EXHIBIT 48

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NSARB-2023-001-AFF-006

2023

NSARB 2023-001

Nova Scotia Aquaculture Review Board

Between:

KELLY COVE SALMON LTD.

APPLICANT

- and -

MINISTER OF NOVA SCOTIA DEPARTMENT OF FISHERIES AND AQUACULTURE

PARTY

- and -

KWILMU'KW MAW-KLUSUAQN NEGOTIATION OFFICE, QUEENS RECREATIONAL BOATING ASSOCIATION, 23 FISHERMEN OF LIVERPOOL BAY, REGION OF QUEENS MUNICIPALITY, and PROTECT LIVERPOOL BAY ASSOCIATION.

INTERVENORS

Affidavit of Peter Cranford
Sworn on January 17, 2024

I, Peter Cranford, of [redacted] St. Andrews, in the Province of New Brunswick affirm as follows:

1. I have personal knowledge of the evidence affirmed in this Affidavit except where otherwise stated to be based on information and belief.

2. I state, in this Affidavit, the source of any information that is not based on my own personal knowledge, and I state my belief of the source.

3. I have been asked to review and provide expert opinion regarding the impacts of the proposed Kelly Cove Salmon Ltd. aquaculture boundary amendment and lease application for locations in Liverpool Bay, Queen's County enumerated as AQ#1205x, AQ#1432, AQ#1433 (the "Application"), on the oceanographic and biophysical characteristics of the public waters surrounding the proposed aquaculture operation, including without limitation on fish habitat and fish prey species, marine plant and aquatic life and habitat, ecological and environmental issues arising or potentially arising

[redacted]

in connection with the Application on behalf of the Region of Queens Municipality ("RQM") .

4. I have authored a report detailing my analysis and conclusions regarding the impacts of the proposal set out in the Application, on Liverpool Bay ("the Report"), attached hereto as **Exhibit "A"**.

5. My qualifications as a subject matter expert on the oceanographic and biophysical characteristics of ocean waters, including the impact of these characteristics and/or changes to these characteristics on fish habitat and fish prey species, ecology and environment are set out in my Curriculum Vitae attached to my Report at page 25.

6. Based on my education and experience my areas of expertise are aquaculture environment interactions, environmental monitoring and management, benthic ecology, biological oceanography and environmental sensing.

7. The Report attached to this affidavit as Exhibit "A" represents my professional opinion with respect to the impacts of the proposed aquaculture operation as set out in the Application, on Liverpool Bay.

SWORN TO at St. Andrews, Province of New Brunswick, this 18th day of January, 2024, before me:

[redacted]

David A. Bartlett K.C.
Notary Public
Province of New Brunswick

DAVID A. BARTLETT, K.C.
NOTARY PUBLIC
NEW BRUNSWICK

[redacted]

Peter Cranford

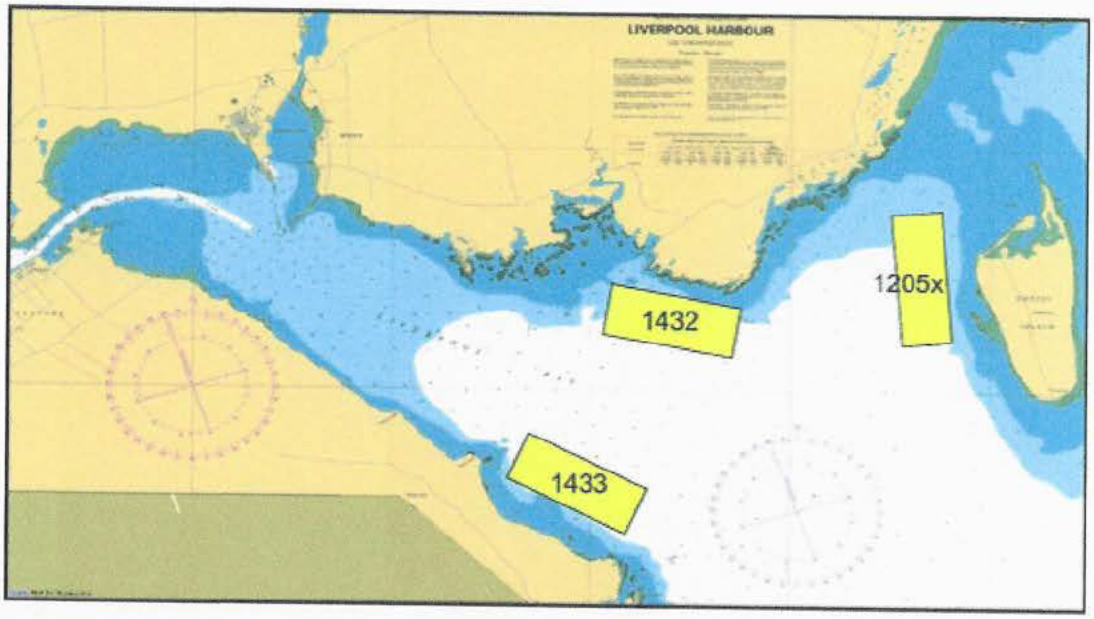
2023 NSUARB 2023-001

This is Exhibit "A" referred to in the
Affidavit of Peter Cranford sworn to
before me this 10th day of January 2024

[redacted]

David A. Bartlett, K.C.
Notary Public Province of New Brunswick

DAVID A. BARTLETT, K.C.
NOTARY PUBLIC
NEW BRUNSWICK



Potential Effects of Solid Organic Wastes on Benthic Habitat and Macrofauna Communities from Kelly Cove Salmon Ltd. Marine Aquaculture Lease Locations in Liverpool Bay (AQ#1205x, AQ#1432, AQ#1433)

Report to the Nova Scotia Aquaculture Review Board

Peter J. Cranford, B.Sc., Ph.D.

17 January 2024

Emeritus Marine

[redacted], St. Andrews, New Brunswick, E5B 1E2

Contents

1. Statement of Substance

Information is presented herein that is relevant to decisions related to salmon aquaculture lease locations in Liverpool Bay (AQ#1205x, AQ#1432, AQ#1433) proposed by Kelly Cove Salmon Ltd. Organic enrichment of the seabed is a key environmental concern across the open water marine aquaculture industry. The known effects on benthic (seabed) habitat, species, communities, fisheries, and ecosystem function are relevant to any decision related to marine aquaculture siting. There is general agreement among stakeholders that the aquaculture regulatory framework for Nova Scotia should be grounded on science. Aquaculture regulatory research in Canada is meant to support the growth of a sustainable aquaculture sector and increase public confidence in the industry. Recent research has raised significant concerns about the ability of existing federal and provincial prescribed methods to effectively predict, monitor and mitigate organic enrichment effects on benthic communities that support fisheries. Relevant research is summarized with the objective of informing the Nova Scotia Aquaculture Review Panel of current regulatory deficiencies that should be rectified, based on the best available science, prior to approving this large-scale industry expansion.

2. Introduction

Solid organic matter contained in waste salmon feed and feces fall under the category of BOD (biological oxygen demanding) matter, which is classed as a deleterious substance under section 34(1) of the *Fisheries Act* (Government of Canada, 1985). Consequently, national, and provincial aquaculture regulations focus on minimizing organic enrichment impacts on benthic habitat and invertebrate communities (Government of Canada 2018 and 2023, Nova Scotia 2021a and 2021b).

