NWMB Final Report

1. NWRT Project Number: NWRT-2024-0000000010

2. Project Title: Developing local capacity for ship-based ballast monitoring at Milne Port

3. Project Leader: Kimberly Howland, Research Scientist, Fisheries and Oceans Canada – Freshwater Institute, 501 University Crescent, Winnipeg, MB, R3T 2N6, Primary phone: 204-891-8733, Email: Kimberly.Howland@dfo-mpo.gc.ca

4. Summary: Ballast water discharge from vessels has been identified as a primary source for aquatic nonindigenous species(NIS) introductions and associated invasions globally[1]. Vessel activity has increased dramatically in the Canadian Arctic since the mid-2000's with global change and opening/increased production at various mines[2]. The single greatest increase in shipping traffic and related ballast water discharge in this region has occurred at Milne Inlet Port, NU, due to the Baffinland Iron Mine (BIM) development[3]. This heightened discharge brings anticipated risks for non-indigenous species (NIS) introductions and potential impacts to nearby sensitive species and marine habitats including the Tallurutiup Imanga National Marine Conservation Area. This project aims to work collaboratively with affected communities to collect ballast water samples from ships arriving to Milne Port (using project-specific protocols developed/tested during a pilot program in fall 2023) to: a) understand the biological risks posed by Baffinland Iron Mines (BIM) Project shipping, and b) develop local capacity and tools to enable ongoing monitoring of risk/regulatory compliance of ballast water discharges at this location and anticipated future ports such as Steensby Inlet (currently in development). The project focuses on training Inuit 'youth' (18-35 years old), to participate in ballast water sampling, testing of compliance monitoring devices, data collection, analysis and development of risk assessment tools that will support monitoring ballast risk/compliance and creating species-specific rapid response plans based on identified risk factors. Together with mentoring and knowledge sharing through a series of planned workshops, youth are encouraged to lead community outreach and seek feedback to guide project activities and outcomes.

5. Project Objectives:

Objectives included in the original submission for reference:

a. Co-develop research plans via community involvement and provide training for Inuit from affected communities in ballast water biological sampling, and build new/draw on existing local capacity for risk assessment and future ballast water monitoring;
b. Develop standardized protocols for biological monitoring of risk/compliance with ballast water management standards for ongoing use at Milne Port, but with potential applicability to other ports/regions of Canada by:
    i. adapting existing ballast biological sampling methods for ships arriving at Arctic ports
    ii. verifying the accuracy/feasibility of a new rapid indicative analysis tool to assess ballast water compliance (based on live organism densities) for future use by community monitors or inspectors at Arctic ports
c. Identify the most important factors related to the risk of introducing NIS in ballast water discharged by ore carriers at Milne Inlet Port by collecting samples from ships using different ballast water management systems
d. Develop a risk assessment tool, incorporating factors identified through results of biological sampling, to facilitate future targeting of higher risk ships for monitoring/compliance and to inform future development of species-specific surveillance and rapid response plans

Existing ballast water protocols were modified to meet research needs, to streamline the sampling process while respecting safety and operational requirements at Milne Port based on lessons learned during the

pilot sampling program in 2023. Following these revisions, DFO researchers hosted a hands on training workshop in Pond Inlet for Inuit youth from Pond Inlet and Igloolik in June 2024 on the use of ballast water sampling and analysis gear including, the SATAKE ballast catch (ballast water collection and filtration tool), SATAKE Ballast eye (indicative analysis tool), citizen sampler (for sampling DNA from the ballast water) and syringe filtration methods (alternative method for sampling DNA from the ballast water), UVT meter (for measuring water clarity), TRO meter (for measuring chorine), refractometer (for measuring water salinity), YSI (for measuring various water quality parameters) and microscopes (for visually examining live vs. dead organisms). Inuit participants were also trained in laboratory, ship boarding and engine room, safety measures. During this workshop, youth worked collaboratively with DFO researchers to create a slide deck and gave an update to key community groups (Mittimatalik HTO (MHTO), QIA, Pond Inlet Hamlet) on the project and sampling plans for the summer/fall. In August, September and October 2024, Inuit youth participants accompanied DFO researchers to Milne Inlet Port and sampled 13 ships over two separate trips. Samples collected on ships during this period will contribute to identifying important risk factors for the introduction of NIS in ballast water by ore carriers and utilized in a future risk assessment.

In December 2024, a follow-up post-field debrief workshop was held in Pond Inlet with local youth from both participating communities to discuss youth experiences during sampling, ways for improving future sampling and workshops and co-develop outreach materials for sharing field activity updates with the broader community. Inuit youth led presentations on field activities which they gave to the Nasivvik Highschool, MHTO and QIA and on local radio. Igloolik participants and DFO also met with the Igloolik HTA (IGHTA) and Hamlet and went on local radio with youth leading presentations of outreach materials they helped develop during the debrief workshop.

In late February-early March 2025, a data analysis workshop was held in Pond Inlet, involving four DFO researchers and Inuit youth from Pond Inlet and Igloolik. During the first three days of the workshop, participants reviewed the aims of the project and relevant background information (what are aquatic non-native species, what is ballast water, why does it matter?) and prepared introductory slides for an outreach presentation. The participants then spent two full days doing hands-on exploratory data analysis – graphing data collected to date in Excel and plotting relevant coordinates into maps using QGIS software. The youth then worked collaboratively with DFO researchers to select the results they felt most important to share in the outreach presentation and to summarize key messages. The outreach presentation was finalized, translated into Inuktitut, and speaking notes prepared. The Inuit youth, with support of DFO researchers, rehearsed the presentation prior to meeting with community leaders. Presentations were delivered (led by Inuit youth who took turns presenting material) to members of the respective Hamlet and HTOs/HTAs in Pond Inlet and Igloolik. In addition, a community open house was held and a presentation delivered to students at the high school in Igloolik.

