.	1	1	0.18
Spiny Dogfish	2	1	0.18
Atlantic Moonfish	34	1	0.18

Northern,common searobin	2	1	0.18
Redfish unseparated	0	1	0.18
Cephalopoda c.	1	1	0.18
Hyas coarctatus	1	1	0.18
Leatherfin Lumpsucker	1	1	0.18

The most common species captured as part of ECW's (2022) intertidal nekton sampling in the MPA (e.g. Atlantic Silverside, Tomcod, and Pollock (*Pollachius virens*)), including species of conservation concern such as White Hake (*Urophycis tenuis*; COSEWIC – threatened; SARA – no status) and Atlantic Cod (COSEWIC – endangered; SARA – no status), were not caught at all or caught infrequently (<2%) in observed trips within SFA 28B.

1.4.3 Fishing Activity in Musquash MPA

The exception of the commercial scallop drag fishery from MPA regulatory prohibitions was central to the community and eNGO-led nomination of the MPA. There is little fishing effort within the MPA relative to other areas of southwest New Brunswick as scallops are not believed to be abundant in the estuary. Dragging for scallops is expected to occur only when weather prevents the vessels from fishing elsewhere (Thompson 2001). Given the small area (0.95 km^2) of Musquash MPA's Zone 3 in relation to the resolution of available data, it is also difficult to quantify fishing effort and the existing data contains uncertainty.

Quantification of fishing effort for this analysis used two datasets: corrected Maritime Fishery Information System (MARFIS) logbook data[1] (DFO 2025b; Figure 7), which monitors commercial fisheries landings including scallop drag; and VMS data, which is a satellite based tracking system that provides the location of fishing vessels. Both datasets include geographic coordinates. MARFIS records include coordinates reported by fishers. These are often rounded and may contain errors. VMS records are automatically generated, typically every hour, but fishing activity must be inferred by vessel travel pattern and speed.

MARFIS logbook records from within and outside the MPA were cross referenced with VMS records within the MPA, resulting in 17 potential fishing events between 2005-2024[2]. Records outside the MPA were included out of caution, to account for errors in reported coordinates. It is also possible that those vessel tracks represent non-fishing activities such as shucking, anchoring, steaming or waiting for tides to change.

Available data suggests that the scallop drag fishery is conducted only sporadically within Zone 3 of the MPA and the last potential trip occurring in 2021. This level of activity amounted to less than 0.5% of total SPA 6C landings in any year that fishing occurred.

[1] The MARFIS data was corrected by DFO's Population Ecology Science Division.

[2] In order to protect privacy, there were too few fishing events to display aggregated catch data or fishery footprints in and around Zone 3.

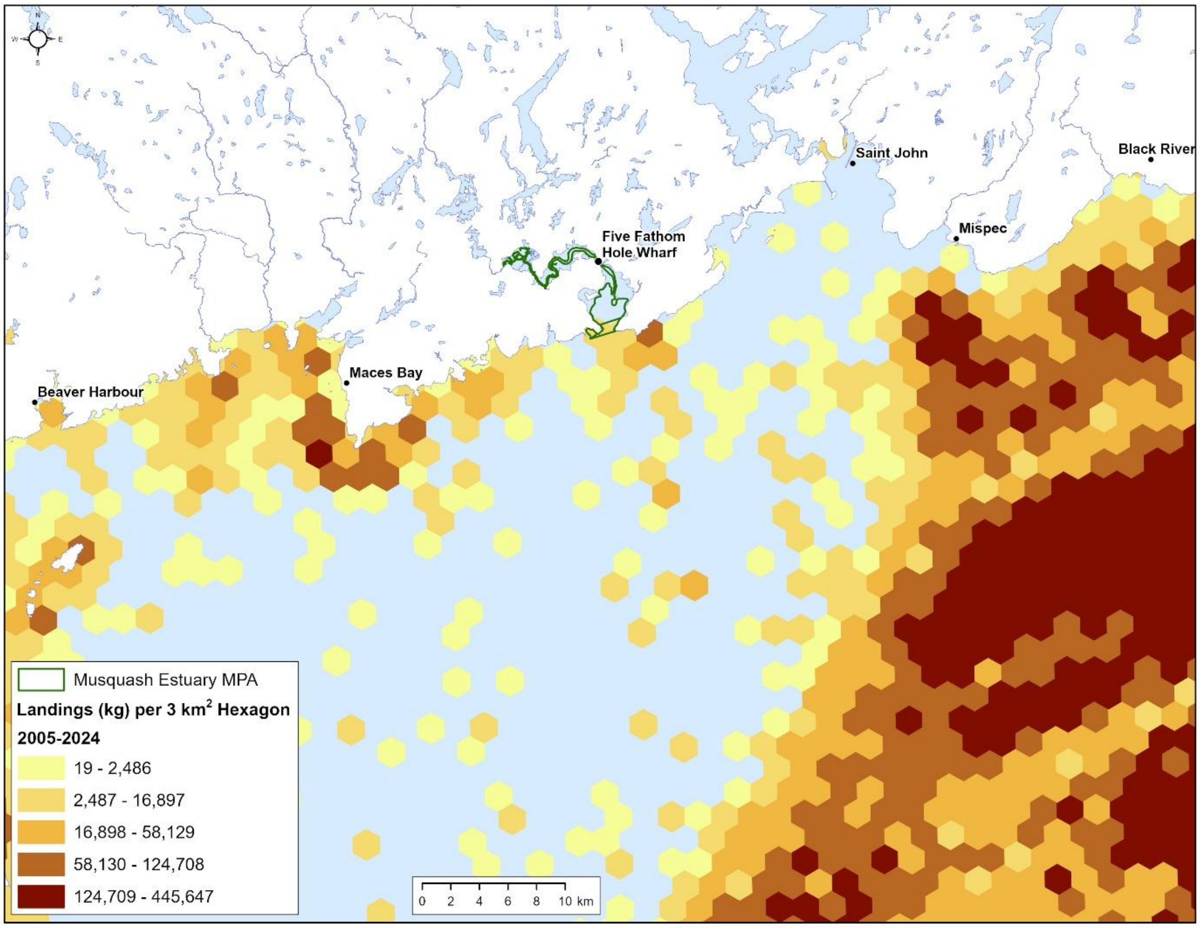

Figure 7. Corrected Inshore Scallop Logbook Data (2005-2024) from the Maritimes Fisheries Information System (MARFIS) in the Musquash Estuary Marine Protected Area (MPA) and surrounding area (DFO 2025b).