The response of benthic organisms and sediments to the deposition of solid organic wastes from open water aquaculture, including waste feed and/or faeces, is well known. Although these effluents have little direct environmental impact beyond some localized smothering of non-mobile organisms, the chemical transformation of organic matter through microbial degradation processes can seriously affect benthic habitats and communities beneath and adjacent to salmon farms. If these impacts are of sufficient magnitude and spatial scale, they risk altering ecosystem function and fisheries production. For these reasons, solid organic waste introduced into aquatic and marine systems is considered a deleterious substance in Canada, requiring management intervention.

A broad range of basic and applied research projects conducted over several decades has led to the development and broad acceptance of the following science conclusions (ASC 2022):

1. The deposition and enrichment of sediments of all types with solid organic matter wastes stimulates aerobic decomposition processes, resulting in an increase in the biological oxygen demand (BOD) of sediments. Organic matter inputs may initially increase macrofaunal biodiversity around farms through the provision of an additional food resource. However, if sediment BOD increases beyond the capacity of local physical processes to resupply oxygen to the seabed from the water column, sediment hypoxic to anoxic conditions will develop.

2. In the absence of oxygen, microbes continue to decompose the excess organic matter through several anaerobic respiration processes that occur in a characteristic sequence. Quantitatively the most important of these processes in marine systems is sulfate reduction in which sulphate is reduced to sulfide gases (H_2S, SH^- and S^{2-}; referred to as total free sulfide) that dissolve in sediment porewaters. These end-products of decomposition create a chemical oxygen demand in sediments that further exacerbates negative effects on benthic fauna from the elevated BOD.

3. Free sulfides are highly toxic to most marine species and the toxicity effect is compounded by low oxygen levels. The production of free sulfides during organic matter decomposition is known to alter benthic macrofauna communities and cause associated changes in ecosystem function.

4. Structural changes in benthic macrofaunal communities resulting from a progressive increase in organic enrichment are well known. Macrofauna species exhibit different sensitivities to hypoxic and sulfidic conditions. Moderate organic enrichment can stimulate the colonization of tolerant species, but additional oxygen depletion and free sulfide accumulation cause a decrease in abundance, biodiversity, and biomass. Even highly tolerant species eventually decline with increasing free sulfide concentrations.

5. Ecosystem function is defined by the multitude of processes that control the flow and cycling of materials to system components. The introduction and decomposition of excess organic matter affects energy/carbon supply to consumers and thereby affects biotic communities and food chains. Depending on the magnitude and spatial extent of effects on ecosystem components, organic wastes may significantly disrupt natural ecosystem function.

6. Numerical modelling has a proven capacity to accurately simulate the major physical processes that control the deposition rate and spatial distribution of deposited organic matter across a wide range of farm environmental settings.

7. The prediction of biological impacts related to any given waste deposition rate is highly complex owing to the wide range of site-specific physical, geochemical, and biological processes that collectively control the capacity of the environment to assimilate organic waste inputs. Recent studies have shown that carbon deposition rates causing significant benthic community impacts can vary by several orders of magnitude depending on the farm location. This environmental variability causes considerable uncertainty in model predictions of benthic impacts from aquaculture.

The literature on benthic community responses to organic enrichment is extensive and the general conclusion is that once the natural capacity of the environment to assimilate waste inputs through physical waste dispersal and aerobic degradation processes is exceeded, further deposition of organic matter triggers a succession of habitat and community alterations that are remarkably consistent regardless of biogeographic location. Figure 1 illustrates the classic benthic community response to increasing organic enrichment. This organic enrichment impact gradient has been validated through extensive research in all benthic habitats including those supporting finfish and aquaculture farms (e.g. Hargrave et al., 2008; Keeley et.al., 2012; Cranford et al. 2020).

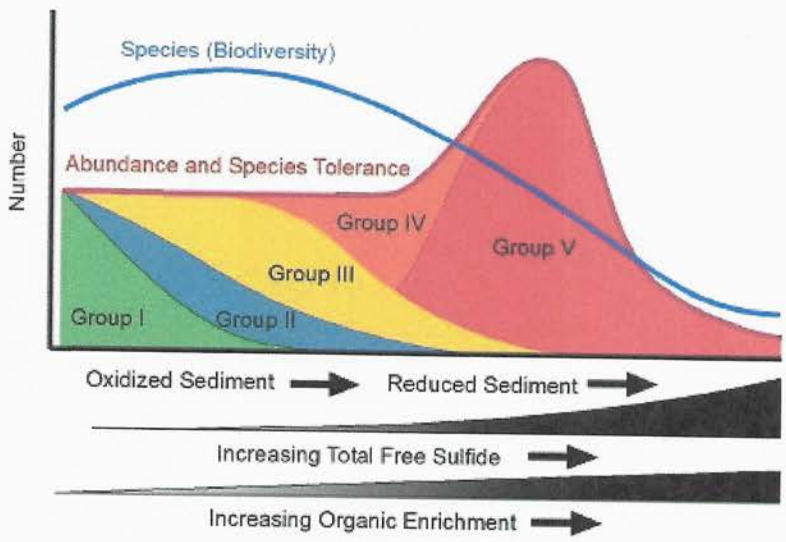


Figure 1. *Generalized patterns of benthic habitat and invertebrate community alterations in relation to the degree of organic enrichment (after Nilsson and Rosenberg (2000) and Borja et al. (2000)). Benthic invertebrate species Groups I to V are defined based on their sensitivity and tolerance to organically enrichment sediments.*

3. Benthic Environmental Monitoring of Marine Salmon Aquaculture

Environmental management frameworks consist of a linked series of activities that identify, critically evaluate, predict, and address potential environmental threats. Given that environmental impact predictions are always subject to uncertainty, owing to unforeseen factors and gaps in knowledge, effective monitoring programs are essential to ensuring that actual effects do not exceed predictions and regulatory objectives.

A multitude of metrics are available to quantify the biological effects of organic enrichment on seabed invertebrates and considerable information on this topic is available in the scientific literature (e.g., Hargrave et al. 2008, Cranford et al. 2020 and 2022). Several sediment chemical measurements are known to be closely associated with the biological effects of organic enrichment on the benthic macrofauna community. Adverse effects of organic matter enrichment on benthic macroinfauna largely result from the generation of toxic sulfidic conditions in surface sediments during microbial decomposition of organic matter. Total free sulfide (hydrogen sulfide, bisulfide, and sulfide) measurements have been adopted in Canada and elsewhere as a practical tool for monitoring aquaculture impacts (Hargrave et al., 2008). The oxidation-reduction potential (redox or Eh_{NHE}) of surficial sediments provides confirmation that total free sulfide is the major end-product of organic matter decomposition and serves as a quality control for sulfide measurements.

3.1 Aquaculture Monitoring Regulations

The national *Aquaculture Activities Regulations* (Section 10(1)) describe sediment monitoring and restocking requirements for Nova Scotia aquaculture facilities operated under an aquaculture licence. Sediment samples are required to be collected between July 1 and October 31, close to peak feeding, and analysed for total free sulfide and redox in the manner specified in the *Monitoring Standard*. The timing of sampling is intended to correspond to the period when sediment organic loading from waste feed and faeces may have the greatest benthic impact. In contrast, international aquaculture monitoring programs generally require sampling to take place during the period of peak biomass (reviewed in ASC 2022), which occurs around the time of fish harvesting. The number of sampling stations required is specified based on the maximum number of fish within the cage array. However, additional samples must be taken if the mean free sulfide concentration exceeds 3000 µM. The operator is not permitted to restock the facility if concentrations continue to exceed this threshold.