6. Materials and Methods:

Community engagement and training were achieved through a series of three approximately 1 week long workshops with 8 locally-recruited Inuit participants from Pond Inlet and Igloolik to exchange knowledge, co-create research plans, explore theory, project methodology, safety and sampling devices, data analysis and computer training as detailed in the achievements in section 5. In addition to workshops, Inuit youth received hands on training/employment through direct participation all research sampling activities described below.

Ballast sampling was conducted during standard de-ballasting operations a team of Inuit youth and DFO researchers with support from ships' engineering staff. From 1000 to 3000 litres of ballast water was taken from the ships' discharge line via the sample port (in engine room) and passed through a sample device (SATAKE Ballast Catch) containing a net to collect large organisms (≥ 50µm size); these were rinsed into a collection bottle for later analysis. At the same time, ~20 to 30 litres of unfiltered (raw) water was placed in

containers to collect smaller organisms for live counts, water for genomic analyses and measuring water quality parameters (pH, salinity, temperature, with YSI probe), water clarity and TRO (chlorine).

Live sample processing was conducted on-site and included detailed live organism counts (zooplankton, phytoplankton) to verify accuracy of indicative analysis tools and inform analysis of different ballast histories. Detailed analysis consisted of microscope counts by a trained individual, while indicative analysis used technology (SATAKE Ballast Eye) that can be operated with limited training to estimate number of viable organisms. A portion of each sample was preserved and shipped to analytical labs for detailed taxonomic identification of organisms to species or lowest feasible level using a combination of morphological and genomic methods (individual- and meta-barcoding with plankton, eDNA, eRNA).

Some adjustments to original proposed methodology included the following: The plan to sample ships with a variety of ballast water management systems proved challenging as ships voyaging to Milne Port are primarily equipped with chlorine-based ballast water treatment systems. Future ballast water risk assessment will therefore aim to reflect the risks associated with these specific treatment systems as opposed to a variety of treatment systems. The sampling period in 2024 was shortened to account for limited lab and accommodation space at Baffinland during other monitoring programs early in the shipping season (July/August). As a result, two 2-week sampling periods were conducted from August 28-Sept 11 and October 9-23. The second sampling trip was initially scheduled to begin at the end of September but due to an unprecedented storm, the tote road connecting the Mary River and Milne Port sites was damaged, leaving no safe way for DFO and Inuit participants to travel to Milne Port. The trip was rescheduled towards the end of the shipping season when fewer ships were transiting to Baffinland. The team consequently sampled fewer ships than originally planned. All other methods and materials were conducted as described in the original proposal.

7. Results:

Most ships that were sampled came from Europe, or in a couple cases Africa (Fig. 1, Fig. 2). These ships discharged ballast water that originated from these locations and was managed through treatment with chlorine on uptake followed by mid-ocean exchange plus treatment (in the North Atlantic; individual ship ballast exchange tracks shown in Fig. 1 below). The majority of ships sampled (8 out of 21) came from Rotterdam in the Netherlands, followed by Hamburg, Germany and Gijon, Spain (3 ships each). Three types of chlorine treatment systems were observed among the ships we sampled.

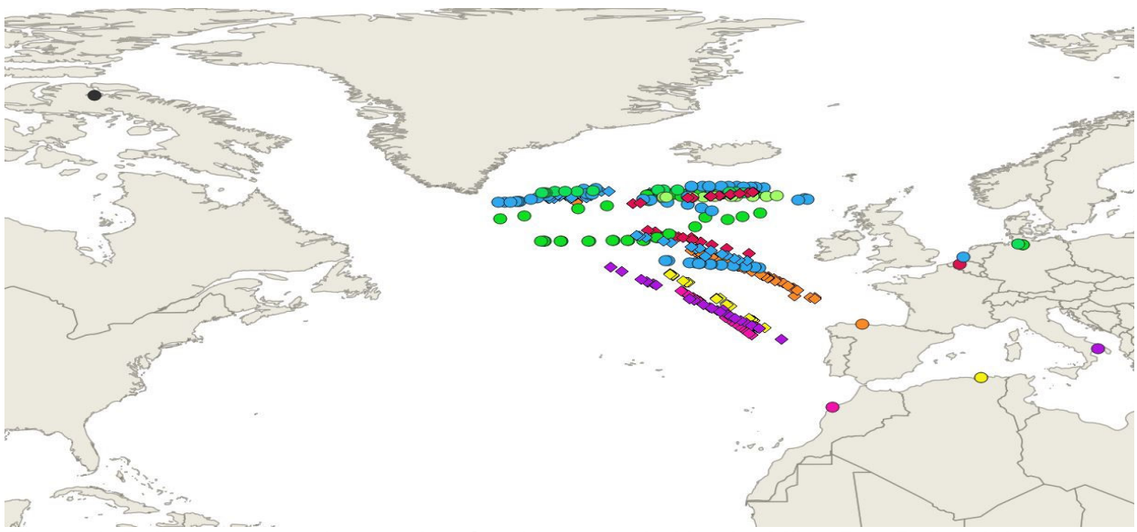

Figure 1: Ballast water exchange sites for ships sampled by the Milne Port Ballast Water team (circles = 2023; diamonds = 2024), classified by port of origin (last port visited shown by similar colored points on land).