1.5 Scope of the Risk Assessment

This risk assessment is to determine if scallop dragging is compatible with Musquash MPA's conservation objectives, as directed by the MPA Protection Standard. No other activity taking place within the MPA nor any of the sub-activities or pressures broadly associated with marine transportation (e.g. noise pollution, input of light, mooring and anchoring, etc.) will be evaluated here.

The pressures associated with scallop dragging operations are bottom disturbance and changes in habitat from interactions with the seafloor – including the resuspension of sediment and abrasion and damage from contact with the gear, bycatch, the introduction of non-indigenous species from the dumping of foreign drag material and changes in the input of organic matter from the discarding of offal.

1.5.1 Pressures to be Assessed

Bycatch

Bycatch and discards are a result of normal operations in the scallop drag fishery. Discarded fish and invertebrates may be injured from the capture and handling process, resulting in unaccounted mortality for certain species (Jenkins et al. 2001; Uhlmann and Broadhurst 2015; Knotek et al. 2018). Therefore, risks posed by bycatch from the scallop drag fishery to Winter Flounder and Atlantic Rock Crab will be assessed (Table 2).

Bottom Disturbance & Changes in Habitat

Mobile bottom fisheries, such as scallop drags, also interact with the seafloor as part of normal operations. This bottom disturbance can result in habitat alterations such as damage to geologic or biologic features, changes in sediment characteristics, a decrease in organic matter and a decrease in the abundance and/or biomass of some infaunal and epifaunal species (Watling et al. 2001; Boulcott and Howell 2011; O'Neill et al. 2013; Grabowski et al. 2014). Species in the path of the drag can also experience abrasion and damage from the contact which may result in additional unaccounted mortality (Jenkins et al. 2001). Therefore, risks posed by the scallop drag fishery to infaunal community habitat from bottom disturbance and changes in habitat will be assessed (Table 2).

Winter Flounder and Atlantic Rock Crab are both opportunistic predators that can inhabit a wide range of benthic habitat types (Krouse 1980; Scott and Scott 1988; Pereira et al. 1999; Gottschall et al. 2000; Stoner et al. 2001; Pezzack et al. 2011); therefore, it is unlikely that changes in habitat will negatively impact habitat for either species. Furthermore, although Winter Flounder and Atlantic Rock Crabs in the path of the drag can be impacted by bottom disturbance through physical contact, it is unknown how frequently this interaction occurs.

Table 2. Potential for interaction between scoped-in pressures associated with scallop drags and the selected conservation priorities for Musquash MPA. Dark blue shading indicates that an exposure pathway exists and effects are known to occur, light blue shading indicates that an exposure pathway exists and effects may occur, and white indicates a lack of interaction. An asterisk indicates that the interaction underwent an impact chain risk assessment.

Conservation Priorities	Bottom Disturbance	Bycatch
Winter Flounder		*
Atlantic Rock Crab		*
Infaunal Community Habitat	*	

1.5.2 Excluded Interactions

Changes in Input of Organic Matter

Fishing activity is infrequent (<1 set per year) in the MPA, and it is believed that the level of discarded offal—if any—would be minimal and likely have negligible effects. Therefore, the release of offal will not be considered any further.

Resuspension of Sediment

Similarly, as the Bay of Fundy represents a naturally turbid environment (DFO 2017a) the resuspension of sediment from occasional dragging is unlikely to significantly contribute to the concentration of sediment in the water column; it is therefore unlikely to affect species or alter their habitat within the MPA, and will not be considered further.

Introduction of Non-Indigenous Species

Didemnum vexillum is an invasive colonial tunicate that was first discovered in the Gulf of Maine in 1993; however, it is believed that the species has been present in the region since the 1970s (Daley and Scavia 2008). The invasive tunicate was first identified in Atlantic Canada in 2013 near Parrsboro, NS, and has since spread to the Minas Basin and Quoddy Region of the Bay of Fundy (Vercaemer et al. 2015; Teed et al. 2024). It is not known to be established in Musquash MPA, but based on temperature and salinity data gathered between 2020 and 2024 as well as habitat suitability modeling based on climate change projections, the outer Musquash Estuary could support the establishment and growth of *D. vexillum* (C. DiBacco, DFO, pers comm. 2024; Coastal Environmental Baseline Monitoring Program 2025).

The growth of *D. vexillum* colonies transforms heterogenous habitat into homogenous habitat (Lengyel et al. 2009). Its presence is negatively correlated with sessile species, such as hydroids and scallops, as it can overgrow these organisms and turn otherwise suitable habitat into unsuitable habitat for recruits (Lengyel et al. 2009; Kaplan et al. 2017). The primary mechanism behind the spread in the Bay of Fundy is thought to be fragmentation through natural (i.e. tides and currents) and anthropogenic disturbance (i.e. scallop drags and vessel traffic) (Moore et al. 2018). Once a fraction of a colony breaks off, it may reattach to the substrate and establish in a new location (Bullard et al. 2007). Despite scallop dragging facilitating the spread of *D. vexillum* in the Bay of Fundy (Moore et al. 2018), *D. vexillum*'s establishment in the Bay of Fundy is related to climate change based on empirical observations and ecological niche models that revealed environmental suitability only during post invasion (~2012-present) but not before (pre 2012) (Moore et al. 2018; C. DiBacco, DFO, pers. comm., 2024). It is possible that the release of contaminated drag material from a fishing vessel could introduce *D. vexillum* to Musquash MPA; however, without further industry-wide changes to fishing practices for drag material disposal and gear cleaning, the restriction of scallop dragging in Zone 3 of Musquash MPA would not be an effective mechanism to reduce the spread of this invasive species. Furthermore, *D. vexillum* establishes on hard substrate between the low intertidal zone and 118m in depth (Bullard et al. 2007; Teed et al. 2024), and although Zone 3 may contain gravel (Figure 2) and shells, it is expected that the majority of the MPA is not a suitable substrate type to support its establishment. Therefore, due to very limited opportunity for the release of potentially contaminated drag material within the MPA and minimal hard substrate within Zone 3, this impact chain (a representation of the cause-and-effect relationship between a human activity, an associated pressure and a negative impact on a conservation priority) will not be considered further on its own. However, it will be included as a variable defining the resilience score of Musquash MPA's habitat.

2.0 METHODS

As previously mentioned, DFO staff working on MPA establishment and management apply the national *Marine Conservation Ecological Risk Process* when examining anthropogenic stressors (DFO 2025a). The risk assessment methodology involves analyzing the Impact Risk (i.e. the likelihood of an adverse ecological impact from the activity-pressure) and the Recovery Lag (i.e. time it takes for an impacted conservation priority to return to its pre-impacted condition after an interaction) between the activity-pressure and selected CPs (Figure 1).