The Nova Scotia aquaculture environmental monitoring program framework objective is to maintain Oxic sediment conditions in which the macrofaunal assemblage contains a wide array of infauna and epifauna (NSDFA 2021a). This corresponds with free sulfide levels less than 1500 µM and redox (Eh_{NHE}) >-50 mV (Table 1). Level I monitoring is required annually on all active finfish sites with sampling required between July 1 and October 31. If oxic sediment conditions cannot be maintained within a lease, operators must comply with a regulatory process that identifies steps required to improve onsite environmental conditions. Additional monitoring (Level II) is required when the results of annual Level I monitoring classify the lease as Hypoxic B or Anoxic (Table 1). Level II monitoring adds additional sampling stations and is used to better define the outer limits of the affected area. The number of monitoring stations for Level I sediment collection, and the timing of sampling, are the same as specified by the federal legislation but must also include stations previously shown to exceed 3000 µM sulfide.

Table 1. *Nova Scotia sediment environmental quality classification definitions (NSDFA, 2021a).*

Indicator	**Oxic**	**Hypoxic A**	**Hypoxic B**	**Anoxic**
Free Sulfide (µM)	<1500	1500 to 2999	3000 - 5999	≥6000
Redox (Eh_{NHE}; mV)	>-50	-50 to -100	-100 to -150	<-150
Macrofauna	Wide array of infauna and epifauna	Mixed group of mostly small infauna		Small infauna only

3.2 Environmental Performance at Liverpool Lease #1205

The existing Liverpool farm site consists of fourteen salmon cages near Coffin Island. Annual benthic monitoring has been conducted since 2009 and the data are reported on the Nova Scotia Open Data Portal. For this size farm, five sampling stations are required (not including reference stations) with three sediment samples collected at each station. The reported number of stations sampled annually between 2009 and 2022 ranged from one to six. Although details on the production cycle employed during most of this period were not available at the time this submission was prepared, the farm did employ a 28-month grow out period between May 2020 and August 2022 followed by an 8-month fallow period (NSDFA, personal communication). Average surficial sediment sulfide and redox conditions beside Lease 1205 detected Hypoxic and Anoxic conditions at several sampling stations, with 10 sites exceeding the Oxic threshold for free sulfide (1500 μM) and 14 stations exceeded redox values < -50 mV. All reference sites showed Oxic conditions.

The production plan described in the lease application (Exhibit 5, p. 79-80) is different than the previous fish production cycle and states that the pens are to be stocked in May and harvested 22 months later in February, followed by a 3-month fallow period. Provincial regulations state that benthic monitoring must take place between July 1 and October 31, meaning that sampling would occur four to seven months before the period of peak biomass. The effects of sediment organic loading on the seabed community have been shown to be greatest prior to harvesting, regardless of the time of peak feeding (e.g. Cranford et al. 2022) (Fig. 3).

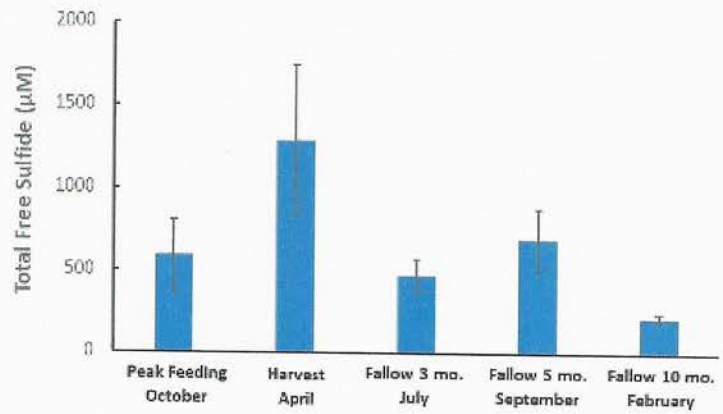


Figure 2. *Variation in total free sulfide concentrations (average ± standard error), measured using the regulatory method, beside salmon pens (0 m distance) at a high-energy farm in Passamaquoddy Bay, NB, during the production and fallowing period (after Cranford et al. 2022).*

An explanation for the time-lag between maximum waste deposition during peak feeding and the appearance of elevated sulfide concentrations several months later is that it takes time for sediment microbes to degrade the organic matter, to fully deplete sediment oxidants, and for free sulfide to accumulate to the maximum levels that impact the benthic community. Bravo and Grant (2018) stated that the waste exposure history *"...needs to be considered in management strategies of finfish aquaculture sites, as it effects the transition to suboxic conditions and recovery time of fallowed sediments."* Chang et al. (2014) reported that measured benthic impacts at salmon farms in New Brunswick were best predicted considering at least a three-month period of feeding rates. The geographic extent and magnitude of benthic impacts from a 22-month grow-out cycle is likely to be underestimated by conducting monitoring activities several months prior to harvesting, as is currently required by federal and provincial regulations. These regulations were established at a time when salmon harvesting generally occurred in the fall.

4. Benthic Recovery After a Three-Month Fallowing Period

Free sulfide data collected beside cages at Lease 1205 appears to show that periods of high sulfide concentrations were followed by recovery to Oxic conditions after fallowing. It is unclear if any additional sampling or mitigation measures were taken to achieve this result. The ability of benthic environments to recover from organic enrichment from salmon farms has been a matter of considerable debate within the research community globally (Bannister et al. 2014). It has been concluded that at energetic coastal locations with moderate impact levels, a 3-month fallowing period can result in recovery of benthic sulfide and redox conditions (Bannister et al. 2014, Cranford et al. 2022 (see Fig. 2 above), Hale et al., 2023). Although sediment sulfide and redox conditions can quickly recover, fallowing periods as long as 3 to 4 years are needed for the structure, abundance, and diversity of benthic infauna to recover to pre-farming conditions (Johannessen et al. 1994, Brooks et al. 2004, Macleod et al. 2006, 2007, Lin & Bailey-Brock 2008, Aguado-Giménez et al. 2012, Bannister et al., 2014, Keeley et al. 2014, Hale et al., 2023). These studies confirm that the 3-month fallowing period is not sufficient to allow recovery of the benthic macrofauna community to Oxic conditions, which is the Nova Scotia aquaculture regulatory objective.

5. Reliability of Total Free Sulfide Monitoring

Both the federal *Monitoring Standard* for sediment monitoring and the Nova Scotia Standard Operating Procedure for monitoring marine aquaculture facilities require surficial sediment samples (0 to 2 cm depth) to be analysed for total free sulfide using a silver/sulfide ion-selective electrode (ISE).

The accurate measurement of free sulfide in water and sediments has been the topic of research for a century. The prescribed ISE method was adapted for measuring free sulfides in 5-mL sediment samples and is relatively simple and inexpensive to perform compared with previously available standard methods (Hargrave et al. 2008). However, numerous users have stated that the ISE method is unreliable. For example, early studies at aquaculture farms led Brooks and Mahnken (2003) to state that *"...experience in British Columbia clearly points out that subtle differences in protocols and/or techniques can result in significant differences in results"*.

