

# **2023 results from watercraft inspection and decontamination at the Emerson, Manitoba international port-of-entry**

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## ABSTRACT

Brougham, K.B., Cockle, S.E., and Spearin, B.D. 2026. 2023 results from watercraft inspection and decontamination at the Emerson, Manitoba international port-of-entry. Can. Tech. Rep. Fish. Aquat. Sci. 3771: viii + 32 p. <https://doi.org/10.60825/hf7t-8954>

In 2023, Fisheries and Oceans Canada's (DFO) Aquatic Invasive Species (AIS) National Core Program and Conservation and Protection Directorate, in partnership with Canada Border Service Agency (CBSA), ran the second season of a watercraft inspection and decontamination program at the Emerson, Manitoba international port-of-entry. Following standards and protocols of programming throughout the western United States and Canada, DFO staff inspected 847 watercraft for Clean, Drain, Dry (CDD) compliance; a requirement for all watercraft entering Canada to ensure that watercraft and water-related gear are free of AIS. DFO inspection staff were operational for 74 days (610 hours) between May 12 and October 7, 2023. Of the watercraft inspected, 53% met CDD requirements. In contrast, 98% of boaters self-reported that their watercraft was CDD. In total, 45% of watercraft were inaccurately reported as CDD. Additionally, seven high risk watercraft with invasive mussels were intercepted during the 2023 season; where all but one watercraft had been inaccurately reported by boaters as CDD. Findings from this season continue to emphasize the importance of physical watercraft inspection at international border crossings to adequately intercept the transport of potentially AIS fouled and high risk watercraft travelling into Canada.

## RÉSUMÉ

Brougham, K.B., Cockle, S.E., and Spearin, B.D. 2026. 2023 results from watercraft inspection and decontamination at the Emerson, Manitoba international port-of-entry. Can. Tech. Rep. Fish. Aquat. Sci. 3771: viii + 32 p. <https://doi.org/10.60825/hf7t-8954>

En 2023, le Programme national sur les espèces aquatiques envahissantes (EAE) de Pêches et Océans Canada (MPO) et la Direction de la conservation et de la protection, en partenariat avec l'Agence des services frontaliers du Canada (ASFC), ont mené un programme d'inspection et de décontamination des embarcations au point d'entrée international d'Emerson au Manitoba. Suivant les normes et protocoles des programmes de l'ouest des États-Unis et du Canada, le personnel du MPO a inspecté 847 embarcations afin de garantir leur conformité à la règle Laver, Vider, Sécher (LVS), une exigence pour toutes les embarcations entrant au Canada, et ce, afin de garantir l'absence d'espèces aquatiques envahissantes. Le personnel du MPO a été en activité pendant 74 jours (610 heures) entre le 12 mai et le 7 octobre 2023. Parmi les embarcations inspectées, 53 % étaient conformes à la règle LVS. Toutefois, 98 % des plaisanciers avaient déclaré que leur embarcation était conforme à la règle LVS. Au total, 45 % des embarcations ont été déclarés de manière inexacte par leurs plaisanciers comme étant en conformité avec la règle LVS. De plus, sept embarcations à haut risque et contaminées par des moules envahissantes ont été interceptées pendant 2023. Tous les embarcations, sauf un, ont été déclarés de manière inexacte comme LVS par leurs propriétaires. Les résultats de cette saison continuent de souligner l'importance de l'inspection physique des embarcations aux points de passage frontaliers internationaux pour intercepter adéquatement le transport d'embarcations potentiellement contaminées par des espèces aquatiques envahissantes et à haut risque entrant au Canada.

## PREFACE

Fisheries and Oceans Canada's Aquatic Invasive Species National Core Program began watercraft inspection and decontamination at the Emerson, Manitoba international port-of-entry in the summer of 2022. The program has worked to improve operational and sampling protocols to maximize the impact of effort while on-site at Emerson. The Ontario and Prairie Region's Aquatic Invasive Species National Core Program will continue watercraft inspection and decontamination programming at the Emerson international port-of-entry for the foreseeable future. As such, technical data reports, such as this, will be produced each year as a sub-series to the 2022 pilot season report (Brougham et al. 2025). Any changes to methodology or operations are noted in these reports, but readers will be referred back to Brougham et al. (2025) for detailed descriptions of methods. An in-depth report is anticipated for every five years, which will highlight major changes and updates to the program as well as present cumulative summaries from the previous five years.

For full description of methods, please refer to:

Brougham, K.B., Wong, C.H.S., and Spearin, B.D. 2025. Piloting watercraft inspection and decontamination at the Emerson, Manitoba international port-of-entry. Can. Tech. Rep. Fish. Aquat. Sci. 3690: viii + 35 p.

## INTRODUCTION

The stowaway pathway, specifically the overland transportation of watercraft and water-related equipment, is a well-documented pathway that has spread aquatic invasive species (AIS) throughout North America (Bossenbroek et al. 2001, Bruckerhoff et al. 2015, Drake 2017). To mitigate this pathway, jurisdictions across North America have implemented 'Clean, Drain, Dry' (CDD) as a three-step requirement for boaters to reduce the risk of transporting AIS on their watercraft. Many jurisdictions also include a final step of 'Decontamination', where any and all organisms are killed by disinfecting the watercraft, typically with hot water.

In 2015, Fisheries and Oceans Canada (DFO) enacted the *Aquatic Invasive Species Regulations* to outline prohibitions around the importation, possession, transportation, and release of aquatic invaders. The regulations prohibited the importation of Zebra and Quagga mussels into Canada, meaning that any watercraft harbouring these species while entering Canada through a highway port-of-entry (POE) would be in contravention of this prohibition. Despite these regulations, the Commissioner for Environment and Sustainable Development's 2019 Audit of DFO's AIS programming highlighted the need for DFO and Canada Border Service Agency (CBSA) to better prevent the introduction of AIS into Canada, stating that DFO should "[work] with the CBSA to address risks associated with watercraft and prohibited imports", such as Zebra and Quagga mussels (*D. polymorpha* and *D. bugensis*; s.1.73; OAG 2019). In response, CBSA adopted Memorandum D19-8-5 to support DFO in the enforcement of the *Aquatic Invasive Species Regulations* at international POEs. This Memorandum advises on the import prohibitions and requirements under the regulations, which includes the requirement that watercraft entering Canada must be CDD and free of Zebra and Quagga mussels.

The volume of watercraft travelling into Canada through highway POEs is not currently monitored and neither is compliance with Memorandum D19-8-5. In DFO's Ontario and Prairie Region, watercraft inspection and decontamination programming run by the provinces of Manitoba, Saskatchewan, and Alberta supports CDD and Decontamination requirements in the interior of the provinces. However, with 34 highway POEs in the Ontario and Prairie Region alone, the lack of watercraft inspection and decontamination at the international borders remains a major gap in effectively managing the stowaway pathway. Additionally, the number of watercraft travelling through these POEs and the risk they pose to Canada is largely unknown.

To respond to the 2019 audit recommendations, assess the CDD compliance of watercraft entering Canada through highway POEs, and test the regulatory tools set out under the *Aquatic Invasive Species Regulations* and Memorandum D19-8-5, DFO's AIS National Core Program in the Ontario and Prairie Region developed a pilot watercraft inspection and decontamination program to be deployed at a single highway POE for part of the open water season. This program was developed and supported by the prairie provinces and DFO's Conservation and Protection (C&P) Directorate. DFO began coordinating with the Emerson, Manitoba CBSA office, cited as 'the busiest highway crossing in the Prairies' (OAG 2019), and developed a strategy to deploy DFO resources on-site. Due to COVID-19 travel restrictions in 2021, the pilot program was not implemented until the summer of 2022. In 2023, DFO ran their second year of the watercraft inspection program.

## METHODS

During 2023, DFO's watercraft inspection and decontamination station operated from Friday, May 12 until Saturday, October 7, 2023, on the Canadian side of the Emerson POE.