Impact Risk

The Impact Risk is determined by combining the results of three separate parameters: spatial overlap, temporal overlap and severity.

The spatial overlap is the degree of areal overlap between the activity-pressure and conservation priority within the MPA during a typical year (DFO 2025a). It is a function of the spatial distribution of the activity, pressure and CP within the MPA and has five potential scores: widespread-even, widespread-patchy, local, site and exogenous (Table 3).

Table 3. Spatial Overlap Categories and Descriptions (from DFO 2025a).

CATEGORY	DESCRIPTION
WIDESPREAD – EVEN	The activity-pressure overlaps the conservation priority by **between 50 and 100%** of the area occupied by the conservation priority in the MPA, and is **evenly distributed** across that area.
WIDESPREAD – PATCHY	The activity-pressure overlaps the conservation priority by **between 50 and 100%** of the area occupied by the conservation priority in the MPA, but the distribution within that area is **patchy.**
LOCAL	The activity-pressure overlaps the conservation priority by **between 5 and 50%** of the area occupied by the conservation priority in the MPA.
SITE	The activity-pressure overlaps the conservation priority by up to **5% of the area** occupied by the conservation priority in the MPA.
EXOGENOUS	The activity-pressure occurs outside of the area occupied by a conservation priority,* but one or more of the pressures would reach the conservation priority **through dispersal.** *The activity is still one that is within the MPA boundary

The temporal overlap is the frequency of the interaction between the activity-pressure and conservation priority within the spatial overlap in a typical year (DFO 2025a). It is a function of the frequency, duration and seasonal nature of the activity and the frequency of the resulting pressure as well as the temporal nature of when the CP is present in the MPA, as certain species may not be present year round. There are five potential scores: frequent, common, occasional, rare and very rare (Table 4).

Table 4. Temporal Overlap Categories and Descriptions (from DFO 2025a).

CATEGORY	DESCRIPTION†
FREQUENT	Where the activity and the conservation priority overlap: a. daily (throughout the year); or b. continuously for 9 months of the year or more and the probability of interaction between the pressure and the conservation priority is high (>50%).
COMMON	Where the activity and the conservation priority overlap: a. weekly to monthly (throughout the year); or b. continuously for 4 to 8 months of the year and the probability of interaction between the pressure and the conservation priority is high (>50%). ***OR*** Where the activity and conservation priority overlap is *frequent*, but the probability of interaction between the pressure and the conservation priority is moderate (>20% and <50%).
OCCASIONAL	Where the activity and the conservation priority overlap: a. quarterly to annually; or b. continuously for less than 4 months of the year and the probability of interaction between the pressure and the conservation priority is high (>50%). ***OR*** Where the activity and conservation priority overlap is *frequent*, but the probability of interaction between the pressure and the conservation priority is low (<20%). ***OR*** Where the activity and conservation priority overlap is *common*, but the probability of interaction between the pressure and the conservation priority is moderate (>20% and <50%).
RARE	Where the activity and the conservation priority overlap:

	a. not every year; or b. continuously for less than 1 month and the probability of interaction with the conservation priority is high (>75%) or moderate (>20% and <50%). ***OR*** Where the activity and conservation priority overlap is *common*, but the probability of interaction between the pressure and the conservation priority is low (<20%). ***OR*** Where the activity and conservation priority overlap is *occasional*, but the probability of interaction between the pressure and the conservation priority is low (<20%) or moderate (>20% and <50%).
***VERY RARE**	Where the activity and the conservation priority overlap: a. every 5 years or less frequently; or b. due to an accidental event or abnormal operations and the probability of interaction between the pressure and the conservation priority is high (>75%). ***OR*** Where the activity and conservation priority overlap is *rare*, but the probability of interaction between the pressure and the conservation priority is low (<25%).

The spatial and temporal overlap scores are then combined to provide a binned exposure level (Table 5).

Table 5. Exposure Binned Categories (from DFO 2025a).

<table>
<tr><th>SPATIAL OVERLAP CATEGORY</th><th>TEMPORAL OVERLAP CATEGORY</th><th>BINNED EXPOSURE</th></tr>
<tr><td>Exogenous</td><td>Very rare</td><td rowspan="4">Very low</td></tr>
<tr><td>Site</td><td>Very rare</td></tr>
<tr><td>Exogenous</td><td>Rare</td></tr>
<tr><td>Site</td><td>Rare</td></tr>
</table>

SPATIAL OVERLAP CATEGORY	TEMPORAL OVERLAP CATEGORY	BINNED EXPOSURE
Exogenous	Occasional	Low
Local	Very rare	
Exogenous	Common	
Widespread – patchy	Very rare	
Site	Occasional	Moderate
Exogenous	Frequent	
Widespread – even	Very rare	
Site	Common	
Local	Rare	
Site	Frequent	Moderately high
Widespread – patchy	Rare	
Widespread – even	Rare	
Local	Occasional	
Widespread – patchy	Occasional	High
Local	Common	
Widespread – even	Occasional	
Local	Frequent	
Widespread – patchy	Common	
Widespread – patchy	Frequent	
Widespread – even	Common	
Widespread – even	Frequent	

The severity is the degree of impact to the conservation priority if an interaction were to occur with the activity-pressure and there are three potential scores: high, moderate and low (Table 6; DFO 2025a). The score is based on existing literature and knowledge of how the CP is known to be impacted by the pressure.

Table 6. Severity Categories and Descriptions (from DFO 2025a).

CATEGORY	DESCRIPTION
HIGH	• The conservation priority (exposed individuals and populations) has low resistance to the pressure. • The pressure has been shown to cause mortality for a large proportion of exposed individuals and/or other severe perturbation, including after a single interaction or short-duration exposure.
MODERATE	• The conservation priority (exposed individuals and populations) has moderate resistance to the pressure. • The pressure has been shown to cause severe perturbation after repeated interactions or sustained exposure at sufficiently high levels.
LOW	• The conservation priority (exposed individuals and populations) has a high resistance to the pressure. • The pressure may in some cases cause some detrimental perturbation after very long-term exposure at sufficiently high levels.

The binned exposure level and severity score are then combined to provide the Impact Risk score (Table 7).

Table 7. Impact Risk Binned Level Categories (from DFO 2025a).