The ISE analysis protocol is conducted on sediment/porewater slurries with the expectation that the presence of particulate sulfides would not interfere with the analysis of free sulfide, which is dissolved in sediment porewater. Exposure of sediment with high concentrations of particulate sulfides to alkaline conditions will increase apparent free sulfide concentrations if they are solubilized (Hargrave, 2008). The ISE protocol requires highly alkaline conditions (pH = 13) and ISE measurement errors related to the mobility of mineral sulfides were first documented by Brown et al. (2011) who concluded that

> *"...the accepted [ISE] protocol can lead to significant bias of free sulfide measurements, with orders of magnitude higher concentration detected in the buffered sediment-porewater slurry than in porewater samples isolated and analysed separately."*

In addition to errors from dissolution of particulate sulfides, Brodecka-Goluch et al. (2018) investigated different free sulfide analysis procedures and reported that samples exposed to the atmosphere lost one third of the free sulfide. Free sulfide is highly reactive, and rapidly de-gasses and oxidizes in the presence of oxygen. DFO held a national science peer review meeting (May 10-12, 2022) to evaluate the effect of sample storage on the accuracy of total free sulfide measurements. The ISE method was acknowledged for its lack of robustness (DFO 2023), and the meeting concluded;

> *"Multiple factors increase the error and variability of results generated using the ISE method. These include differences in procedures (e.g., sampling, sample storage, and analysis protocols), as well as potential lack of consistency in the implementation by analysts and laboratories across the country, resulting in varying levels of differences in measured sulfide concentrations."*

This DFO science advisory report stated that,

> *"...the ISE method has the ability to resolve differences between low (e.g., hundreds μM, i.e., oxic) and high (e.g., thousands μM, i.e., anoxic) sulfide concentrations characteristic of enriched sediments."*

The advisory process did not consider the importance of particulate sulfide contamination as a major source of errors, but reached the above conclusions based solely of sample storage issues. ISE sulfide measurements are highly inaccurate and cannot be used to accurately quantify the four Oxic status groups (Table 1) used to assess and regulate the magnitude of organic enrichment effects on benthic communities. Consequently, the results of current aquaculture benthic monitoring programs mandated by federal and provincial regulations are largely uninterpretable.

In response to science and industry concerns, DFO Aquaculture Management made a request in 2014 to DFO Aquaculture Science to investigate, develop and validate accurate alternatives to the ISE method. Funding was directed for four science projects between 2014 and 2019 to scientists at the Bedford Institute of Oceanography (Table 2). Two alternative methods were subsequently developed; a microplate adaptation of the methylene blue method and a simplified UV spectrophotometric method (Cranford et al. 2017 and 2020). The UV method measures free sulfide directly without the need to convert it to some other detectable form and can rapidly quantify a wide range of concentrations in the field at low cost. These methods were extensively tested at aquaculture sites in Nova Scotia, New Brunswick, Prince Edward Island, British Columbia, New Zealand and Norway. An intercalibration exercise confirmed the poor accuracy of the ISE method, relative to the alternative methods, even when the analysis was performed immediately onboard the sampling vessel (Fig. 3).

Table 2. *Science projects under the DFO Program for Aquaculture Regulatory Research (PARR) to investigate problem with the ISE sulfide method, to develop and validate alternative methods, and recommend a revised benthic impact classification system.*

PARR # Leader	Dates	Title	Funding (x1000)	Publication
2014-M-05 Peter Cranford	2014 - 2015	Development and validation of alternative detection methods for performance indicators of the oxic state of bottom sediments	\$284	Cranford et al. 2017
2014-M-06 Peter Cranford	2014 - 2017	Assimilation capacity of organic matter from salmon aquaculture (ACOM): Improving model predictions of benthic impacts	\$603	Cranford et al. 2022
2016-M-07 Peter Cranford	2016 - 2017	Alternative detection methods for performance indicators of the oxic state of bottom sediments: indicator inter-calibration and thresholds	\$24	Cranford et al. 2020, 2022, 2024
2016-M-08 Lindsay Brager	2016 - 2019	Robustness of alternative benthic impact indicators: Quantification of spatial and temporal variability of alternative methods, and application at aquaculture sites across different farm and environmental conditions	\$552	Cranford et al. 2022

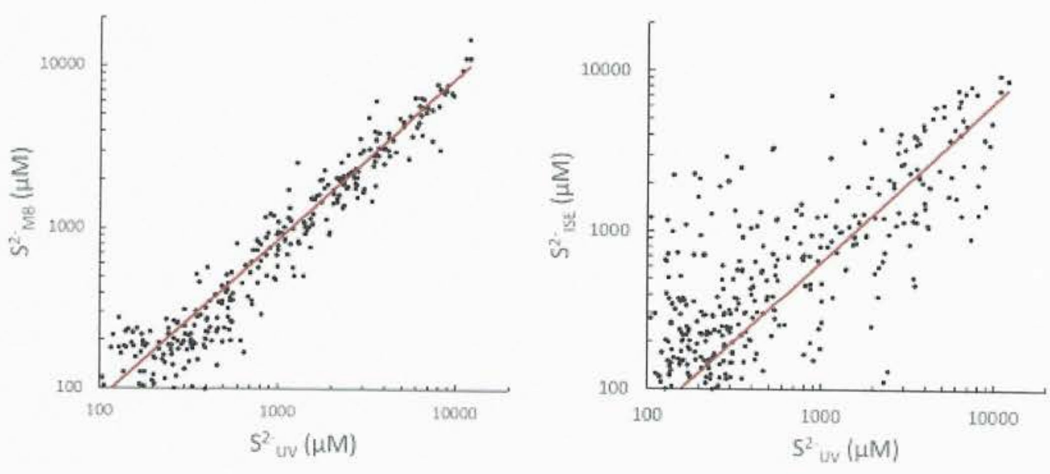


Figure 3. *Comparison of average total free sulfide concentrations in grab or core samples from aquaculture farms measured by UV spectrophotometry (S^{-2}_{UV}), ion-selective electrode potentiometry (S^{-2}_{ISE}), and methylene blue colorimetry (S^{-2}_{MB}). From Cranford (2022).*

As noted in Section 3 (above), redox measurements are used as a quality control measure for sulfide measurements. The formal redox potential for sulfate reduction to sulfide is -220 mV but is pH dependent and ranges between -160 and -220 in the pH region of 6-8. Figure 4 shows that the relationship between redox and free sulfide concentrations measured at aquaculture farms using the simplified UV method conforms with the expectation that redox will decline until sulfate reduction becomes the dominant organic matter degradation process. After this occurs, redox stabilizes and indicates the dominance of free sulfide production (sulfite reduction) in sediments during organic matter degradation. The relationship in Figure 4 is in contrast with the lack of any interpretable relationship between redox potential and free sulfide measured using the ISE method (Fig. 4). The relationship shown in Figure 4 is a requirement for redox to be used to confirm sulfide measurements, as is intended in the provincial and national monitoring standards. Significant errors generated by ISE measurements causes the poor relationship with redox.