Inspection staff were present at Emerson for 74 days (610 hours) of operation, which was split into two distinct operational periods 1) Summer Operation and 2) Fall Operation. Summer Operation ran for 64 days (530 hours) between May 12 and September 3, 2023. One inspection crew of two or three staff was on-site for four days each week: Thursday, Friday, Saturday, and Sunday (Table 1). Fishery Officers from DFO C&P also provided enforcement support on 40 days throughout Summer Operation. Fall Operation ran on a reduced, two-day per week schedule for 10 days (80 hours) between September 8 and October 7, 2023 (Table 2). Two inspection staff were on-site for an eight-hour shift on Fridays and Saturdays, with Fishery Officers providing occasional enforcement support.

**Table 1.** Hours of operation by day of the week during Summer Operation.

<b>Weekday</b>	<b>Count</b>	<b>Hours of Operation</b>	<b>Start Time</b>	<b>End Time</b>
Thursday	13	6	12:30	18:30
Friday	17	9	9:30	18:30
Saturday	17	9	7:30	16:30
Sunday	17	8	8:30	16:30

**Table 2.** Average hours of operation by day of the week during Fall Operation.

<b>Weekday</b>	<b>Count</b>	<b>Hours of Operation</b>	<b>Start Time</b>	<b>End Time</b>
Friday	5	8	10:30	18:30
Saturday	5	8	7:30	15:30

Operation in the 2023 season varied from the program's pilot season in that only one crew was deployed each week in 2023, rather than the two crews that were deployed each week in 2022. This operational change was initiated to streamline the program and reduce operation costs while maximizing the number of watercraft captured during operational hours. The updated schedule was based on the daily hours of operation that saw the most watercraft in 2022. As a result of this operational change, hours of operation went down from an average of 11 hours per day in 2022 to 8 hours per day in 2023, which resulted in 195 fewer hours of operation for the season overall. Operation began earlier in the 2023 season (May 12) than operation in 2022 (June 3), which resulted in six more days of operation in 2023. The inspection and decontamination station was also not operational on any Mondays in 2023, which differed from the 2022 season.

Full details of the 2022 season's operations are found in Brougham et al. (2025).

## Watercraft Inspection

Boaters were initially inspected by CBSA via a verbal questionnaire based on the requirements of Memorandum D19-8-5, where they were required to report their watercraft as CDD or non-CDD (see Appendix 1). Following the verbal questionnaire, CBSA would direct boaters to DFO’s inspection and decontamination station where the watercraft would undergo a physical inspection to verify the results of the questionnaire.

An additional verbal questionnaire was also conducted by DFO (see Appendix 1). Four questions were added to DFO’s questionnaire in the 2023 season (see Brougham et al. 2025). These new questions asked boaters whether their watercraft had been previously inspected and/or decontaminated by DFO, what the primary purpose of their trip was, and if the watercraft was a rental or for resale.

For the physical watercraft inspection, DFO followed inspection protocols outlined in the *Uniform Minimum Protocols and Standards for Inspection and Decontamination Programs for Dreissenid Mussels in the Western United States* (UMPS IV; Elwell & Phillips 2021) to systematically inspect watercraft for the presence of aquatic organic material (e.g., aquatic vegetation, organisms, and/or mud); unremoved drain plugs; and standing water. If a watercraft was observed as CDD and passed DFO’s inspection, the boater would be educated on AIS in their destination jurisdiction and the watercraft was released into Canada. If a watercraft was found as non-CDD and failed DFO’s inspection, the watercraft was either identified as low, moderate, or high-risk based on what was found during the inspection and actions were taken to eliminate the risk to Canada’s waters based on the risk category (Table 3).

**Table 3.** Biological risk categories for non-CDD watercraft and the likely actions taken by DFO to minimize the risk that incoming watercraft at the Emerson POE pose to Canada’s waters.

<b>Risk Category</b>	<b>Non-CDD Indicators</b>	<b>Likely Action Taken</b>
<b>Low Risk</b>	Watercraft with drain plug(s) that have not been pulled or trace amounts of water.	DFO inspection staff make the watercraft CDD without a decontamination – pulling a drain plug and/or drying water – prior to education and release into Canada.
<b>Moderate Risk</b>	Watercraft that are not clean (i.e., organic material present), not drained, and/or not dry (i.e., standing water) but that do not show signs of Zebra or Quagga mussels.	DFO inspection staff recommend, or a Fishery Officer issues an official direction ordering, that the watercraft undergo a full, on-site decontamination prior to education and release into Canada.
<b>High Risk</b>	Watercraft with evidence of dead and/or live Zebra and/or Quagga mussels or watercraft suspected to be carrying AIS.	DFO inspection staff request the assistance of CBSA to refuse entry to the watercraft into Canada.

## **Watercraft Decontamination**

For watercraft that were recommended or ordered to decontaminate, DFO inspection staff directed boaters to the on-site, trailered watercraft decontamination unit. The standard decontamination process is outlined in Brougham et al. (2025).

## **Environmental DNA Sampling**

Environmental DNA (eDNA) was collected from a random sample of the 847 inspected watercraft, with a bias towards watercraft that failed for having standing water onboard. In total, 259 samples were collected from 130 different watercraft. Samples were collected according to DFO Ecosystems and Oceans Science protocols from watercraft hulls, engines, and onboard raw water compartments (e.g., live wells). Samples were analyzed using validated qPCR assays described in Gingera et al. (2017) that target dreissenid mussels and analyzed by DFO's Genetics Lab at the Freshwater Institute in Winnipeg, Manitoba. eDNA results were not used to determine the risk category of watercraft, but solely for detecting the presence-absence of dreissenid mussel DNA.

## **Origin and Destination Mapping**

Using the criterion outlined in Brougham et al. (2025) origin (i.e., the waterbody of last launch) and destination coordinates were generated for 484 and 791 boaters, respectively. This translated into 467 complete coordinate pairs out of a possible 847 watercraft inspected. Failure to establish waterbody coordinates was due to 1) boaters not identifying a specific origin or destination waterbody (96 watercraft), 2) boaters using their watercraft exclusively at their destination waterbody (i.e., same origin and destination coordinates; 121), or 3) the origin waterbody not being located in the watercraft residence jurisdiction (i.e., state or province; 163).

A detailed description of the road network analysis is found in Brougham et al. (2025).

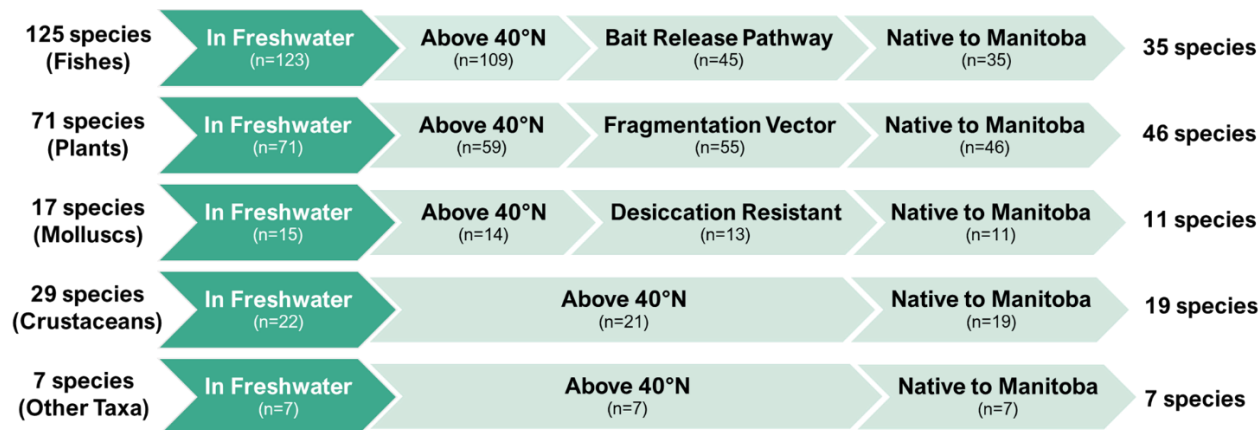
## **AIS Interceptions**

Origin waterbody coordinates were used to produce a list of AIS that may enter Manitoba on watercraft travelling overland. Origin waterbodies identified in the study were summarized into 155 HUC08 subbasins (Jones et al. 2022) and used as a filtering query for the United States Geological Survey - Nonindigenous Aquatic Species (USGS-NAS) database (USGS 2023). This query provided a list of 286 species with a mean of 13 introduced species per subbasin. The species list was further filtered to remove redundant generic species, subspecies, and sterile hybrids. Reptiles, amphibians, and mammals are not as commonly transported on watercraft as they travel overland and were therefore omitted from analysis. In total, 249 aquatic nonindigenous species comprising nine broad taxa were found in the study's origin subbasins and considered for further analysis.