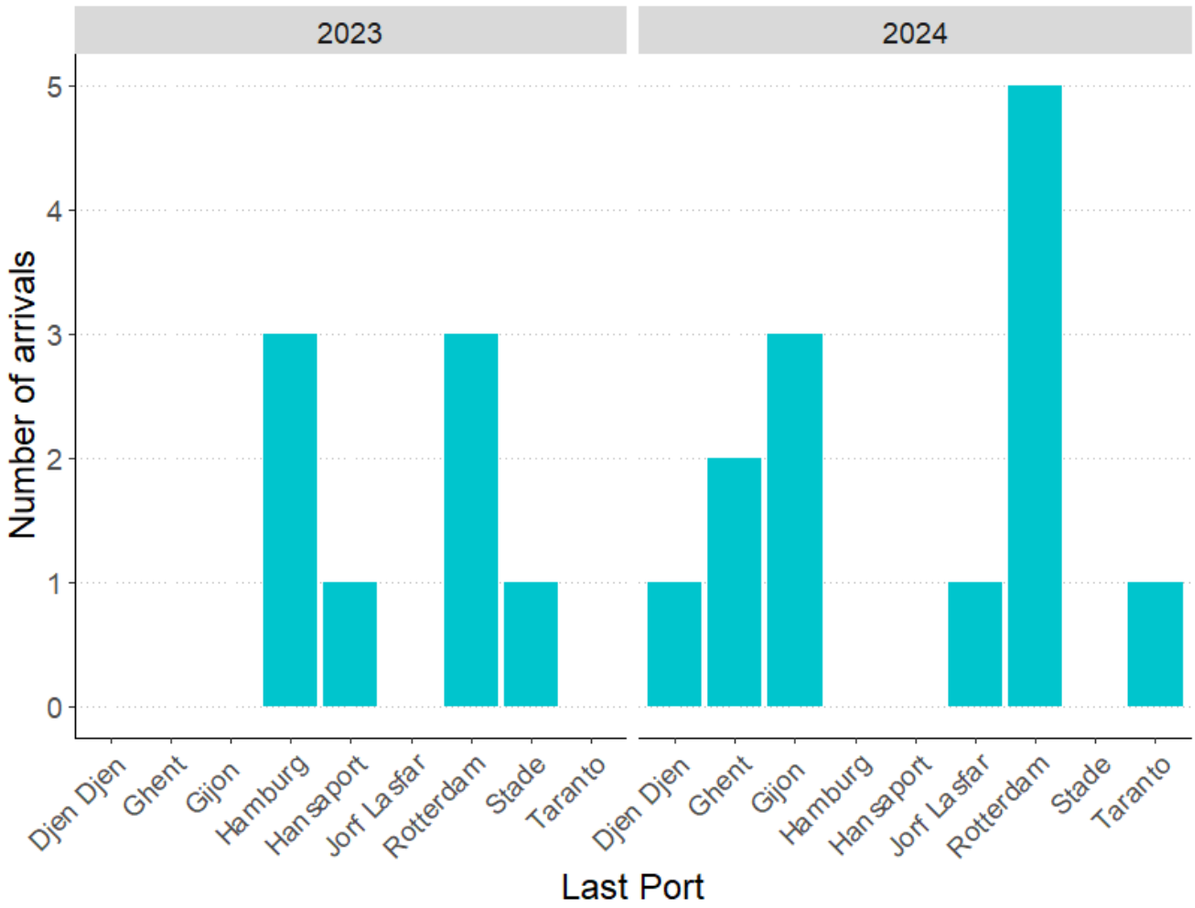

Figure 2: Last port visited by ships arriving at Baffinland that were sampled by the Milne Port Ballast Water team.

On average the ships we sampled discharged approximately 35 million litres of water (range ~19,000 to 82,000 litres) (Fig. 3).