BINNED EXPOSURE LEVEL	SEVERITY CATEGORY	IMPACT RISK (IR) BINNED LEVEL
High	High	**High**
High	Moderate	
Moderately High	High	
Moderately High	Moderate	**Moderately high**
Moderate	High	
Moderate	Moderate	
Low	High	
High	Low	**Moderate**
Moderately High	Low	
Low	Moderate	
Very low	High	
Moderate	Low	**Low**
Low	Low	
Very low	Moderate	
Very low	Low	

Recovery Lag

The Recovery Lag is scored by combining two separate parameters: persistence and resilience.

Persistence is the time it takes for the pressure to disappear from the environment after the activity has ceased; there are four potential scores: continuous, high, moderate and low (Table 8; DFO 2025a).

Table 8. Persistence Categories and Descriptions (from DFO 2025a).

CATEGORY	DESCRIPTION
CONTINUOUS	The pressure takes more than 10 years to disappear, or never leaves the system, even after the activity stops.
HIGH	The pressure takes 1 to 10 years to disappear after the activity stops.
MODERATE	The pressure takes weeks to a year to disappear after the activity stops.
LOW	The pressure dissipates instantly or in less than a week after the activity stops.

Resilience is the ability for the CP to return to pre-impact status after the pressure has disappeared and there are four potential scores: high, moderate, low or none (DFO 2025a). It is scored by combining several relevant variables indicative of the population's health or the species' overall ability to quickly increase population (Table 9). Examples include COSEWIC status or stock health, fecundity, mortality rates, age at maturity, etc.

Table 9. Resilience Categories (from DFO 2025a).

Categories	High	Moderate	Low	None
COSEWIC status	No status / Not at Risk	Special Concern	Threatened	Endangered
Sustainable Fisheries Framework	fish stock in Healthy Zone	fish stock at or near Target Reference Point (TRP)	fish stock in Cautious Zone	fish stock in Critical Zone
Species Recovery Factors *(adapted from O et al. 2015)*				
Fecundity **The population-wide average number of offspring produced by a female each year**	>100,000	100-100,000	<100	
Breeding strategy **Winemiller's index (1989) method. The level of**	<1	1 to 3	>3	

mortality that may be expected for offspring in the first stages of life.			
Recruitment pattern **Populations with sporadic and infrequent recruitment success are often long-lived and thus be expected to have lower levels of productivity.**	>75%	10-75%	<10%
Natural mortality rate **Instantaneous mortality rate. Populations with naturally higher instantaneous mortality rates likely have higher recovery rates.**	>0.4	0.2-0.4	<0.2
Age at maturity **Age of sexual maturation (i.e., age at which reproduction may begin**	<2 years	2-4 years	>4 years
Life stage **The life stage(s) affected by a stressor**	Not affected or only mature stages	Only immature stages	All stages
Population connectivity **Realized exchange with other populations based on spatial patchiness of distribution, degree of isolation, and potential dispersal capability.**	Regular (not a distinct population segment or evolutionarily significant unit)	Occasional	Negligible (distinct population segment or evolutionarily significant unit)
Habitat recovery from bottom trawl and dredging **(CSAS 2006/057)**	Less consolidated coarse sediments		More stable biogenic, gravel, and mud

	in areas of high natural disturbance show fewer initial effects, recovery is also faster	habitats experience the greatest change and have the slowest recovery rates

The persistence and resilience scores are combined to score the Recovery Lag (Table 10).

Table 10. Recovery Lag Binned Categories (DFO 2025a).

PERSISTENCE CATEGORY	RESILIENCE CATEGORY	RECOVERY LAG (RL) BINNED LEVEL
Continuous	None	High
High	None	
Moderate	None	
Low	None	
Continuous	Low	
High	Low	
Moderate	Low	Moderately High
Low	Low	
Continuous	Moderate	
High	Moderate	
Continuous	High	Moderate
High	High	
Moderate	Moderate	
Low	Moderate	
Moderate	High	Low
Low	High	

Combined, the Impact Risk and Recovery Lag give a risk level of acceptable, may be tolerable or intolerable (i.e. low, moderate or high), which represents the risk the activity-pressure poses to the CP (Figure 8; DFO 2025a). Any time the risk level falls into the may be tolerable or intolerable categories, mitigation measures must be considered—and in cases of intolerable—implemented to decrease the risk to at least a may be tolerable score.

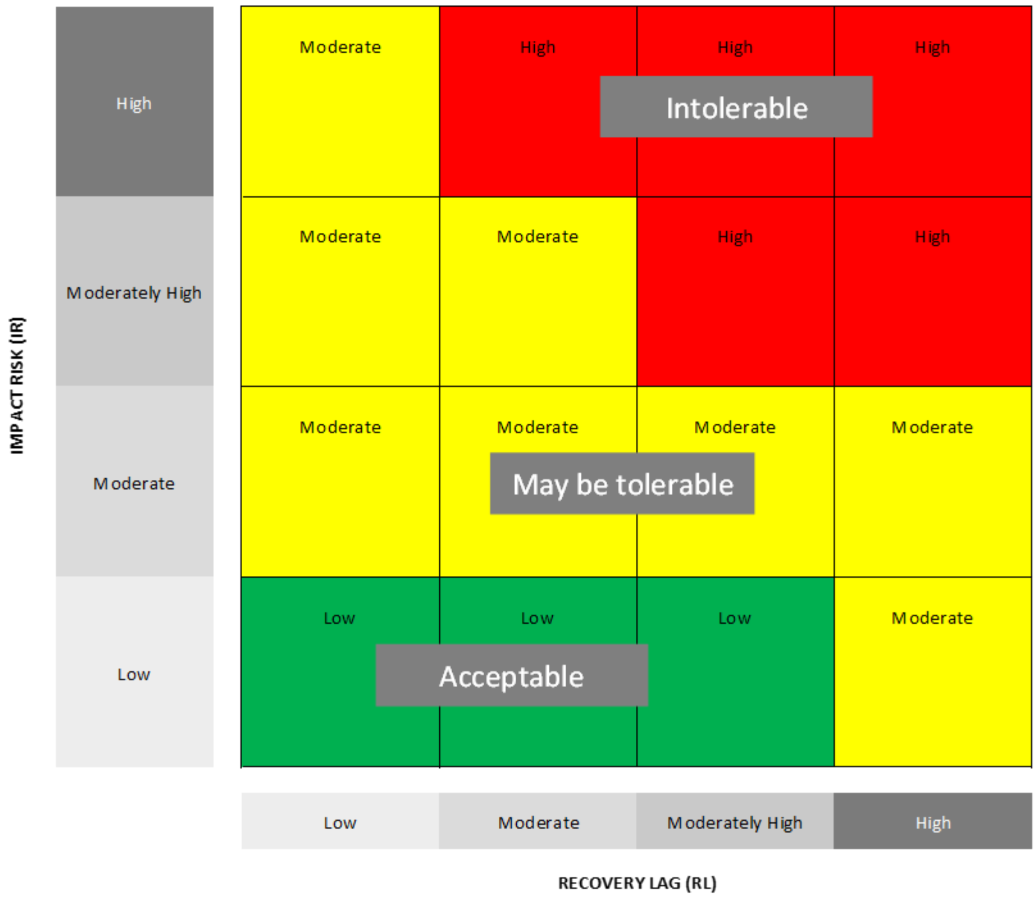

Figure 8. Heat Map of the Risk Tolerance based on the Combination of the Impact Risk (IR) and Recovery Lag (RL) Scores (from DFO 2025a).