To further refine this list, several criteria were used to identify species with a high establishment risk in Manitoba (Figure 1). The Hudson Bay is not accessible by road in Manitoba thus, only freshwater species were considered in this study. In the absence of climate matching data for these species, seasonal ice cover was considered a potential limiting factor for many tropical and subtropical species. Only species found above 40°N – a latitudinal proxy for winter ice-up – were retained. This proxy was selected as a very broad climate matching selector to coarsely

screen out AIS with a weak environmental match for Canada. Other taxa-specific criteria included means of introduction (fish), desiccation resistance (molluscs), and the possibility of vegetative reproduction (plants). Finally, any species that were native to Manitoba were removed.

After applying the aforementioned coarse filters, the list of 249 AIS present in the origin waterbodies were refined to a total 118 species that could have been introduced into Manitoba via the stowaway pathway on watercraft inspected during the 2023 season.



**Figure 1.** Coarse filters applied to refine the list of possible AIS interceptions during the 2023 season from 249 species to 118 species (see Appendix 3 for final list; n=118).

## RESULTS

During the second year of the Emerson POE watercraft inspection and decontamination program, DFO interviewed 809 boaters and inspected 847 watercraft (Table 4) from 29 different resident jurisdictions (provinces or states). Twenty-one boaters were hauling two watercraft (3% of all boaters), and six were hauling more than two watercraft (1%). For types of watercraft inspected, 84% were outboard watercraft, 7% were canoes or kayaks, 3% were unidentified, and 6% were either pontoons, simple boats, personal watercraft, or inboard-outboard watercraft. Ten inspected watercraft were commercial shipments being brought to Canada for resale (1% of all watercraft). Two per cent of all watercraft were carrying bait as they crossed the border, all of which were intercepted by CBSA and directed to surrender their bait prior to entry into Canada.

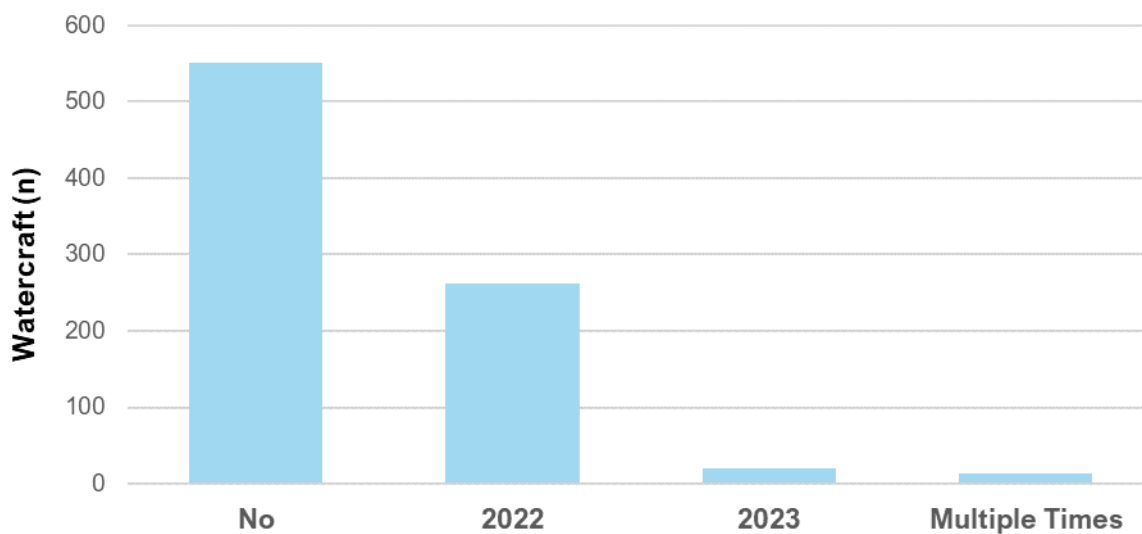
Thirteen watercraft (2% of all watercraft) were reported to have already passed through a watercraft inspection station on their current trip; meaning that they would have been inspected by an inspection program somewhere in the United States (U.S.) prior to travelling into Canada. Of these 13 watercraft, six failed DFO’s inspection (54% CDD). The most commonly reported jurisdictions of previous inspection were South Dakota (5 watercraft) and Colorado (2).

**Table 4.** Summary of watercraft inspection and decontamination results for 2023 season. ‘Misreported as CDD’ refers to watercraft that were reported as CDD to CBSA and then failed DFO’s inspection.

Category	Count (n)	Proportion (%)
Inspections	809	-
Watercraft Inspected	847	-

<b>CDD Watercraft</b>	447	53%
<b>Non-CDD Watercraft</b>	400	47%
<b>Low Risk Watercraft</b>	254	30%
<b>Moderate Risk Watercraft</b>	139	16%
<b>High Risk Watercraft</b>	7	0.8%
<b>Invasive Mussel Watercraft</b>	7	0.8%
<b>Misreported as CDD</b>	423	45%

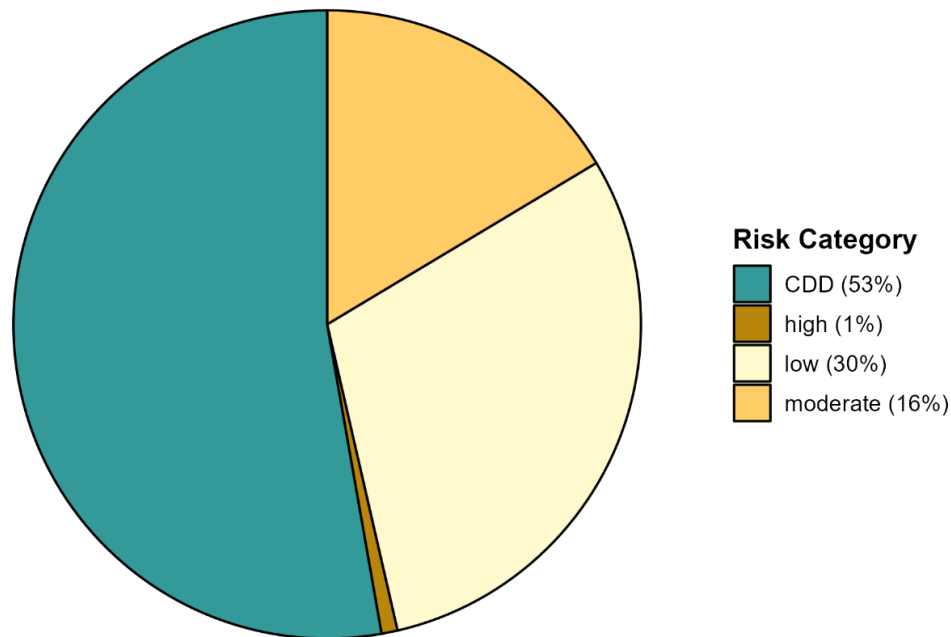
According to boater interviews, 551 watercraft (65%) had never been inspected by DFO at the Emerson POE before and 296 watercraft (35%) had been previously inspected by DFO. Of the watercraft that had been previously inspected by DFO, 262 had been inspected in 2022 (89%), 20 had been inspected earlier in 2023 (7%), and 14 had been inspected multiple times, either within or between years (5%; Figure 2). Only 54% of these previously inspected watercraft were CDD; with 94 low risk watercraft (32%), 40 moderate risk (13%), and two high risk (0.7%). Both high risk watercraft were fouled with invasive mussels.



**Figure 2.** Responses as to whether watercraft were previously inspected by DFO at the Emerson POE: “No”, “Yes, in 2022”, “Yes, in 2023”, or “Yes, multiple times”.

## Clean Drain Dry Compliance

Out of the 847 watercraft inspected, 400 failed DFO's inspection and were found to be non-CDD (47% of all watercraft). In total, the proportion of CDD watercraft for the 2023 season was 53% (Figure 3). When broken down by risk category, 254 watercraft (30%) were classified as low risk, meaning they were made CDD by either drying any wet areas or removing drain plugs. There were 139 watercraft (16%) classified as moderate risk, which were all decontaminated on-site by DFO. In total, seven watercraft (1%) were classified as high risk due to the confirmed or highly suspected presence of AIS. Five of these high risk watercraft were refused entry into Canada by CBSA and two were decontaminated by DFO.