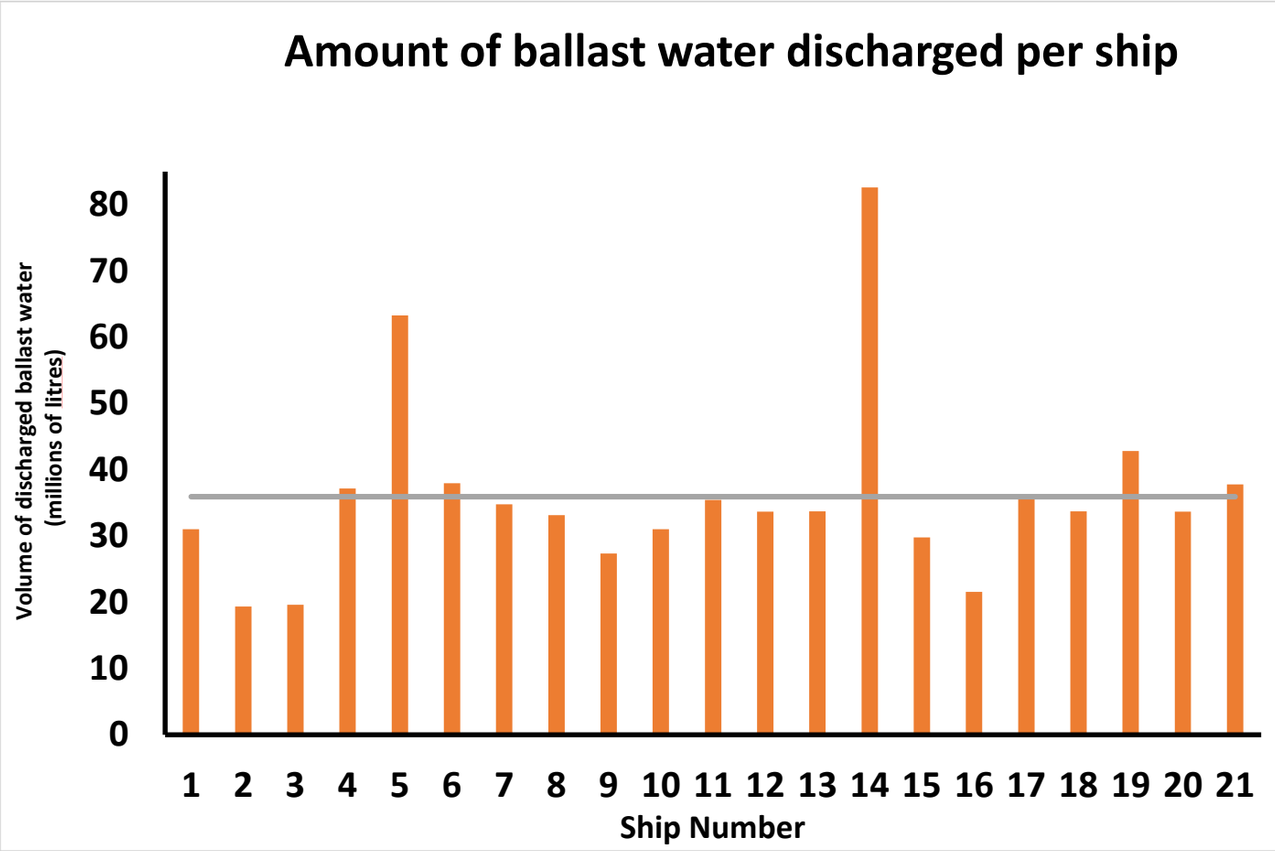

Figure 3: Volume of ballast water discharged by each ship sampled by the Milne Port Ballast Water team.

Preliminary results for live organism counts showed small size-class (10-50 um, primarily phytoplankton) samples from all 21 ships sampled over the 2 years (2023 and 2024) ships met the limit of the International Maritime Organization (IMO) Regulation D-2 standard (less than 10 organisms/millilitre of ballast water). Live phytoplankton cells were only observed in 2/21 processed microscope (human eye) subsamples and in 2/21 of the samples tested with the ballast eye; in all of these cases, there were 2 or fewer live cells/millilitre (Fig. 4).

For the large size class (≥50um, primarily zooplankton) overall, 4 out of 21 ships that were sampled (19%) exceeded (failed) the Regulation D-2 limit (the requirement of less than 10 organisms/1000 litres), based on microscope (human eye) counts, although some (an additional 4 ships) still contained low densities of live organisms ranging from 2-4 organisms/1000 litres (Fig. 5). It should be noted that our aim was to sample true ballast tanks (i.e., tanks that took up water at a source port, applied treatment and then mid-ocean exchange). However, among the sampled ships, only 13 samples were taken from true ballast tanks, six were sampled from water in cargo holds rather than true ballast tanks, and two were samples containing a mix of water from cargo holds and ballast tanks. All sampled cargo holds contained water that was only taken up in the mid-Ocean (North-Atlantic and in one case from Milne Port), rather than in an overseas source port, thus it is important to consider results by type of tank sampled as these different tank types/ballast sources have different histories and could be expected to have different levels of risk since mid-ocean waters are generally considered lower risk than water from source ports. When true ballast tank samples were compared to cargo hold samples, a higher proportion of true ballast tanks were found to contain organism densities that exceeded the Regulation D-2 Standard (Microscope and Ballast Eye: 3/13 or 23% of sampled ships) than cargo holds (Microscope 1/6 or 17%, Ballast Eye: 0/6 or 0%, of sampled

ships, respectively). The sample size of two for mixed samples was considered too low to be representative so should be interpreted with caution, but showed ½ ships had exceedances based on microscope counts, and none had exceedances based on the Ballast Eye counts.

Compared to microscopy (the standard method), preliminary findings show the Ballast Eye (indicative analysis tool) was effective at detecting live organisms in both regulated size classes, with 100% accuracy for the small size class and ~83% accuracy for the large size class; low false negative and false positive rates (~8%) occurred when analyzing marine ballast water samples for the large size class.

Further details of project progress, particularly with respect to youth training, workshops and community outreach are provided above in section 5 (updates and status of project objectives).