Uncertainty

The uncertainty score is determined based on the availability of literature or knowledge about the interaction, the quality of the literature (peer reviewed vs grey literature) and whether it is on the ecological component of interest or a proxy (Table 11; DFO 2025a). There are three potential scores: high uncertainty, moderate uncertainty and low uncertainty. Increased uncertainty is not a reason to delay decisions; however, management may consider it when deciding mitigation measures. A heightened uncertainty may also indicate the need to collect more data or increase monitoring.

Table 11. Uncertainty Level Categories and Descriptions (from DFO 2025a).

UNCERTAINTY LEVEL	DESCRIPTION
LOW UNCERTAINTY	Widely accepted information, applicable to study area, and supported by peer reviewed, science-based literature. No or minimal additional data collection needed.
MODERATE UNCERTAINTY	Limited/non-peer-reviewed literature and/or partial data available. Science-based evidence available but potentially requiring updating or validation for specific location or time frame.
HIGH UNCERTAINTY	Little to no science-based data and/or published material available. Some general knowledge and/or data may exist but would require validation.

3.0 SINGLE IMPACT CHAIN RISK ASSESSMENTS

3.1 Winter Flounder (*Pseudopleuronectes americanus*) – Bycatch

Risk Statement: Scallop dragging operations may result in bycatch of Winter Flounder which can lead to reduced abundance and loss of ecosystem function of the local population within Musquash MPA.

Table 12. Winter Flounder – Scallop Dragging Operations – Bycatch.

Risk factor	Score	Rationale
Spatial Overlap	**Local**	Nekton sampling has never taken place in Zone 3 of Musquash MPA due to the challenging nature of the site (see Section 1.3). However, Winter Flounder have been sampled in neighbouring Zones 2A and 2B (ECW 2022) and eDNA sampling in Zone 3 has detected this species (Cooper et al., unpublished data). Generally, younger Winter Flounder are associated with fine muddy sediment and in shallower waters than older fish (Pereira et al. 1999; Stoner et al. 2001). As Winter Flounder age, they are more likely to also be associated with more heterogenous bottom types, like sand, shells, cobble and boulders (Scott and Scott 1988; Pereira et al. 1999; Gottschall et al. 2000). The majority of Winter Flounder that were sampled from Musquash MPA between 2019-2021 in the spring, summer and fall were between 30mm-70mm (ECW 2022), suggesting an association between small fish and the fine sediment present at Zone 2 sampling sites. Therefore, it is expected that younger individuals may be found throughout Zones 2 and 3 of the MPA and older individuals may be restricted to the outer reaches of Zone 2 and 3. In Musquash MPA, scallop drags have the potential to fish in the entirety of Zone 3, which covers approximately 14% of the MPA. Therefore, the scallop drag fishery overlaps with a maximum of **14%** of potential Winter Flounder habitat in the MPA. The spatial distribution of bycatch is identical to the scallop dragging footprint, resulting in a local spatial overlap score.
Temporal Overlap	**Rare**	Young-of-the-year Winter Flounder are expected to remain in shallow inshore waters for their first year of life (Pereira et al. 1999); therefore, they are expected to be present in the MPA year-round. Dependent on bottom water temperature and foraging behaviour (Pereira et al. 1999; DFO 2026), some older individuals may also be present in Zone 3 during winter. Scallop fishing can only occur in SPA 6C from the second Tuesday in January through March (Roddick and Butler 2002). Based on

		MARFIS and VMS data between 2005-2024, there was <1 fishing event per year in Zone 3 of the MPA. Observers on inshore scallop drag vessels recorded Winter Flounder (age unknown) in approximately 23% of sets in SFA 28B between 2000-2024 (Table 1; DFO Observer Data, 2000-2024). However, most juveniles (like those found in Musquash MPA) would have been small enough to pass through the 82mm mesh of the scallop drag prescribed by the *Atlantic Fishery Regulations (SOR/86-21)*. For bycatch, the frequency of the pressure is identical to the frequency of scallop dragging in Zone 3. The scallop drag fishery within the MPA overlaps with the expected presence of Winter Flounder less than once per year and Winter Flounder may be expected to be caught as bycatch in some drag sets. However, young-of-the-year, which are expected make up the majority of individuals present during the winter, are expected to be caught less frequently due to their length in relation to net mesh size. Therefore, a temporal overlap score of rare was assigned.
Binned Exposure = Spatial Overlap * Temporal Overlap = **Moderate**		
Severity	**Moderate**	The handling process of fish bycaught in towed mobile gears can result in scale loss, torn fins, broken bones, wounds, subsequent infections and stress potentially leading to mortality post-release (Anderson et al. 2021; Broadhurst et al. 2006; Kaiser and Spencer 1995; Neilson et al. 1989). There is no available literature on the survival rates of discarded Winter Flounder from scallop drags; however, there was a study that characterized the injuries of Yellowtail Flounder (*Limanda ferruginea*), Windowpane (*Scophthalmus aquosus*), and Fourspot Flounder (*Paralichthys oblongus*) caught in commercial scallop drags (Anderson et al. 2021). Anderson et al. (2021) found that the majority of flounder caught in the commercial scallop drag had no observable injuries or only minor injuries in the form of skin abrasion, torn fins and mucus damage; however, it was noted that all captured flounder had some degree of reflex impairment, which can be indicative of post-release mortality (which was not assessed in the former study). Studies on flatfish released from trawls have produced mixed results, but generally suggest a high mortality rate. Ross and Hokenson (1997) found that Winter Flounder had >90% survival rate after capture and sorting in a Gulf of Maine commercial shrimp vessel; however, they only assessed the survival for the