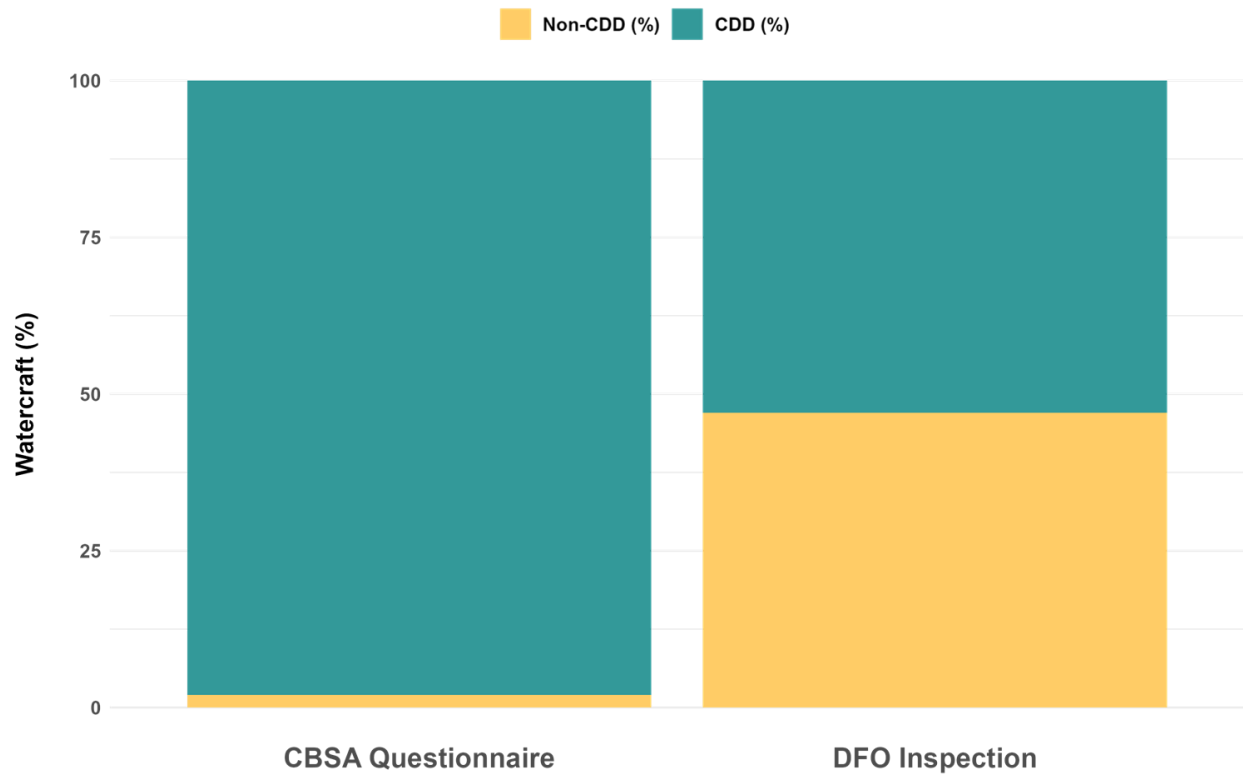


**Figure 3.** Percentage of CDD and risk categories for non-CDD watercraft.

The results of CBSA's verbal questionnaire under Memorandum D19-8-5 were compared against DFO's verbal and physical watercraft inspections. For this comparison, 23 watercraft had missed CBSA's questionnaire prior to stopping at DFO's inspection and were thus omitted.

Based on CBSA's questionnaire, 98% of boaters reported that their watercraft was CDD (n=824; Figure 4). In contrast, DFO inspection staff observed only 53% of watercraft as CDD (Figure 3). These findings indicate that 45% of boaters inaccurately reported to CBSA that their watercraft was CDD and, had they not undergone DFO's physical inspection, these non-CDD and potentially high-risk watercraft could have entered Canada.

During their inspections, DFO found seven total watercraft to be fouled with invasive mussels, five of which were refused entry into Canada by CBSA and two decontaminated by DFO. DFO inspection staff decontaminated two of the seven watercraft for having less severe fouling, in that there were few observed invasive mussels, the likes of which were dry and desiccated. Six of these high risk watercraft were initially reported to CBSA as CDD and could have entered Canada without intervention by DFO if not for a physical inspection at the Emerson POE.

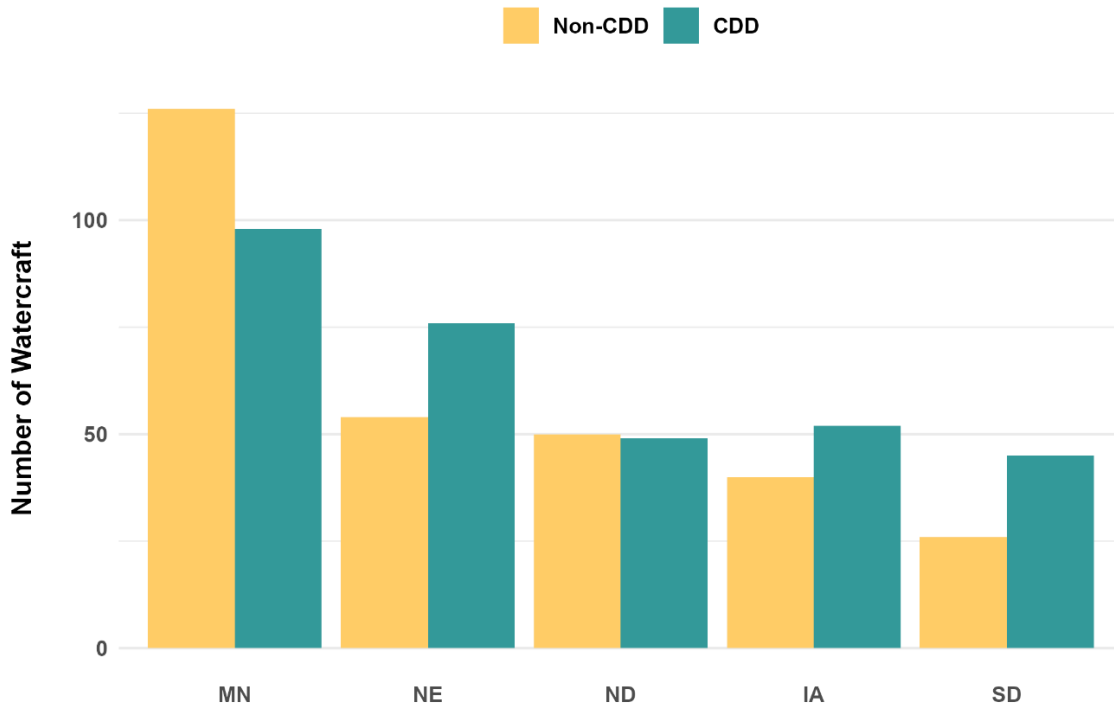


**Figure 4.** Comparison in the proportion of CDD and non-CDD watercraft based on boater reports to CBSA (left bar) and DFO’s physical watercraft inspection (right bar; n=824).