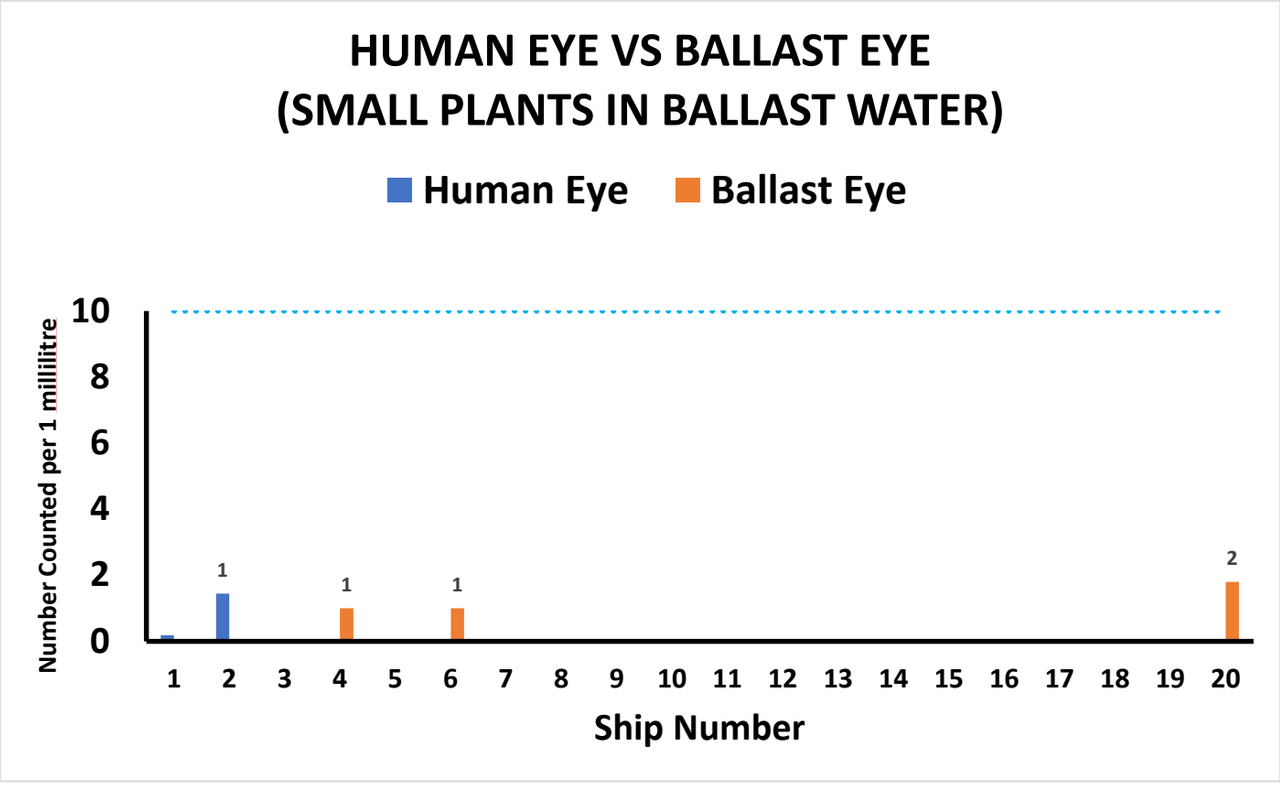

Figure 4: Number of live phytoplankton counted for each ship sampled by the Milne Port Ballast Water team, using a microscope (human eye – blue) and an automated counter (ballast eye - orange). Note: The blue dotted line represents the D-2 limit (10 live phytoplankton/1 ml of ballast water).