		first two hours after capture. In an ex-situ study, Neilson et al. (1989) found that 65% of Atlantic Halibut released from trawls died within two days, with smaller fish showing higher mortality rates than larger ones. Two further studies predicted that up to 70% of Yellowtail Flounder released from trawls (Barkley and Cadrin 2012) and between 45-99% of skates (varied between species) released from scallop drags (Knotek et al. 2018) would die based on health indicator scores. In addition, due to lower swim speeds and reduced vigilance of recently discarded fish, they may be at an increased susceptibility to predation (Ryer et al. 2004). Some larger individuals are expected to be present and caught in drags; however, most Winter Flounder found in Musquash MPA were between 30mm and 70mm (ECW 2022), indicating that most would be small enough to pass through the required 82mm mesh of the scallop drag (DOJ 1985). Though difficult to quantify, the level of injuries, stress or disorientation sustained by the small fish that pass through the gear would likely be less than what is presented above for larger fish retained by the mesh and hauled aboard. Therefore, a moderate severity was chosen.
Impact Risk = Severity * Binned Exposure = **Moderately High**		
Persistence	**Low**	The pressure of bycatch disappears from the environment as soon as the tow has ended, resulting in a low persistence score.
Resilience	**Moderate**	Winter Flounder demonstrate characteristics of both high and low resilience. Factors of high resilience: Winter Flounder abundance has remained above the 80% threshold since the 1980s (DFO 2023b). Winter Flounder also have high fecundity (up to >1,000,000 eggs; Buckley et al. 1991; McElroy et al. 2013), more than 80% of the population appears to spawn annually on a reliable basis (McBride et al. 2013), and this species demonstrates a high natural mortality rate (Buckley et al. 1991). Factors of low resilience: the stock found in Musquash is the Western Scotian Shelf stock, which matures at >4 years of age (DeCelles and Cadrin 2011), and bycatch can affect both mature and immature fish. Although Western Scotian Shelf Winter Flounder are managed as one unit, it is comprised of at least two separate stocks (DeCelles and Cadrin 2011). The connectivity of Musquash Estuary

		spawning Winter Flounder with the rest of the Bay of Fundy is unknown. Warming waters and ocean acidification associated with climate change, may cause a northward shift in Winter Flounder distribution (Cheung and Oyinlola 2018) as well as a decrease in recruitment and lower survival for those inhabiting the southern portion of their range (mid-Atlantic United States; Huebert et al. 2021). Winter Flounder residing in the Scotian Shelf bioregion are believed to have low vulnerability to warming waters as projections are not near their thermal threshold; however, the effects of ocean acidification have not been studied in this population (Stortini et al. 2015). Based on the mixture of resilience levels in the life-history characteristics of Winter Flounder and using the precautionary approach, a moderate resilience score was assigned.
Recovery Lag = Persistence * Resilience = **Moderate**		
Overall Risk = Impact Risk * Recovery Lag = **Moderate**		
Uncertainty	**High**	The abundance of Winter Flounder within Zone 3 of the MPA is not known. There is also no available literature on the post-release survival of Winter Flounder from drag fisheries, and other fish and/or trawl fisheries were used as proxies. Additionally, the potential impacts sustained by small fish that pass through the mesh is unknown.

3.2 Atlantic Rock Crab (*Cancer irroratus*) – Bycatch

Risk Statement: Scallop dragging operations may result in bycatch of Atlantic Rock Crabs which can lead to reduced abundance and loss of ecosystem function of the local population within Musquash MPA.

Table 13. Atlantic Rock Crab – Scallop Dragging Operations – Bycatch.

Risk factor	Score	Rationale
Spatial Overlap	**Local**	Nekton sampling has never taken place in Zone 3 of Musquash MPA due to the challenging nature of the site (see Section 1.3). However, Atlantic Rock Crabs have been sampled in neighbouring Zones 2A and 2B (ECW 2022). Atlantic Rock Crabs can be found on all types of substrate, including mud, sand and rock (DFO 2022; Hudson and Lamarche 1989; Krouse 1980); therefore, it is assumed that rock crabs and their potential habitat are found throughout Zone 3 as well as the entire MPA. Scallop dragging is limited to Zone 3, which covers approximately 14% of the MPA. It is expected the Atlantic Rock Crabs occur throughout the MPA, and therefore, the scallop drag fishery overlaps with a maximum of **14%** of potential Atlantic Rock Crab habitat within the MPA. The spatial distribution of bycatch is identical to the scallop dragging footprint, resulting in a local spatial overlap score.
Temporal Overlap	**Rare**	Atlantic Rock Crabs are expected to remain within inshore waters year-round (Bigford 1979; Comeau et al. 2012); therefore, they are expected in the MPA year-round. Scallop fishing is only permitted to occur in SPA 6C from the second Tuesday in January through March. Based on MARFIS and VMS records from 2005-2024, there was <1 fishing event per year in Zone 3 of the MPA. Atlantic Rock Crabs were present in **~45%** of observed inshore scallop drag sets in SFA 28B between 2000-2024 (Table 1; DFO Observer Data, 2000-2024). As such, it is expected that they are captured in 45% of sets. For bycatch, the frequency of the pressure is identical to the frequency of scallop dragging in Zone 3 of Musquash MPA. The scallop drag fishery within the MPA overlaps with expected presence of Atlantic Rock Crabs less than once per year. Additionally, Rock Crabs are expected to be caught as bycatch in approximately 45% of drag sets. Therefore, a temporal overlap score of rare was assigned.

Binned Exposure = Spatial Overlap * Temporal Overlap = **Moderate**		
Severity	**Moderate**	There is no available literature on the survival of discarded Atlantic Rock Crabs from scallop drags; therefore other species were used as proxy. Sameoto et al (2015) found that 20% of Atlantic Lobsters die post-release from scallop drags in SFA 29. In a study taking place off of the Isle of Man, Jenkins et al. (2001) found that approximately 20% of *Cancer pagarus* that were caught in scallop drags were dead upon evaluating the catch and a further 20% of crabs in the bycatch had suffered minor or major damage (i.e. limb loss and carapace cracks). Similarly, Öndes et al. (2016) found that 30% of *C. pagarus* caught in scallop drags were dead with an additional 15% suffering major damage (i.e. carapace cracks). These types of injuries may lead to further mortality post-release through infection and increased vulnerability to predation (Juanes and Smith 1995; Kaiser and Spencer 1995; Uhlmann et al. 2009). Newly moulted crabs (i.e. soft crabs) were more likely to suffer greater levels of damage than those with thicker shells (Öndes et al. 2016). As most crabs moult in the summer in Atlantic Canada (DFO 2008), it is unlikely that a scallop drag operating in Musquash MPA would encounter a newly moulted crab. Based on the available literature, a severity score of moderate was chosen.
Impact Risk = Severity * Binned Exposure = **Moderately High**		
Persistence	**Low**	The pressure of bycatch disappears from the environment as soon as the tow has ended, resulting in a low persistence score.
Resilience	**Moderate**	Atlantic Rock Crabs demonstrate characteristics of high, moderate and low resilience. High resilience: Atlantic Rock Crabs have not been assessed by COSEWIC. There is no indication of abnormal connectivity with this population, and females can produce up to 500,000 eggs per spawning event (DFO 2022). Atlantic Rock Crabs also have naturally high mortality rates (>75% in their second year of life; Reilly and Saila 1978). Moderate resilience: Male and female rock crabs inhabiting the Bay of Fundy are estimated to reach 50% maturity at a carapace width of 62mm and 49mm, respectively, (Campbell and Eagles