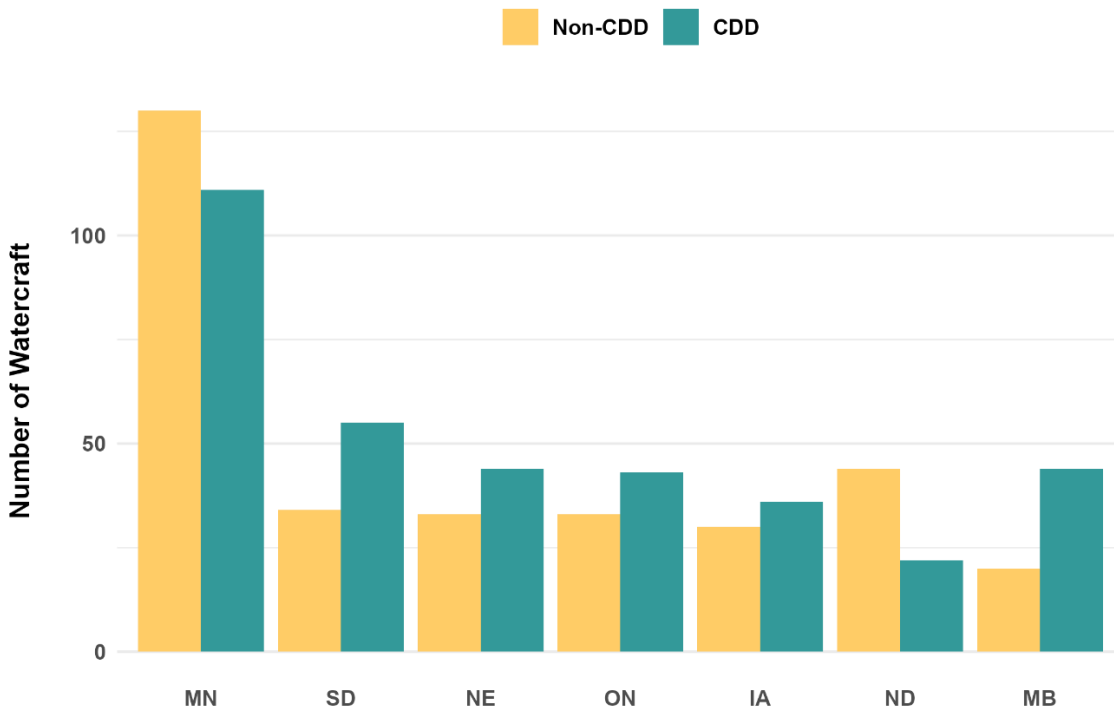
During the 2023 season, boaters reported to DFO both the jurisdiction (i.e., state or province) of watercraft residence and origin (i.e., of last launch) for 94% of inspected watercraft. For watercraft residence jurisdiction, DFO inspected watercraft from 25 U.S. states and four Canadian provinces. The five most cited residence jurisdictions made up 73% of all inspected watercraft: 225 from Minnesota (27% of all inspected watercraft), 130 from Nebraska (15%), 99 from North Dakota (12%), 92 from Iowa (11%), and 71 from South Dakota (8%; Figure 5).

For these five most frequently reported jurisdictions of watercraft residence, the proportion of boats that were CDD ranged from 51% to 63%; with 51% CDD from North Dakota, 56% from Minnesota, 57% from Iowa, 58% from Nebraska, and 63% from South Dakota.

For the origin jurisdiction, DFO encountered watercraft last used in waterbodies from 26 U.S. states and five Canadian provinces. The most frequently reported origin jurisdictions were Minnesota (28%), South Dakota (11%), Nebraska (9%), Ontario (9%), Iowa (8%), North Dakota (8%), and Manitoba (8%; Figure 6). The proportion of CDD watercraft from each of these jurisdictions ranged from 33% (North Dakota) to 69% (Manitoba).

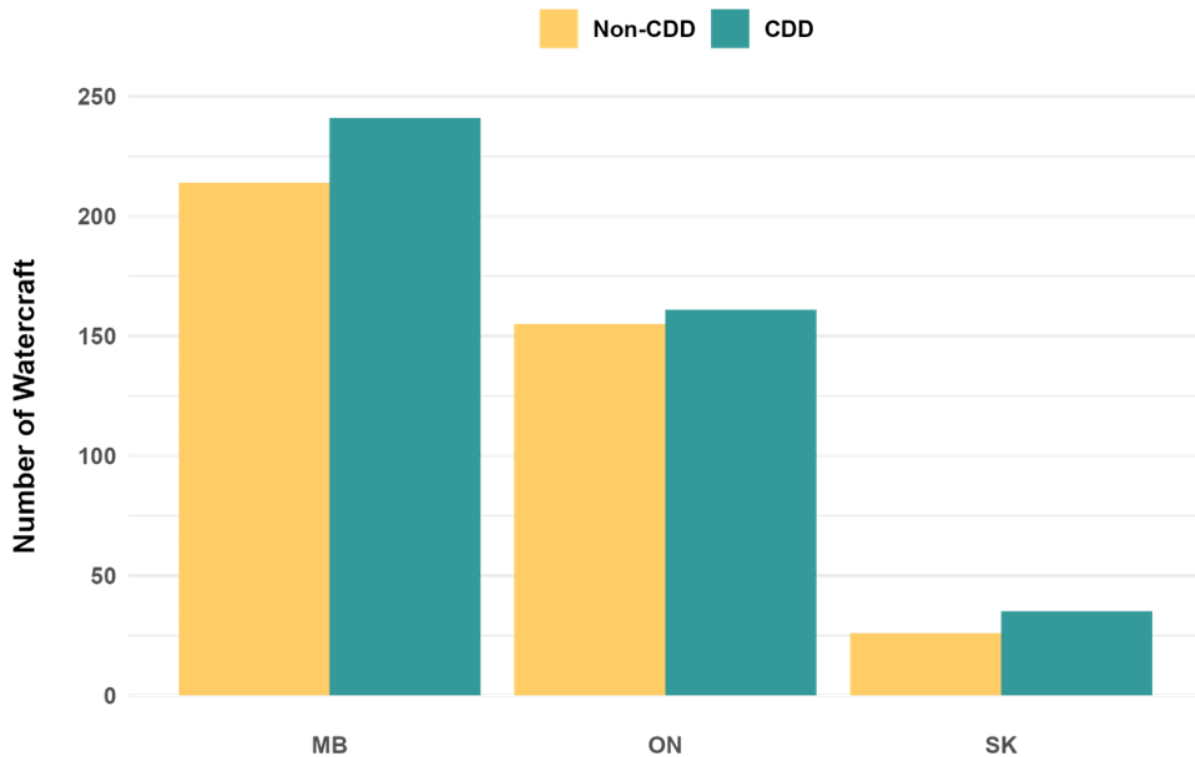


**Figure 5.** CDD and non-CDD watercraft from jurisdictions of watercraft residence (see Appendix 2). Only jurisdictions that represent five per cent or more of data are presented.



**Figure 6.** CDD and non-CDD watercraft from jurisdictions of last launch (see Appendix 2). Only jurisdictions that represent five per cent or more of data are presented.

Boaters also reported to DFO the jurisdiction of their destination waterbody. The most frequently cited watercraft destination jurisdictions were Manitoba (54%), Ontario (37%), and Saskatchewan (7%), with 455, 316, and 61 watercraft, respectively (Figure 7). The proportion of CDD watercraft headed to these destination jurisdictions ranged from 51% (Ontario) to 57% (Saskatchewan).