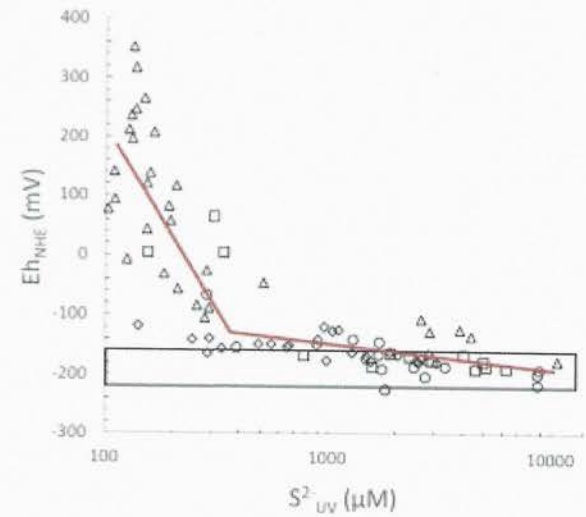


Figure 4. *Relationship between total free sulfide, measured by the simplified UV spectrophotometric method (S^{2-}_{UV}), and redox potential (Eh_{NHE}) in surficial sediments collected at multiple aquaculture farms. The red line is the best fit by linear regression. The box shows the range of redox values indicating sulfate reduction.*

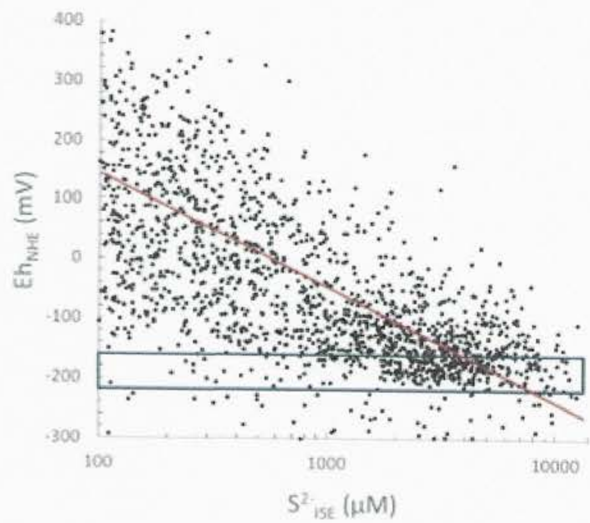


Figure 4. *Relationship between total free sulfide measured by the ion-selective electrode method (S^{2-}_{ISE}), and redox potential (Eh_{NHE}) in surficial sediments collected at all Nova Scotia farm sites (NSDFA Open Data Portal). The red line is the best fit by linear regression. The box shows the range of redox values indicating sulfate reduction.*

The inconvenient conclusion from these studies is that historical free sulfide monitoring data collected at open water fish farms in Canada, including Lease 1205, have not provided a reliable indication of benthic impacts from solid organic waste deposition or the environmental quality status of the seabed habitat. Although DFO managers have long known and confirmed that major problems exist with current sulfide monitoring practices, and have identified science solutions, the national aquaculture *Monitoring Standard* has not been changed to rectify the issue. Canadian scientists have been vocal in stating that DFO's aquaculture policies are not always supported by the best available science, creating socio-economic uncertainty (Godwin et al. 2023).

6. Benthic Environmental Quality Status Classification

The sediment environmental quality classification system employed in Nova Scotia (Table 1) is inherently linked to ISE-based free sulfide measurements (Hargrave et al. 2008) and the system needs to be corrected to account for erroneous measurements. The revised Ecological Quality Status (EQS) classification system shown in Figure 6 was scientifically validated based on measured relationships between free sulfide concentrations (UV method) and multiple benthic community response indicators measured at numerous aquaculture sites across Canada (Cranford et al. 2020). The five EQS sediment classifications (High, Good, Moderate, Poor, and Bad) were calibrated to correspond with the five 'Oxic system' classifications (Oxic A and B, Hypoxic A and B, and Anoxic). Threshold free sulfide values separating each EQS classification were determined for a wide range of benthic community impact indicators employed globally to monitor the effects of aquaculture organic enrichment on the seabed invertebrate community (Fig. 6).

Surficial sediments classified as Hypoxic B by ISE analysis (3000 to 6000 μM free sulfide) are equivalent to a 'Poor' EQS classification (500 to 1100 μM free sulfide) measured by UV spectrophotometry. The Hypoxic B and Poor habitat classifications correspond with the same 75 to 85% reduction in the number of benthic invertebrate species (species richness (S%) in Fig. 6). Both classifications represent the same unacceptable environmental conditions defined in the *Aquaculture Activities Regulations* and the Nova Scotia aquaculture environmental monitoring program framework. Cranford et al. (2020) compared sediment organic enrichment classifications based on the current (Oxic) and revised (EQS) seabed quality classification systems and reported that 25% of the sediment samples collected in that study were classified as Poor EQS compared with just 1% of samples assessed as Hypoxic B. That study reached the following conclusion:

> *"The existing [Oxic] site classification system apparently exhibits a bias towards underestimating the spatial extent and severity of impacts from aquaculture organic enrichment."*