<table>
<tr><td></td><td></td><td>1983), or three years of age if growth rates are similar to crabs in southern New England (Reilly and Saila 1978).

Low resilience: Bycatch affects both mature and immature individuals, and mature females may be carrying eggs at the time the fishery occurs in the MPA (Krouse 1972; DFO 2022).

There are few studies looking at the effects of climate change on Atlantic Rock Crabs or similar species. Whiteley (2011) reviewed multiple studies and determined that coastal species inhabiting areas with freshwater input, as is the case in Musquash MPA, are likely to possess high levels of resilience to ocean acidification due to their strong acid-base and osmoregulation abilities. Subject matter experts also believe that Atlantic Rock Crabs inhabiting the southern Gulf of St. Lawrence will not reach their thermal limit as a result of ocean warming, but may shift to deeper waters similar to their present depth distribution in the mid-Atlantic or their abundance may change as a result of shifts in the distribution of predators and prey (DFO 2025c). Currently, no correlation has been found between CPUE and bottom temperatures in the southern Gulf of St. Lawrence suggesting variation in bottom temperatures currently has little influence on their abundance (Harbicht et al. 2025).

Based on the mixture of resilience levels in the life-history characteristics of Atlantic Rock Crabs an using the precautionary approach, a moderate resilience score was assigned.</td></tr>
<tr><td colspan="3">Recovery Lag = Persistence * Resilience = Moderate</td></tr>
<tr><td colspan="3">Overall Risk = Impact Risk * Recovery Lag = Moderate</td></tr>
<tr><td>Uncertainty</td><td>High</td><td>There is no data on the epifaunal community in Zone 3, and the presence of Atlantic Rock Crabs in Zone 3 is assumed based on their confirmed presence in Zones 2A and 2B, as well as the general distribution of rock crabs over multiple bottom types. There is also no data on the survival of C. irroratus from scallop drags and very little data on the reliability of spawning for Atlantic Rock Crabs or their stock status in the Bay of Fundy.</td></tr>
</table>

3.3 Infaunal Community Habitat – Bottom Disturbance

<u>Risk Statement</u>: Scallop dragging operations may cause bottom disturbance which can result in disruption to benthic infaunal habitat and reduce its ecosystem function within Musquash MPA.

Table 14. Infaunal Community Habitat – Scallop Dragging Operations – Bottom Disturbance.

Risk factor	Score	Rationale
Spatial Overlap	**Local**	The infaunal community found within Zone 3 of Musquash MPA is dominated (by abundance and biomass) by polychaetes, small species of crustaceans and small species of bivalves (Cooper and Blanchard 2023). The dominant species in Zone 3 are also found in Zones 2A and 2B. The silt/clay mixture dominated sediment that supports this infaunal community occurs throughout the majority of the MPA (Figure 3). Scallop dragging is limited to Zone 3, which covers approximately 14% of the MPA. Silt/clay mixture dominated sediment covers the majority of the MPA, including Zone 3. Therefore, the scallop drag fishery overlaps with a maximum of **14%** of potential infaunal community habitat in the MPA. The spatial distribution of bottom disturbance is identical to the scallop dragging footprint, which results in a local spatial overlap score.
Temporal Overlap	**Rare**	The infaunal community is expected to be present in the MPA year-round. Scallop fishing is only permitted to occur in SPA 6C from the second Tuesday in January through March. Based on MARFIS and VMS records from 2005-2024, there was <1 fishing event per year in Zone 3. Given that scallop drag gear is designed to interact with the substrate, an interaction between the infaunal community and the gear is expected each time the gear is deployed. For bottom distribution, the frequency of the pressure is identical to the frequency of scallop dragging in Zone 3 of Musquash MPA. The scallop drag fishery within the MPA overlaps with infaunal community habitat less than once per year. Therefore, a rare temporal overlap score was chosen.
Binned Exposure = Spatial Overlap * Temporal Overlap = **Moderate**		
Severity	**Moderate**	Scallop dragging can damage geologic and biologic features found in soft sediment by flattening natural depressions, creating furrows and destroying polychaete tubes (DeAlteris et al. 2000;

		Grabowski et al. 2014; Eigaard et al. 2016; Stewart and Howard 2016; Government of Wales 2022). Dragging also resuspends infauna that inhabit the penetration depth of the gear (Watling et al. 2001; O'Neill et al. 2013). Although most species appear to resettle in the sediment after the dragging is complete, it isn't clear if they survive the process (O'Neill et al. 2013), as the abundance of sensitive infaunal species can decrease post-dragging (Watling et al. 2001). Along with studies on other mobile gears, such as bottom trawls, there is ample evidence to suggest that mobile bottom gears can reduce species richness, diversity and biomass of infaunal species residing in soft sediments (Kaiser et al. 2006; Sciberras et al. 2018; Sköld et al. 2018). Impacts to low trophic level species can alter food web dynamics manifesting through to higher trophic levels (Hiddink et al. 2016; Amiraux et al. 2022). However, fauna that inhabit areas that are subjected to frequent environmental disturbance (e.g. tides, storms) often possess communities that are less impacted by mobile bottom gears, such as drags, than communities in areas with little natural disturbance (Brylinsky et al. 1994; Kaiser and Spencer 1996; Rice 2006; Clark and Koslow 2007; Sciberras et al. 2018). The Musquash Estuary is a high-energy environment with silt and clay as the primary substrates (Figure 2; DFO 2017a). Although scallop dragging can damage benthic habitat and the infaunal organisms that inhabit it, reducing ecosystem function, impacts are less severe in habitats routinely exposed to natural disturbance. Additionally, the infaunal community is generally composed of organisms that are less severely impacted by disturbance (e.g. compared with sensitive sessile benthic organisms). Therefore a moderate severity score was assigned.
Impact Risk = Severity * Binned Exposure = **Moderately High**		
Persistence	**Low**	The pressure of bottom disturbance disappears from the environment as soon as the tow has ended, resulting in a low persistence score.
Resilience	**High**	Recovery time from scallop drags varies greatly between habitat types, and is influenced by several variables. Typically, geological features in soft sediment return to their original state more quickly than those made of hard sediment (i.e. mud burrows vs. boulder crevices; Grabowski et al. 2014). However, sediments