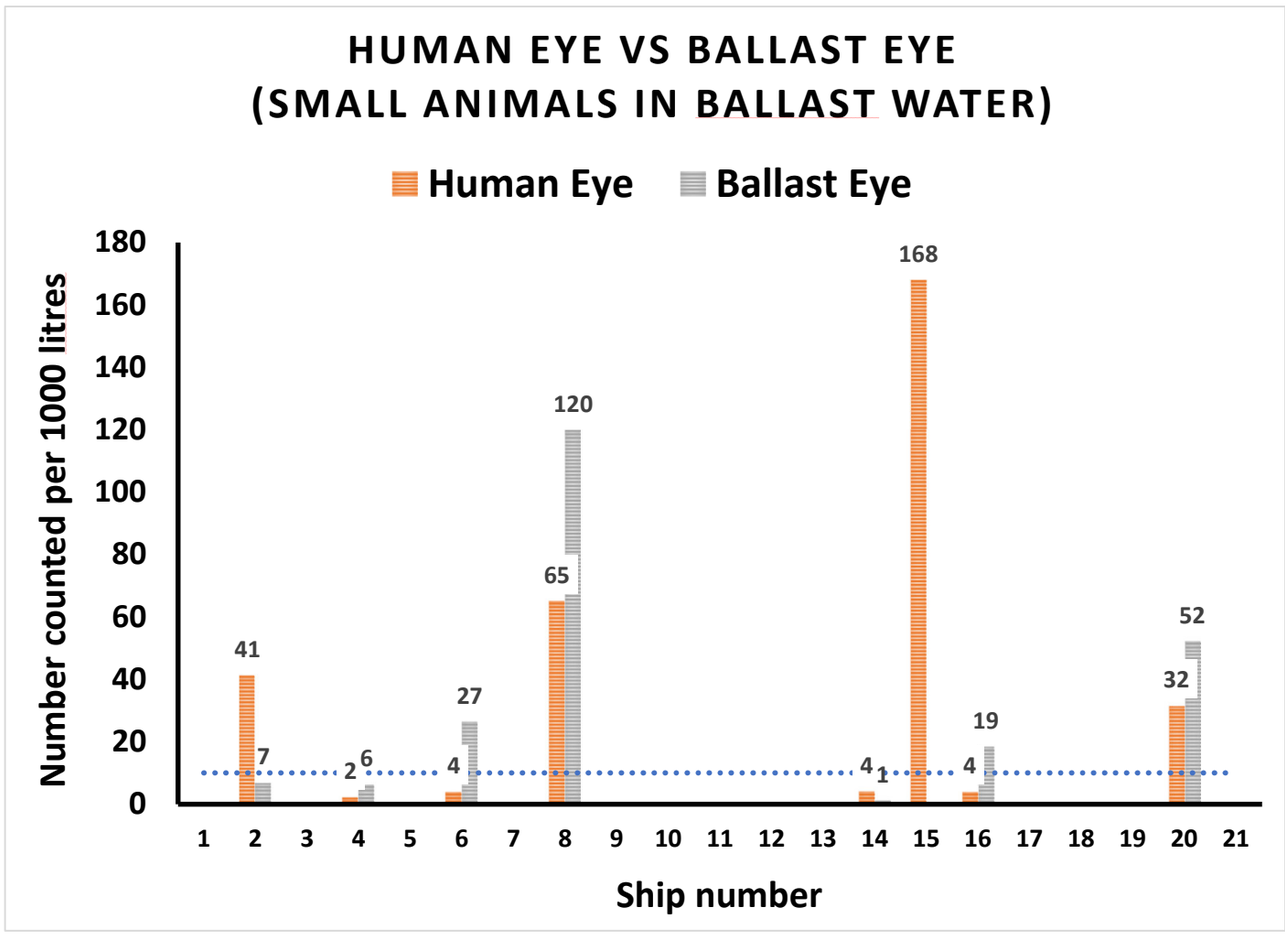

Figure 5: Number of live zooplankton counted for each ship sampled by the Milne Port Ballast Water team, for each ship using a microscope (human eye – orange) and an automated counter (ballast eye- grey). Note: The blue dotted line reflects the D-2 limit (10 live zooplankton/1000L of ballast water).

All ships had salinity levels that were close to or exceeded 30 ppt suggesting that they had conducted mid-ocean exchange or uptake (the latter in the case of sampled cargo holds).

In total, 12 samples had chlorine levels below the expected limit of 0.1 milligrams/litre. The remainder(N=9) had more than the expected chlorine level of 0.1 milligrams/litre (Fig. 6 and 7).

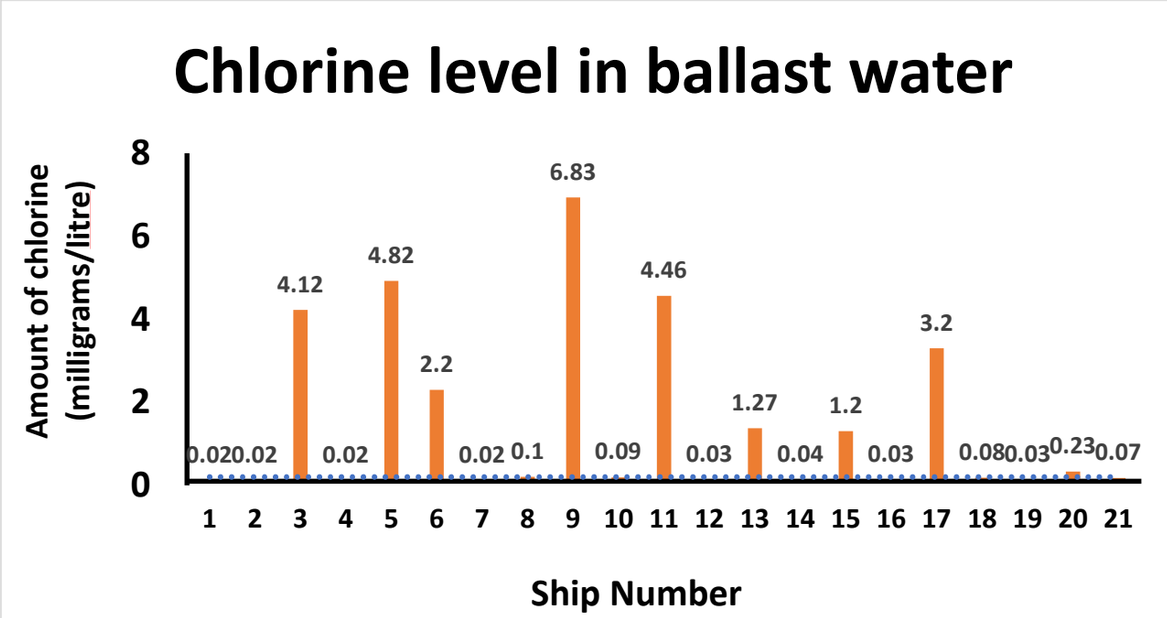

Figure 6: Residual chlorine levels in ballast water of ships sampled by the Milne Port Ballast Water team. Note: The blue dotted line indicates the expected chlorine level of 0.1 milligrams/litre after neutralization onboard ships prior to discharge.

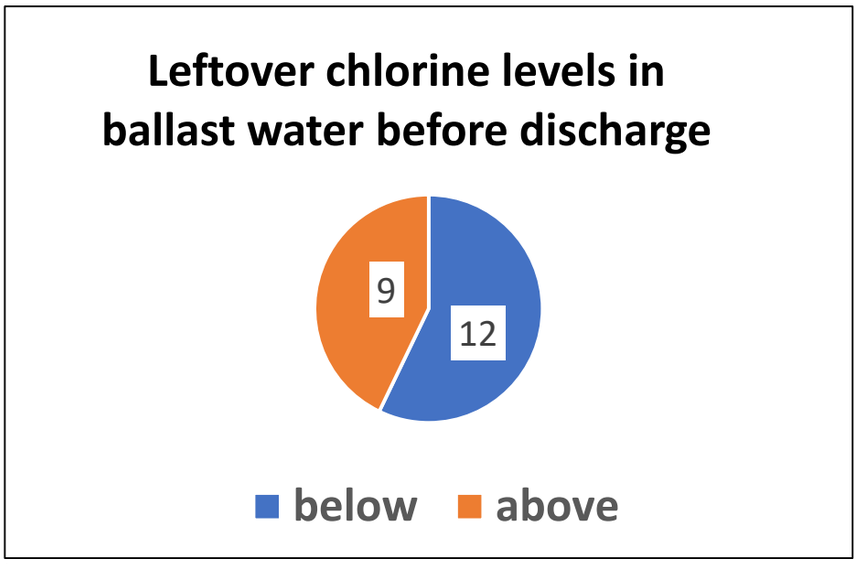

Figure 7: Number of ships sampled by the Milne Port Ballast Water team that were above and below the expected level of residual chlorine after neutralization and prior to ballast water discharge.