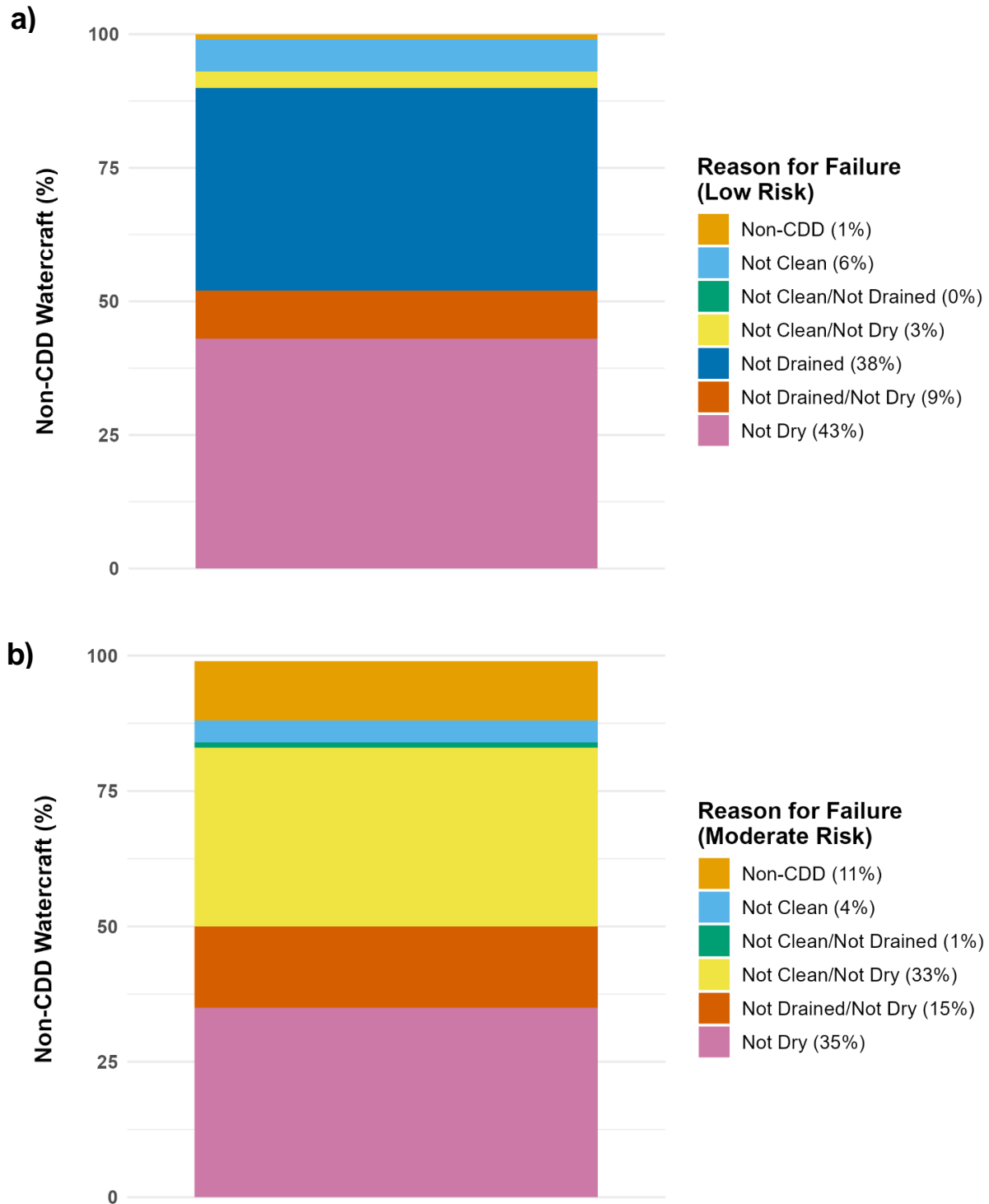


**Figure 7.** CDD and non-CDD watercraft from destination jurisdictions (see Appendix 2). Only jurisdictions that represent five per cent or more of data are presented.

### Non-Clean Drain Dry Watercraft

For the 400 watercraft that failed DFO’s physical inspection, the reasons for inspection failure ranged from being not “Clean” (i.e., organic material and/or AIS), not “Drain” (i.e., unremoved drain plugs), or not “Dry” (i.e., standing water) to some combination of the three. The most common location for inspection failure was in watercraft live wells, with 253 watercraft having organic material, unremoved drain plugs, and/or standing water found during DFO’s inspection. The engine compartment and bilge were two other common locations of inspection failure, with 125 failing in the engine (organic material and/or standing water) and 121 failing in the bilge (organic material, unremoved drain plugs, and/or standing water).

For low risk watercraft, the two primary reasons for inspection failure were that watercraft were not dry (43%) or not drained (38%; Figure 8a). To a lesser degree, low risk watercraft also failed for being not drained and not dry (9%) or not clean (6%). For moderate risk watercraft, the primary reasons for inspection failure were that watercraft were not dry (35%); not clean and not dry (33%); not drained and not dry (15%); or neither clean, drained, nor dry (11%; Figure 8b).



**Figure 8.** Reasons for inspection failure for a) low risk watercraft and b) moderate risk watercraft.

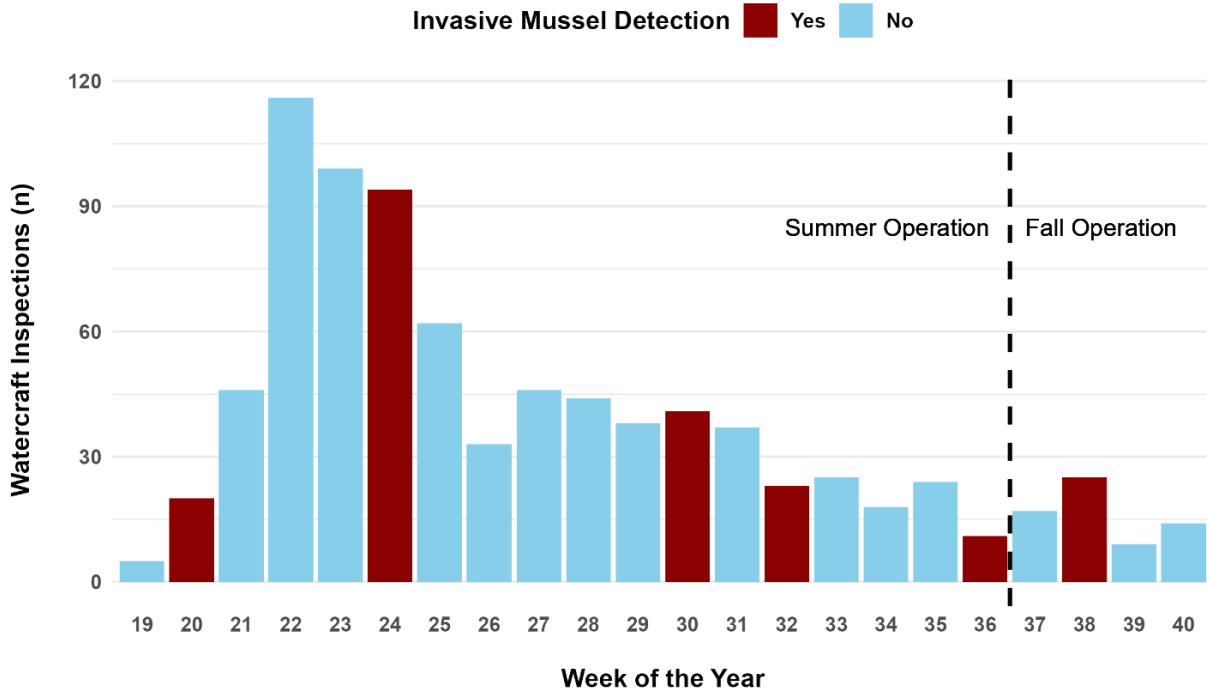
For high risk watercraft, all seven failed for being not clean with either the confirmed or highly suspected presence of AIS, such as Zebra Mussel. Of these high risk watercraft, 71% failed for being not clean and 29% failed for being not clean and not dry. Overall, 272 watercraft failed for being not dry, 162 for not drained, and 102 for not clean.

## Watercraft Traffic Trends

During Summer Operation, from May 12 to September 3, inspection staff were operational at the Emerson POE four days per week, from Thursday to Sunday. During this operational period, the days of the week that saw the most watercraft were Friday and Saturday. The busiest overall day was Saturday with 308 (40%) watercraft inspected, followed by Friday with 284 (37%), Sunday with 126 (16%), and Thursday with 53 (7%). Friday and Saturday were also the days with the highest average number of watercraft per day, Friday with an average of 15 watercraft and Saturday with an average of 16. Sunday and Thursday have considerably lower averages, being eight and four watercraft, respectively.

During Fall Operation, from September 8 to October 7, inspection staff were only operational two days each week, on Friday and Saturday. Saturday continued to be the busiest day for inspections, with 41 (54%) watercraft inspected on Saturdays over the fall period and 35 (46%) watercraft inspected on Fridays.

For weekly watercraft inspected, numbers started relatively low and increased steadily over the first few weeks of Summer Operation (weeks 19-21 or May 12 to May 28, 2023), with a sudden steep increase into week 22 (June 4 to 7, 2023; Figure 9). After week 22, there was a rather steady decline from week 23 through to week 36, the last weekend of Summer Operation. Fall Operation saw relatively lower weekly numbers of watercraft than Summer Operation. The maximum number of watercraft inspected in one week across both operational periods was 119 during week 22. The minimum was week 19 and 39 with five and nine watercraft, respectively. Overall, DFO inspected an average of 39 watercraft per week of operation.