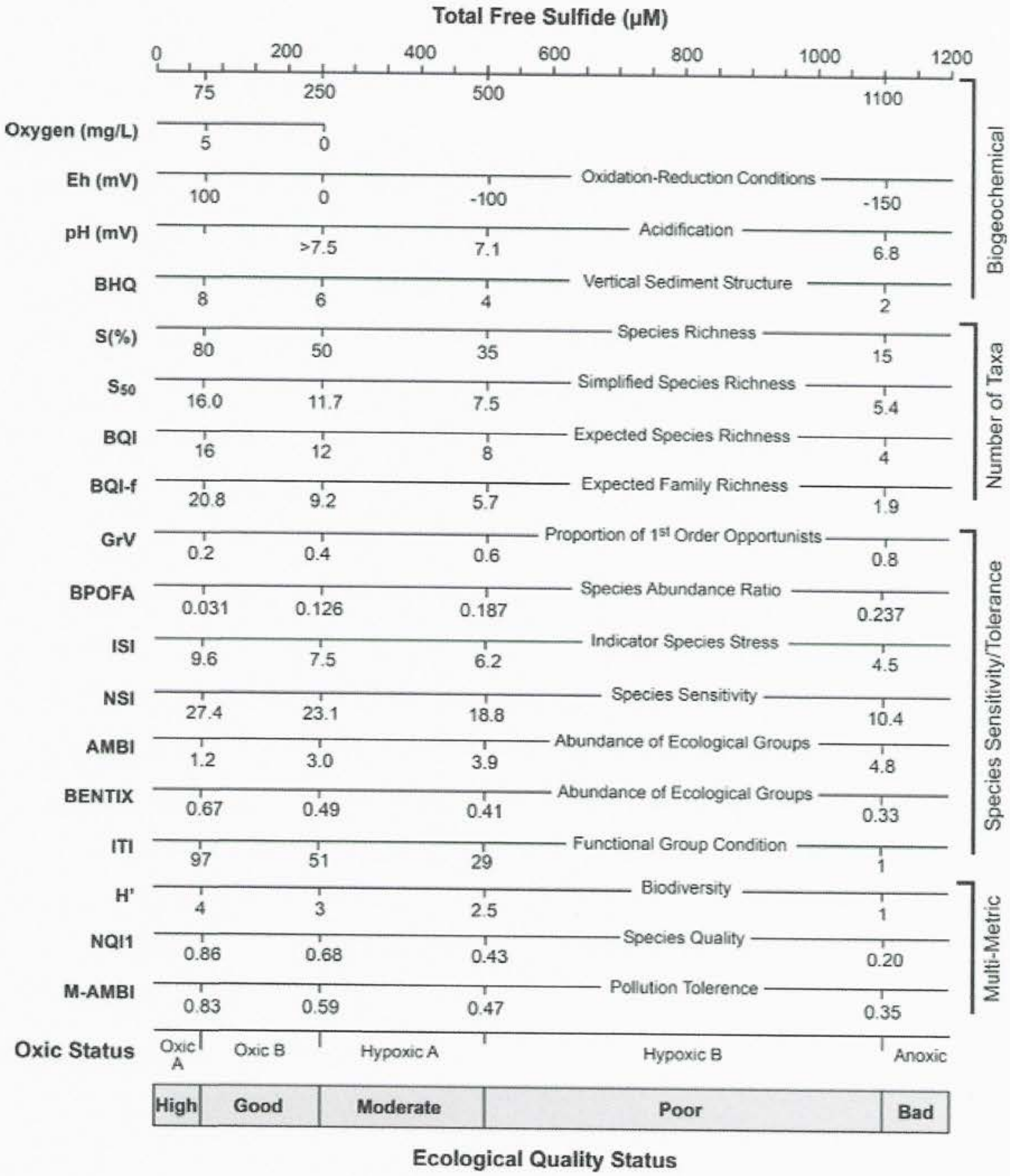


Figure 6. *Ecological quality and Oxic Status classifications for benthic organic enrichment corresponding with geochemical and biotic indicator values (from Cranford et al. 2022). The Hypoxic B, Anoxic, Poor and Bad classifications indicate benthic conditions where restocking is generally not permitted by Canadian and international aquaculture monitoring standards.*

7. Potential Effects of Benthic Organic Enrichment on Fisheries

There is limited knowledge and understanding on the influence that solid organic wastes have on fisheries within the same regional area of salmonid farms. Opposing hypotheses assert that waste feed and feces (1) act as a food subsidy/supplement to wild fish diets, and (2) decrease the availability of benthic invertebrate prey through the effects of increased sediment toxicity. The following analysis considers the potential impact of the latter hypothesis on commercial fish species. This analysis is based on (1) reports of demersal and benthic fishery species present in Liverpool Bay, (2) published information of their corresponding invertebrate prey species, (3) published knowledge on the sensitivity/tolerance of these prey species to organic enrichment, and (4) the area of seabed in which these forage species are predicted to be impacted by organic wastes.

The DFO science review of the proposed Liverpool Bay aquaculture lease sites (DFO 2022) identified active commercial groundfish fishery species in the region to include haddock, Atlantic cod (located within the 4X5Y Critical zone), Atlantic halibut, yellowtail flounder, American plaice, and winter flounder. Lobster is the largest commercial invertebrate fishery although clam, crab, mussels, sea urchins, and welk are present. A requirement under the *Aquaculture Activities Regulations* Paragraph 8 (1)(b) is that new finfish aquaculture sites conduct a survey that identifies the fish on the seabed and water column in the lease area. The fish and fish habitat surveys reported in Exhibit 5 (Appendix K) do not identify resident fish but was limited to identifying the presence of benthic invertebrates and algae on the sediment surface.

7.1 Fishery Prey Species Sensitivity to Organic Enrichment

Borja et al. (2000) developed a benthic macrofauna species list that aligns each species to one of five ecological groups based upon their sensitivity/tolerance to pollution stress (Fig. 1). The list currently includes 11,347 species from all seas. The program for assigning invertebrate species to each group is available at no cost (www.ambi.azti.es; AMBI 6.0). The distribution of resident species into these five ecological groups provides a biotic index that corresponds with the Ecological Quality Status classifications shown in Figure 6. The AZTI Marine Biotic Index (AMBI) has been validated for assessing benthic impacts from aquaculture organic enrichment and has been applied at salmonid farms in Canadian waters (Cranford et al. 2020). Table 4 summarizes AMBI index values associated with the five Ecological Quality Status classifications.

Table 4. *Summary of AZTI Marine Biotic Index (AMBI) values describing the sensitivity of different benthic invertebrate groups to pollution and the corresponding habitat requirement (Ecological Quality Status) for each group to survive (after Borja et al., 2000 and Cranford et al. 2020).*

AMBI Value Range	Dominant Ecological Group	Group Description	Ecological Quality Status
0.0 to <1.2	I	Very sensitive	High (Oxic A)
1.2 to <3.0	III	Tolerant	Good (Oxic B)
3.0 to <3.9	IV	2nd Order Opportunist	Moderate (Hypoxic A)
3.9 to <4.8	IV-V	All Opportunists	Poor (Hypoxic B)
≥4.8	V	1st Order Opportunist	Bad (Anoxic)

Benthic macrofauna diets of fishery species on the Scotian shelf were obtained from the scientific literature (Appendix 1 and 2) along with the relative contribution of each prey to fishery diets. These data were entered into the AMBI program to determine the sensitivity/tolerance of the prey (i.e. their ecological group), the AMBI-value of the prey community (sensitivity/tolerance), and their habitat requirement (Ecological Quality Status classification).

The diet of haddock has been reported for the Scotian Shelf by Mahon and Neilson (1987), Smith and Link (2010) and Kenchington et al. (2005) and consists primarily of amphipods, brittlestars and polychaete worms. Kenchington et al. (2005) provided a detailed account of the relative abundance of benthic invertebrate species consumed by adult haddock. AMBI analysis of these data showed that 97.5% of prey species were from Ecological Groups I and II resulting in an AMBI index of 0.860 (Table 5). This AMBI value indicates that haddock prey species are very sensitive to sediment organic enrichment and require 'High' quality benthic habitat (Table 4). Juvenile haddock prey reported by Mahon and Neilson (1987) showed a similar ecological grouping of prey species as the adults that also indicated a requirement for undisturbed benthic habitat (Table 4).

AMBI analysis of prey species consumed by Atlantic cod, yellowtail flounder, American plaice, and winter flounder (Kenchington et al. 2005) indicated that these fisheries also rely on invertebrate prey species from Ecological Groups I and II (Table 5) and require undisturbed benthic conditions with 'High' Ecological Quality Status. The diet of Atlantic halibut consists mainly of other fish species and was not included in the AMBI analysis.