8. Discussion/Management Implications:

Based on our observations, exceedances for the large size class were lower than those observed in ballast of vessels with treatment arriving to the Atlantic and Pacific coasts (10s to 100s of individuals/1000 litres in vessels arriving to Milne Port versus up to 1000s of individuals per m^3[4]) suggesting that risks are generally lower for ships transiting to this Arctic Port. Organism densities are also far lower than those reported in vessels arriving to Canadian ports on various coasts including the Arctic, prior to implementation of treatment systems (1000s to 10,000s of individuals/1000 litres in the large size, and 100s to 1000s/millilitre in the small size class [5]), suggesting that treatment is effective in reducing risk of introducing new and potentially harmful organisms. The lower exceedances in vessels arriving to Arctic waters may be due to a combination of colder conditions and longer transit times [e.g., 6], but the additional protective measures of exchange in addition to treatment required for vessels arriving to Milne Port specifically, may further reduce organism densities. This could be particularly important in cases when vessels cannot use treatment during uptake in source ports due to challenging (silty) water conditions and must bypass or forgo use of their ballast water management systems [7]. In these cases, exchange with cleaner mid-ocean waters enables treatment to be applied at this stage. Salinity measurements and ballast reporting information suggest that most ships are complying with requirements for mid-ocean exchange in addition to treatment.

The majority of live organisms were copepods, however further analysis of data and preserved samples over the coming months is required to identify species, determine origins of taxa (native versus non-native) and identify important risk factors for the introduction of NIS in ballast water of ore carriers arriving at Milne Port.

The ballast eye generally produced results that were aligned with microscopy. With some training, the instrument could be reliably operated by new participants who joined the program from Pond Inlet and Igloolik. Likewise non-experts on the team were able to learn use of the citizen sampler for the filtration and collection of genomic samples. Following a period of training and guidance they were able to operate the device and collect sample more or less independently suggesting promise for use of these tools in future monitoring programs.

A high proportion of vessels had chlorine levels (measured as total residual oxidant (TRO), expressed as total residual of free chlorine), exceeding the Maximum Allowable Discharge Concentration (MADC) of 0.1 milligrams/litre as set during the Ballast Water Management System type approval, a level that is considered optimal. The proportion of ships exceeding this level among those sampled at Milne Port was ~43% as compared to 7% based on 600 commissioning tests [8]. This may be due to: chemical reaction rates that are slowed by colder water temperatures in ships arriving to Arctic ports (temperatures of ballast water on most ships (17/21) was less than 10^{o}C, with the remaining four vessels from 10.5-13.5^{o}C), poor maintenance of TRO sensors (e.g., expired calibration fluids) that determine the level of chlorine and neutralizer dosage, incorrect neutralizer preparation (neutralizer is not concentrated enough to fully nullify the residual chlorine level). This information and recommendations for improved maintenance were communicated to Baffinland representatives and they agreed to include this in their 2025 shipping season communications with vessel owners. Continued collection of samples and observations of TRO sensors/neutralization

systems during ship visits in 2025 will be used to try and better understand this issue and options for improvement.

9. Report by Inuit participants:

See attached.

10. Reporting to communities/resource users:

Community reporting took place following the below schedule:

Community/HTO	Before Research	During Research	After Research	Notes
Pond Inlet	Spring/Summer 2023: emails and phone correspondences with Mittimatalk HTO; plain language project summaries distributed and project support letter (HTO) requested - Complete			
Pond Inlet	July 2023 - virtual introductions and project discussions with potential Inuit youth participants from Pond Inlet - Complete			
Pond Inlet	September 2023: Project summaries and phone/email correspondences with the Pond Inlet Hamlet and QIA – Complete			
Pond Inlet	September 26, 2023: In-person meeting with Mittimatalik HTO members (Letter of support provided) - Complete	Continued online/phone correspondences Sept 2023 – Oct 2023. Complete	Post sampling: October 11 2023: In person meetings with Mitimatalik HTO members and hamlet together with youth participants and DFO to provide feedback/seek input on preliminary field work & training outcomes. Anticipated ongoing email./phone communications, sharing plain language written report and meetings with HTO, Hamlet, QIA to discuss Pilot	No plain language report was provided, instead presentation slides and notes were shared with HTO members following in-person meeting.

			sampling results (up to March 31, 2024) - Complete	
Pond Inlet	Anticipated email/phone communications between March 2024 and July 2024. HTO/Hamlet meetings to discuss 2024 sampling plans (in June-July 2024) - Complete Similar pre-field planning community organizations anticipated in early spring/summer 2025 - Complete	During sampling 2024: Continued communication from July 2024 – October 2025 with updates on field progress and planning for fall meetings with community organizations - Complete Similar plan for communication in 2025 during field season.	Post-field sampling: October 2024 – in-person meetings with Mitimatalik HTO members, hamlet QIA, together with youth participants and DFO to provide feedback/seek input on field work & training outcomes. Anticipated ongoing email/phone communication, sharing of plain language written report and meetings with HTO, Hamlet, QIA to discuss Pilot sampling results (up to March 31, 2025) - Complete Similar communications and reporting cycle planned in 2025-26. Risk assessment and communication of final results with youth participants, HTO, Hamlet, QIA in 2026-27.	Workshop and community meetings held in December 2024 instead of October due to busy schedules.
Pond Inlet			Community Open house to share outcomes. meetings with QIA and the HTO to discuss strategies for supporting ongoing community-led monitoring program in 2027-2028.	Future activity planned in 2027-2028

11. References

1. Bailey, S.A., Brown, L., Campbell, M.L., Canning-Clode, J., Carlton, J.T., ... Zhan, A. 2020. Trends in the detection of aquatic non-indigenous species across global marine, estuarine and freshwater ecosystems: A 50-year perspective. Diversity and Distributions 26: 1780-1797.