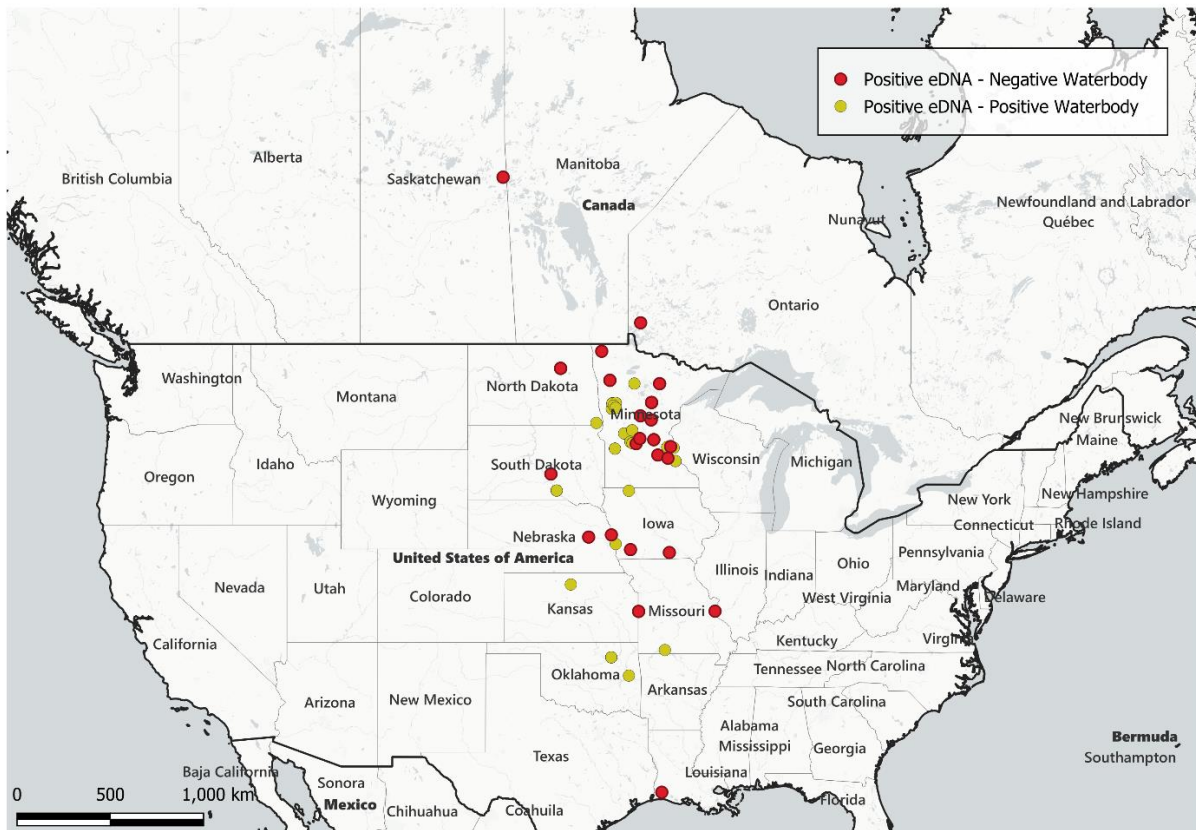
**Figure 9.** Total number of watercraft inspected per week of the year (from June 3 to October 22, 2023). Invasive mussel watercraft were intercepted during weeks 20, 24, 30, 32, 36, and 38.

The seven watercraft that were found to be carrying invasive mussels were intercepted on weeks 20, 24, 30, 32, 36, and 38, with two intercepted on week 32. Excluding the watercraft intercepted during week 24, all invasive mussel fouled watercraft were intercepted on weekends with relatively low numbers of watercraft traffic (Figure 9).

### Environmental DNA Analysis

In total, 259 individual eDNA samples were collected from 130 different watercraft during the season, with 64 samples from CDD watercraft and 195 from non-CDD watercraft. Of the total 259 samples, 86 samples were positive (33%) and 173 samples were negative (67%) for the detection of dreissenid mussel DNA. All samples passed an internal positive control test used to determine probability of inhibitory influences effecting eDNA detection.

Of the 86 positive samples, two were from a watercraft with no origin waterbody recorded and 49 were from watercraft with an origin waterbody that's known to be positive for (i.e., invaded by) dreissenid mussels (Figure 10). An unexpected result was that 35 samples were from watercraft with an origin waterbody that is not yet known to be invaded by dreissenid mussels. The majority of these non-invaded waterbodies were clustered in Minnesota, with the others scattered across the central midwest, from North Dakota down to Louisiana, and in Saskatchewan and Ontario.



**Figure 10.** For positive eDNA samples, the origin waterbodies: positive for dreissenid mussels (red) and negative for dreissenid mussels (yellow).

A total of 34 CDD watercraft were sampled for eDNA with an average of two samples taken from each watercraft. Samples were typically taken as swabs of the hull, trailer, engine, or live well. Of these 34 CDD watercraft, 11 had at least one positive sample for dreissenid mussel DNA, seven of which had last been in a U.S. waterbody that is known to be invaded with Zebra Mussel.

The bulk of eDNA samples were taken from watercraft that failed DFO's inspection, with 97 non-CDD watercraft sampled. An average of two samples were taken from each watercraft, with these samples taken as swabs of the hull, trailer, engine, or live wells and water samples of the live wells or other interior compartments found to be holding water. Of these 97 non-CDD watercraft, 47 had at least one sample positive for dreissenid mussel DNA. Only one watercraft that came back positive was high risk, with dead invasive mussels found in the splash well at the stern of the watercraft. Seven eDNA samples were taken from this high risk watercraft following the detection of invasive mussels, with three coming back negative for dreissenid mussel DNA (samples of live well, gimbal, and trailer) and four coming back positive (samples of hull, engine, and two through-hull fittings). The remainder of the non-CDD watercraft with positive sample(s) were either low risk (46 watercraft) or moderate risk (50), with all moderate risk watercraft decontaminated prior to entry in Canada.

It is worth noting that a positive eDNA detection does not necessarily mean that there were live mussels present on a watercraft. Positive eDNA detections indicate the presence of dreissenid DNA, which can be shed into the environment from both living and dead organisms. Additionally, the results of the eDNA sampling were not used to inform any regulatory or risk assessment activities completed by DFO, but rather to support DFO Science and the further refinement of this technique as an early detection and monitoring tool.

### **Origin and Destination Mapping**

Of the 847 inspected watercraft, 484 origin (i.e., waterbody of last launch) and 791 destination waterbody coordinates were identified based on information provided by boaters during DFO's watercraft inspection questionnaire. The 484 origin waterbodies were spread across 274 unique waterbodies of last launch; with 91 waterbodies recorded as the origin waterbody of multiple boaters. Origin waterbodies were primarily in Minnesota (166), Nebraska (67), Iowa (51), South Dakota (51), and North Dakota (44). The Missouri River was the single most cited origin waterbody (15; Table 5), with boaters having last launched from sites located in three separate jurisdictions: Nebraska (8), South Dakota (6), and Missouri (1). The five most cited origin waterbodies comprised 10% of all identified origin waterbody coordinates.

For waterbodies north of the border, the 791 destinations provided by boaters were limited to just 355 unique waterbodies. Eighty-one of these 355 destination waterbodies were visited by multiple travelling parties. Boater convergence to certain waterbodies was top-heavy, with the top ten most-cited destination waterbodies encompassing 58% of boater destinations. Cedar Lake, Manitoba; Lake of the Woods, Ontario; and Lac Seul, Ontario each alone accounted for over 5% of total cited boater destinations (Table 6).

**Table 5.** Top five origin waterbodies most frequently cited by boaters. Jurisdiction(s) refers to each waterbody’s state or province; ‘Multiple’ is listed when a waterbody occurs in more than one jurisdiction.