		with higher concentrations of mud are more stable and may take longer to recover than other types of soft sediment that are less consolidated, such as clean sand (Dernie et al. 2003; Rice 2006; Clark and Koslow 2007). Similarly, environments exposed to frequent tides or currents typically possess ecological communities that recover more quickly from disturbance than fauna that inhabit areas with little natural disturbance (Brylinsky et al. 1994; Schratzberger and Warick 1998). The hypothesized effects of climate change on the ecological function of the benthic community include many possible individual-level impacts (e.g. change in shell calcification rate and distributional shifts) which may lead to ecosystem-level impacts such as changes in community structure and benthic-pelagic coupling (ICES 2009; Birchenough et al. 2015; Bianchi et al. 2021). However, local conditions are an important consideration in overall outcome to ecological function, which will manifest differently across areas. For example, Weinert et al. (2022) projected a consistent overall rate of a key benthic ecosystem process (i.e. bioturbation) in the southern North Sea despite species-level changes under different climate scenarios. Additionally, McGarrigle and Hunt (2024) demonstrated that abiotic water conditions were not influential on total bivalve abundance in the Bay of Fundy, while they were influential in the Southern Gulf of St. Lawrence. Differences in response also exist amongst a community (Kirby et al. 2007; Widdicombe et al. 2007) and it is suggested that species diversity can help mitigate the effects of disturbance (Goldbod and Solan 2009; Weinert et al. 2022). Overall, though more investigation is needed on the impacts of climate change to the infaunal community in particular, it is not expected to outweigh the overall tendency of the other Resilience factors towards a High score. Though the total impact from the introduction and establishment of an invasive species is difficult to predict, effects are known to occur through competition for resources (e.g. space) and the growth of *D. vexillum* colonies is known to transform heterogenous habitat into homogenous habitat (Lengyel et al.

		2009). Its presence is negatively correlated with sessile species, such as hydroids and scallops, as it can overgrow these organisms and turn otherwise suitable habitat into unsuitable habitat for recruits (Lengyel et al. 2009; Kaplan et al. 2017). *D. vexillum* establishes on hard substrates and though Zone 3 may contain gravel and shells, it is expected that the majority of the MPA is not a suitable substrate type to support establishment. Therefore, the possible establishment of non-indigenous species is noted here for its potential to impact Resilience, though it is not expected to outweigh the overall tendency of the other infaunal community habitat Resilience factors towards a High score. As the Musquash Estuary is a high energy environment with a seabed primarily consisting of a sediment mixture dominated by silt and clay with some sand (Figure 2; DFO 2017a), recovery will likely be in the order of weeks to months rather than years (Brylinsky et al. 1994; Watling et al. 2001; DFO 2006; Grabowski et al. 2014; Sciberras et al. 2018). Following the guidance in Knight et al. (2015), a full recovery within two years is considered high resilience.
Recovery Lag = Persistence * Resilience = **Low**		
Overall Risk = Impact Risk * Recovery Lag = **Moderate**		
Uncertainty	**Moderate**	Small infauna-dominated communities are made up of both opportunistic, short lived species as well as more sensitive species that may not recover as quickly (Sciberras et al. 2018). The primary species of polychaetes and bivalves in Musquash MPA have not been studied directly to inform how they respond to disturbance. However, research on nearby communities within the Minas Basin in the Bay of Fundy (Brylinsky et al. 1994) and northern Gulf of Maine (Watling et al. 2001) would suggest that impacts would be minimal or the recovery would likely take place within the year.

4.0 RECOMENDATIONS FOR FURTHER RESEARCH

Future reviews would benefit from more information on the species composition and detailed habitat characterization of Zone 3 of Musquash MPA. Past attempts at conducting biodiversity research in Zone 3 using methodologies such as SCUBA and dropcam surveys have been largely unsuccessful due to challenges presented by the sampling environment (e.g. strong currents and high turbidity). However, it may be worth exploring whether advancements in camera equipment technology may provide an opportunity for visual surveys in this Zone. Other sampling methods that are currently being employed in the MPA and offer promise include: eDNA, Autonomous Underwater Vehicle (AUV) surveys, and an enhanced Ocean Tracking Network (OTN) acoustic receiver array. Another possibility is to encourage existing scallop drag fishing in Zone 3 of the Musquash MPA to carry observers to monitor and collect information on bycatch, and therefore, community composition. Lastly, future efforts should focus on tracking the spread of *D. vexillum* in the Bay of Fundy.

5.0 SUMMARY

Available literature suggests that benthic communities composed of small and short-lived marine species and habitats in high-energy environments, like those found in Zone 3 of Musquash MPA, are generally less affected and recover quickly from the effects of mobile bottom contact fishing gear. In addition, at the current level of dragging, the volume of groundfish and invertebrate bycatch is not expected to reduce the ecosystem function of either ecosystem component within the MPA. Although this review looked at commercial fisheries, food, social and ceremonial fisheries associated with Aboriginal and Treaty Rights should be evaluated under the Protection Standard on a case-by-case basis. As the overall risk of current levels of commercial scallop dragging is deemed *May be tolerable*, the overall risk of the currently smaller food, social and ceremonial drag fishery is expected to be the same.

In conclusion, based on our present knowledge of the ecosystem, the risk of scallop dragging in Zone 3—at its current frequency and intensity—may be tolerable for Musquash MPA's conservation objectives as designated under the *Oceans Act* section 35(1).

Summary Table

Table 15. Summary Of Overall Risk Scores To Conservation Priorities By Pressure. All Pressures Are Directly Associated With The Activity Of The Scallop Drag Fishery.

Conservation priority	Pressure	Overall risk
Winter Flounder	Bycatch	May be tolerable
Atlantic Rock Crab	Bycatch	May be tolerable
Infaunal Community Habitat	Bottom Disturbance/ Change in Habitat	May be tolerable

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