2. Dawson, J., Pizzolato, L., Howell, S. E. L., Copland, L., & Johnston, M. E. 2018. Temporal and spatial patterns of ship traffic in the Canadian Arctic from 1990 to 2015. Arctic 71:15-26.

3. Goldsmit, J., McKindsey, C.W., Schlegel, R.W., Stewart, D.B., Archambault, P. and Howland, K.L. 2020. What and where? Predicting invasion hotspots in the Arctic marine realm. Global Change Biology 26: 4752-4771.

4. Bailey, S.A., Brydges, T., Casas-Monroy, O., Kydd, J., Linley, R.D., Rozon, R.M. and Darling, J.A., 2022. First evaluation of ballast water management systems on operational ships for minimizing introductions of nonindigenous zooplankton. Marine Pollution Bulletin, 182, p.113947.

5. Casas-Monroy, O., Linley, R.D., Adams, J.K., Chan, F.T., Drake, D.A.R. and Bailey, S.A., 2014. National risk assessment for introduction of aquatic nonindigenous species to Canada by ballast water. Fisheries and Oceans Canada.

6. Chan, F.T., Briski, E., Bailey, S.A. and MacIsaac, H.J., 2014. Richness–abundance relationships for zooplankton in ballast water: temperate versus Arctic comparisons. ICES Journal of Marine Science, 71(7), pp.1876-1884.

7. Bradie, J., Rolla, M., Bailey, S.A. and MacIsaac, H.J., 2023. Managing risk of non-indigenous species establishment associated with ballast water discharges from ships with bypassed or inoperable ballast water management systems. Journal of Applied Ecology, 60(1), pp.193-204.

8. Drillet, G., Gianoli, C., Gang, L., Zacharopoulou, A., Schneider, G., Stehouwer, P., Bonamin, V., Goldring, R. and Drake, L.A., 2023. Improvement in compliance of ships' ballast water discharges during commissioning tests. *Marine Pollution Bulletin*, *191*, p.114911.

Howland, Kimberly (DFO/MPO)

From: Sutherland, Justine (she, her / elle, la) (DFO/MPO)
Sent: Monday, September 29, 2025 12:21 PM
To: Jeannie Qiyuapik
Subject: RE: NWMB final report

Hi Jeannie,

Thanks for putting something together for the NWMB final report. Greatly appreciated 😊

Cheers,

Justine

From: Jeannie Qiyuapik <jeannieqiyuapik27@gmail.com>
Sent: Monday, September 29, 2025 11:28 AM
To: Sutherland, Justine (she, her / elle, la) (DFO/MPO) <Justine.Sutherland@dfo-mpo.gc.ca>
Subject: NWMB final report

Jeannie Ootoova: I would like to start off from when I first started, the first time I joined this workshop I didn't understand anything, when we were doing the data from the last summer until the next time joined again and they were talking about where the data goes and after doing the training for when we go to Baffinland in the fall, that's when I understand how we do sampling and how it'll help out our community of Pond Inlet. All summer long I see the ship passing by that are going to Baffinland, and wondering how the water they dump out is going to affect our water around Pond Inlet and if they have new species that are never around here, but from what I see it's going really well and haven't heard they have many alive ones, also learned what I enjoy doing, if I could be doing this forever I would and not get tired of it, also the fun part of this is that I train my little how to do eDNA from this trip to Baffinland.

Howland, Kimberly (DFO/MPO)

From: Sutherland, Justine (she, her / elle, la) (DFO/MPO)
Sent: Monday, September 29, 2025 11:18 AM
To: Savana Qiyuapik
Subject: RE: Workshop

Hi Savana,

Thanks for putting something together for the NWMB final report!

Cheers,

Justine

From: Savana Qiyuapik <qiyuapiksavana@gmail.com>
Sent: Saturday, September 27, 2025 1:34 PM
To: Sutherland, Justine (she, her / elle, la) (DFO/MPO) <Justine.Sutherland@dfo-mpo.gc.ca>
Subject: Workshop

I'll start in the beginning on how I joined the program, A few years ago DFO and the youth went to high school to do presentation on how they do research and on top of that my sister confess me how they do that we're not said in the presentation and since then I was interested to join. I've learned a lot of things like Satake ballast catch , ballast eye, "one of my favourite thing to do" is eDNA.

THU AT 17:31

Hey everyone,

We've discussed some of the funding agencies (people who give us money) for the ballast water study in the past. One of those agencies is NWMB (Nunavut Wildlife Managemsnt Board) and they ask us to write them a report with updates on how the project is going, how money is being spent and things like that. They also ask us to see if any of the people we work with (you guys) want to write a report about the project. You could write about your thoughts on the project, things you've learned, is it benefitting you/your community and anything else you want to write about. It doesn't need to be super long.

I talked with some of you about this but wanted to give everyone the opportunity to write up blurb about the project if they want

things like that. They also ask us to see if any of the people we work with (you guys) want to write a report about the project. You could write about your thoughts on the project, things you've learned, is it benefitting you/your community and anything else you want to write about. It doesn't need to be super long.

I talked with some of you about this but wanted to give everyone the opportunity to write up blurb about the project if they want.

The deadline to get this done and sent to me would be Monday Sept 29 at 4:00 pm. You can send me what you've written by email.

I will be around all day on monday if anyone wants to go over it with me. You can also send me a message this weekend if you have questions.