Table 5. *Sensitivity of commercial fisheries prey to aquaculture organic enrichment. The Ecological Group gives the percentage of prey species that are sensitive (Group I) to very tolerant (Group V) to enrichment. The AMBI-value represents the overall sensitivity of the prey community (Table 4). The Ecological Quality Status (EQS) classification describes the seabed habitat required by the prey of each fishery to survive.*

Commercial Fish	Ecological Group					AMBI Value	Habitat EQS
	% I	% II	% III	% IV	% V		
Haddock	45.1	52.5	2.5	0	0	0.860	High (undisturbed)
Haddock (Juvenile)	59.2	40.5	0.3	0	0	0.617	High (undisturbed)
Cod <45 cm	55.7	44.3	0	0	0	0.664	High (undisturbed)
Cod >45 cm	42.0	58.0	0	0	0	0.871	High (undisturbed)
American Plaice	72.8	24.1	0	0	0	0.454	High (undisturbed)
Yellowtail Flounder	98.7	1.3	0	0	0	0.020	High (undisturbed)
Winter Flounder	46.0	48.6	0	0	0	0.892	High (undisturbed)
Lobster	28.6	33.8	37.6	0	0	1.636	Good (slightly disturbed)

7.2 Predicted Zones of Effects from Organic Enrichment

DFO conducted a precautionary first order estimate of benthic exposure zones in Liverpool Bay to assess the potential for impacts on the benthic community and seafloor from the deposit of waste feed and feces (DFO, 2023). The authors stated that the predicted exposure zones (PEZ) "*...are considered sufficient for identifying, albeit at a larger spatial scale, the potential for impacts from the proposed activity*". The PEZ radius for the outer limit of faeces deposition around each of the three lease sites averaged 2.46 km for a total exposure area of approximately 66 km^2. This zone represents a highly precautionary estimate of the impact zone.

The *Aquaculture Activities Regulations* (sec. 8 (1)(a)) require the operator to submit the predicted contours of the footprint of BOD matter deposition. Numerical modelling results reported in Exhibit 6 utilized AquaModel software to estimate the 1 g m^{-2} d^{-1} organic carbon deposition contour. This contour is meant to represent the zone of effect in which benthic impacts are predicted to exceed Oxic status ($\geq$ 1500 µM sulfide). This threshold waste deposition rate has been attributed to research reported in Chamberlain and Stucci (2007) and Hargrave et al. (2008). Later studies show that the association between waste deposition and ecological impacts is more complex than can be encapsulated simply by using the 1 g C m^{-2} d^{-1} threshold. This same deposition rate has been shown to result in Hypoxic B to Anoxic conditions at some farms (e.g., Keeley et al. 2013). More recent studies have reported that the critical carbon loading rate can vary by at least an order of magnitude from 0.2 to 10 g C m^{-2} d^{-1} depending on the farm location (Bravo and Grant 2018, Hargrave et al. 2022, Fox et al. 2023). Chang et al. (2014) compared model predictions of waste deposition with measured sulfide levels at six salmon farms and found a lack of consistent agreement between deposition predictions and the actual impact indicated by free sulfide measurements. A comprehensive depositional modelling and environmental monitoring study by Fox et al. (2023) at Cooke Aquaculture salmon farms in Scotland over sandy sediments concluded the following;

> *"The present study adds to the body of literature where particle-based models have been applied to simulate the benthic footprint of fish farm waste, but where predictions have failed to match either direct and/or indirect observations".*

Hypoxic A sediment conditions represent the transition zone from what is unacceptable (i.e., restocking not permitted if free sulfide $\geq$3000 µM) and Oxic B conditions (<1500 µM) (Table 1). Hypoxic A status is defined in part by the loss of 50 to 65% of benthic macroinfauna species, relative to reference sites (Fig. 6), including all the fisheries forage species listed in Appendix 1 and 2. The spatial extent of Hypoxic A benthic status is therefore important, but is not monitored in Nova Scotia despite the provincial objective to maintain Oxic sediment conditions. All monitoring is conducted at the farm edge (0 m distance) and at distant reference sites. Hypoxic conditions are monitored in British Columbia by sampling away from the cage array with the requirement that Oxic B status be achieved at 30 m distance. This sampling distance was established based on global research on the observed spatial distribution of benthic effects across a wide range of fish farms. The State of Maine Department of Environmental Protection General

Permit for Net Pen Aquaculture requires a similar benthic community status be achieved 35 m from the net pens. Comparable distance thresholds for Hypoxic A benthic conditions exist for farms in Washington State and in other international monitoring frameworks (e.g. ASC 2022).

Extensive benthic macrofauna community monitoring at two salmon farms over sandy sediments detected impacts equivalent to Hypoxic A status ("Moderate" ecological quality; Fig. 6) beyond 100 m from the farm in the predominant current direction (Fox et al. 2023). Sampling in multiple directions around these farms showed that the impact area occurred within an average distance of 30 m. Both farms were half the size of the proposed Liverpool Bay farms and one had slower currents. Assuming that the zone of Hypoxic A effects at the proposed Liverpool Bay leases will be limited to within 30 m from the cage array, an approximation of the total area of Hypoxic A to Anoxic habitat conditions can simply be estimated from the dimensions of the 20-cage arrays (90 x 610 m from Exhibit 6, p 789). The results are shown in Table 6.

Table 6. *Estimates of the area of seabed in which benthic infauna, including commercial fisheries prey, may be impacted by the deposition of solid organic wastes. The calculation assumes that Hypoxic A, B and Anoxic sediments are limited to within 30 m distance from the fish cage array.*

Lease	Lease Area (ha)	Cage Array Area (ha)	≥Hypoxic A status area (ha)
1205X	40.703	5.5	10.1
1432	40.703	5.5	10.1
1433	40.703	5.5	10.1
Total	122.109	16.5	30.3

Although this is admittedly a first order calculation of the potential area of Hypoxic A to Anoxic benthic conditions, it does not make any questionable assumptions about the critical waste deposition rate. Instead, it is based on reports of the average distance at which these impacts have been measured at smaller fish farms. The benthic impact zones shown in Table 6 are approximately three times larger than predicted in Exhibit 6 for the 1 g C m^{-2} d^{-1} depositional contour. The predicted 30.3 ha area encompassing the combined Hypoxic and Anoxic impact zones represents a substantial loss of fish foraging habitat in Liverpool Bay. For context, this area is equivalent to the size of 68 football fields.

Benthic habitat provides many critical ecological services connected with fisheries productivity by providing space for shelter, feeding, and breeding by coastal fishes and motile invertebrates. Benthic monitoring in Nova Scotia is currently limited to sites at the edge of fish cages and at distant reference sites with the objective of determining if sulfide concentrations exceed limits at which few benthic species can survive. This regulatory approach ignores the bigger picture in which the alteration and disruption of fish and fish habitat can occur at greater distances.

Scientists promote Ecosystem-Based Management (EBM) in commercial fisheries policy and the related concept of Ecological Carrying Capacity (ECC) in aquaculture development (Fisher et al. 2023). These approaches consider how industry activities interact with the environment in concert with the environment's capacity to support other species use of the same spatial area for their needs. An ECC approach to open water aquaculture would take account of the interaction between farms and their ecosystems as is embodied in the Canadian *Oceans Act* legislation. Ecosystem-based management requires greater attention to habitat conservation and recognizes the ecological and biological value of benthic ecosystems and their role in supporting aquatic species that Nova Scotians depend on. However, aquaculture management policies in Canada are not based on an EBM or ECC regulatory framework but instead relies on the difficult to quantify concept of "not having undue impact" (Fisher et al. 2023). Management and regulatory trigger points (thresholds) have not been established that define the acceptable geographic extent and broader ecological consequences of benthic effects from salmonid aquaculture development on fish and fish habitat. This means that decision makers (e.g., the Nova Scotia Aquaculture Review Board) are not provided with a science-based tool that would facilitate consistent decisions that support the growth of a sustainable aquaculture sector and increase public confidence in the industry.

8. Summary and Conclusions

Solid organic matter contained in waste salmon feed and feces fall under the category of BOD (biological oxygen demanding) matter, which is classed as a deleterious substance under section 34(1) of the *Fisheries Act* (Government of Canada, 1985). The national *Aquaculture Activities Regulations* permit aquaculture facilities operating under a licence to deposit BOD matter if certain conditions are followed to minimize detriment. The Nova Scotia aquaculture environmental monitoring program framework objective is to maintain Oxic sediment conditions in which the macrofaunal assemblage contains a wide array of infauna and epifauna. Federal and provincial methods prescribed to ensure that these regulatory objectives are upheld have been scientifically proven to be ineffective. National and global science programs have reached the following relevant conclusions:

1) State-of-the-art numerical modelling methods employed worldwide specifically to address the regulatory requirement to predict contours of the depositional footprint of BOD matter have consistently failed to match observations of benthic organic enrichment and community impacts.

2) The primary indicator used to monitor BOD matter effects on benthic communities is the total free sulfide concentration in surficial sediment, which must be analysed using a silver/sulfide ion-selective electrode (ISE). Multiple peer-reviewed published studies over more than a decade have shown this method to provide highly biased results that cannot resolve differences between the current regulatory decision thresholds.

3) Existing regulatory trigger points (thresholds) that describe habitat quality classifications at fish farms are specific to measurements performed using the ISE method. Published research has concluded that this site classification system exhibits a bias towards underestimating the spatial extent and severity of impacts from aquaculture organic enrichment.

4) The timing of benthic monitoring is meant to coincide with the period of maximum biological effects on benthic communities. Regulations require sampling to take place near the period of

peak salmon feeding. However, research shows that biological effects are greatest near the time of fish harvesting (peak biomass). Under the site development plans for Liverpool Bay, regulations would require benthic monitoring take place three to six months prior to harvesting. This requirement would underestimate benthic habitat and macrofauna effects from organic enrichment.

5) Fallowing of farms is undertaken as a regulatory means of allowing the seabed to recover between production cycles. The 3-month fallow period stipulated in the development plan may permit recovery of benthic sulfide and redox conditions, but global research indicates that benthic community recovery requires a much longer period (years). Regulatory objectives to maintain a wide array of infauna and epifauna species at aquaculture sites cannot be achieved under the proposed development plan.

6) Benthic habitat provides many critical ecological services connected with fisheries productivity by providing space for shelter, feeding, and breeding by coastal fishes and motile invertebrates. Benthic prey species of important commercial fisheries are sensitive to pollutants, including organic wastes, and require high quality benthic habitat. Estimates of the distance and area in which these forage species could be impacted are well outside the area monitored under current regulations. Thresholds that define the acceptable geographic extent of organic enrichment effects on fish forage species and fisheries have not been established.

The national *Aquaculture Activities Regulations* bring together provincial and federal legislation for the greater protection of fish and fish habitat and to bring aquaculture into compliance with the spirit and intent of the *Fisheries Act*. DFO and federal partners have made a commitment to modify the site, monitoring and mitigation requirements when needed in response to knowledge and technology advances (see AAR Guidance Document). The Atlantic Canada Fish Farmers Association recommended to the Doelle-Lahey Panel that an aquaculture regulatory framework for Nova Scotia, including monitoring requirements, should be grounded on science (ACFFA 2013). The results of aquaculture regulatory research support the need for improved methods to predict, monitor and mitigate organic enrichment effects on benthic habitat and communities that support fisheries. These regulatory changes should be implemented prior to significant industry expansion, such as proposed for Liverpool Bay, to better support sustainable aquaculture development and public confidence in the industry.

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Appendix 1

Reported Groundfish Prey Species on the Scotian Shelf. The Ecological Group is defined based on sensitivity/tolerance to organic enrichment and was assigned by AMBI 6.0 (www.ambi.azti.es).

Prey Category	Prey species and Ecological Group*	
Echinoderms	*Asterias vulgaris III* *Echinarchnius parma I*	*Henricia sp. I* *Strongylocentrotus pallidus I*
Ophiuroids	*Ophiopholis aculeata II*	*Ophiuridea sp. II*
Bivalves	*Modiolus modiolus II* *Mesodesma donacium I* *Cerrastoderma pinnulatum III*	*Cerrastoderma pinnulatum III* *Mactromeris sp. II* *Stenosemus albus I*
Polychaetes	*Polygordius sp. I* *Chone sp. II* *Nephtys neotella II* *Phyllodoce maculate II* *Maldanidae sp. I* *Sabellidae sp. I* *Ampharetidae sp. I*	*Thelepus Cincinnatus II* *Glycera capitata II* *Notomastus latericeus III*
Cumaceans	*Diastylis quadrispinosa II* *Diastylis sculpta II*	
Arthropods	*Unciola irrorate I* *Ericthonius fasciatus I* *Tiron spiniferum I* *Caprellidae sp. II* *Anonyx spp. II* *Dichelopandalus leptocerus II* *Cancer borealis II* *Pagurus acadianus II*	*Lysianassidae sp. I* *Tiron spiniferum I* *Erythrops erythropthalma II* *Janira alta I* *Syrrhoe crenulate II* *Leptocheirus pinguis III*

*Group *I* = Very sensitive; Group *II* = Indifferent; Group *III* = Tolerant; Group *IV* = 2nd Order Opportunist; Group *V* = 1st Order Opportunist

Appendix 2

Reported Prey Species of American lobster. The Ecological Group is defined based on sensitivity/tolerance to organic enrichment and was assigned by AMBI 6.0 (www.ambi.azti.es).

Prey Category	Prey species and Ecological Group*	
Gastropods	*Acmae testudinalis I* *Lacuna vincta II*	*Skeneopsis striatum I*
Bivalves	*Mytilus edulis III* *Modiolus modiolus II* *Cerastoderma pinnulatum III* *Anomia* sp. I	*Hiatella* sp. I *Mya* sp. II *Musculus* sp. I
Polychaetes	*Nereis* sp. III	*Cistena* sp. I
Crustaceans	*Idotea* sp. II *Corophium* sp. III *Homarus americanus* (not assigned)	*Pagurus* sp. II *Cancer* sp. II *Hyas* sp. I
Echinoderms	*Psolus* sp. II *Strongylocentrotus drobachiensis I*	*Asterias vulgaris III* *Ophiopholis aculeata II*

*Group *I* = Very sensitive; Group *II* = Indifferent; Group *III* = Tolerant; Group *IV* = 2nd Order Opportunist; Group *V* = 1st Order Opportunist

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Dr. Cranford's research over the past 40 years has focused on obtaining science knowledge to provide decision support to the Canadian government for the development of effective area-wide management strategies for promoting the sustainability of marine industries. Since 1998, his multidisciplinary research has focused on aquaculture ecosystem interactions and the resulting expertise has been applied nationally and internationally towards the development of monitoring frameworks for finfish and shellfish aquaculture. Dr. Cranford's research has included leadership and collaborative efforts with scientists in Canada, Norway, Spain, Portugal, The Netherland, Denmark, and New Zealand where he contributed to studies on ecosystem-level interactions with aquaculture. He is currently working with the Aquaculture Stewardship Council to develop new certification standards designed to minimize, mitigate, or eliminate impacts from seabed organic enrichment on benthic habitat, biodiversity and ecosystem function. During his career, he published 59 documents and edited one book (www.SCOPUS.com author profile shows 2484 published citations and an *h*-index of 31).

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