No.	Origin Waterbody	Jurisdiction(s)	Count	Percent
1	Missouri River	Multiple	15	3%
2	Devils Lake	North Dakota	12	2%
3	Lake Sakakawea	North Dakota	11	2%
4	Lake Oahe	Multiple	7	1%
4	Mississippi River	Multiple	7	1%
5	Branched Oak Lake	Nebraska	6	1%

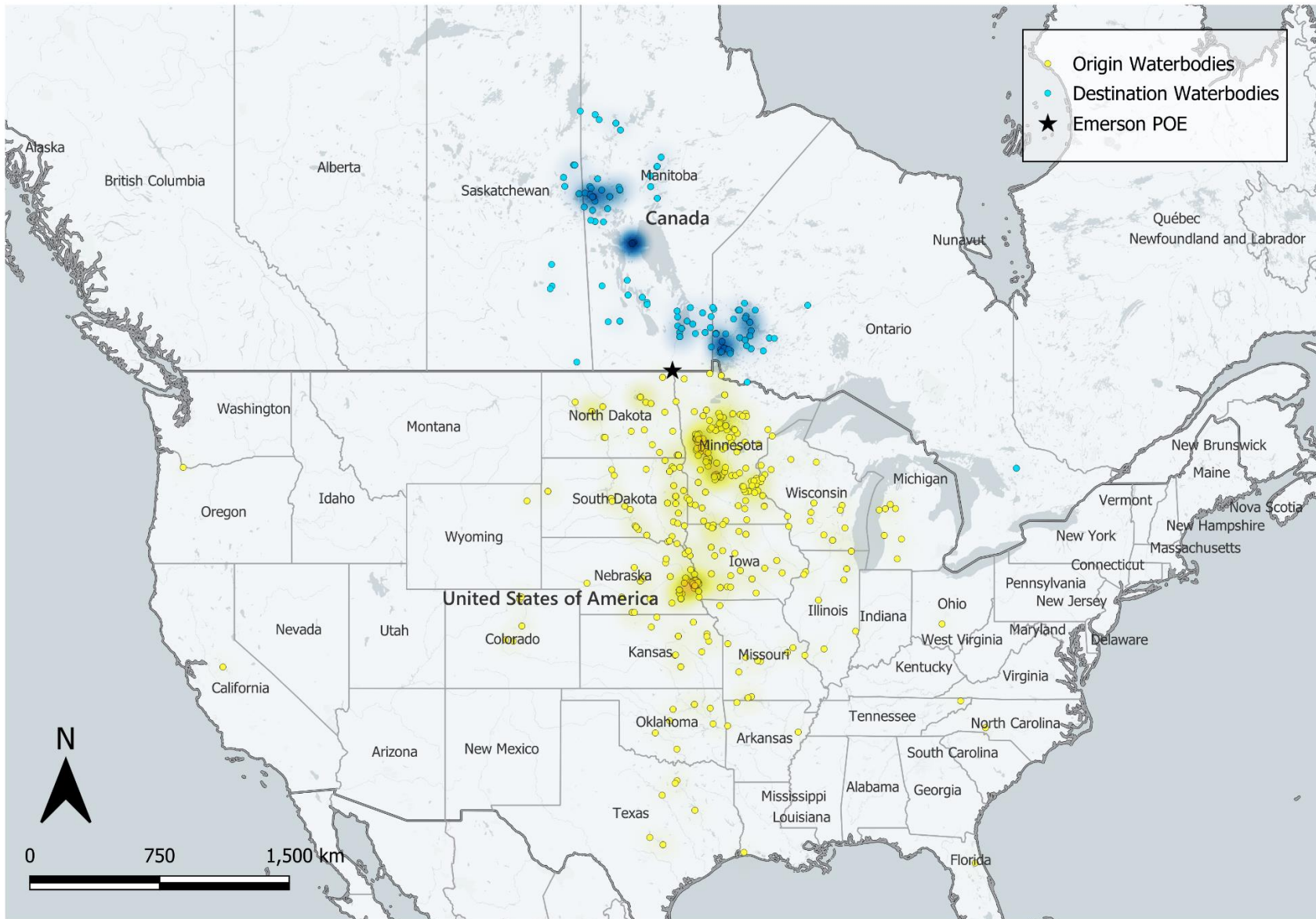
**Table 6.** Top five destination waterbodies most frequently cited by boaters. Jurisdiction(s) refers to each waterbody’s state or province; ‘Multiple’ is listed when a waterbody occurs in more than one jurisdiction.

No.	Destination Waterbody	Jurisdiction(s)	Count	Percent
1	Cedar Lake	Manitoba	87	11%
2	Lake of the Woods	Ontario	69	9%
3	Lac Seul	Ontario	59	7%
4	Winnipeg River	Multiple	40	5%
5	Lake Winnipeg	Manitoba	34	4%

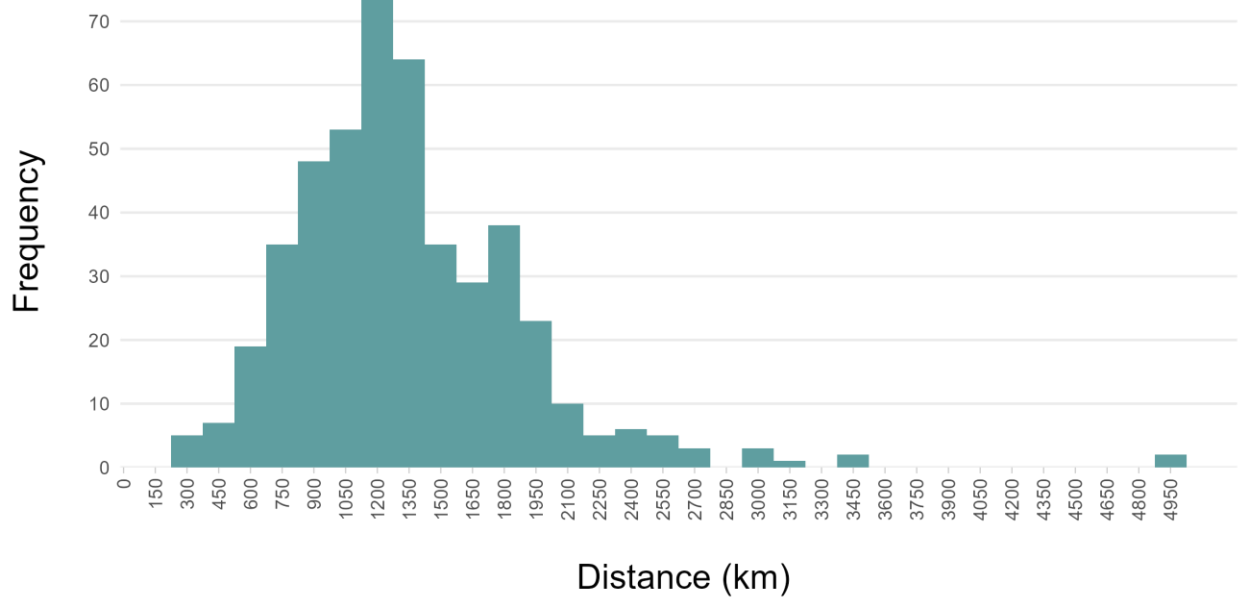
Only 467 complete origin and destination waterbody coordinate pairs were identified from the 847 total inspected watercraft and used for the following analyses (see Methods). There were several noticeable origin and destination waterbody clusters observed throughout the 2023 season (Figure 11). Origin waterbodies were densely clustered around cities in central to north-central Minnesota (e.g., Detroit Lakes and Minneapolis) and eastern Nebraska (e.g., Omaha and Lincoln) and often occurred along the Interstate-29 highway. Overall, most watercraft came from the midwestern U.S., exhibiting a strong north-south trend.

For destination waterbody clusters, after crossing through the Emerson POE, boaters converged on waterbodies in northwestern Ontario (e.g., Minaki), central to western Manitoba (e.g., Grand Rapids and Flin Flon), and west central Saskatchewan (Creighton; Figure 11). Boaters travelling eastward rarely reported continuing past Dryden, Ontario. Most boaters that remained in Manitoba after crossing through the Emerson POE appeared to launch in waterbodies found along the Manitoba-6 highway.

Based on the road network analysis, watercraft were transported between 267 km and 4,922 km to reach their destination waterbody, with mean and median estimates of 1,341 km and 1,255 km, respectively (Figure 12). As was the case in 2022, this indicates that the program’s dataset captures a boater demographic that is considered relatively rare and infrequent in literature, as most trips involving boaters are relatively short (under 200 km; Drake 2017).

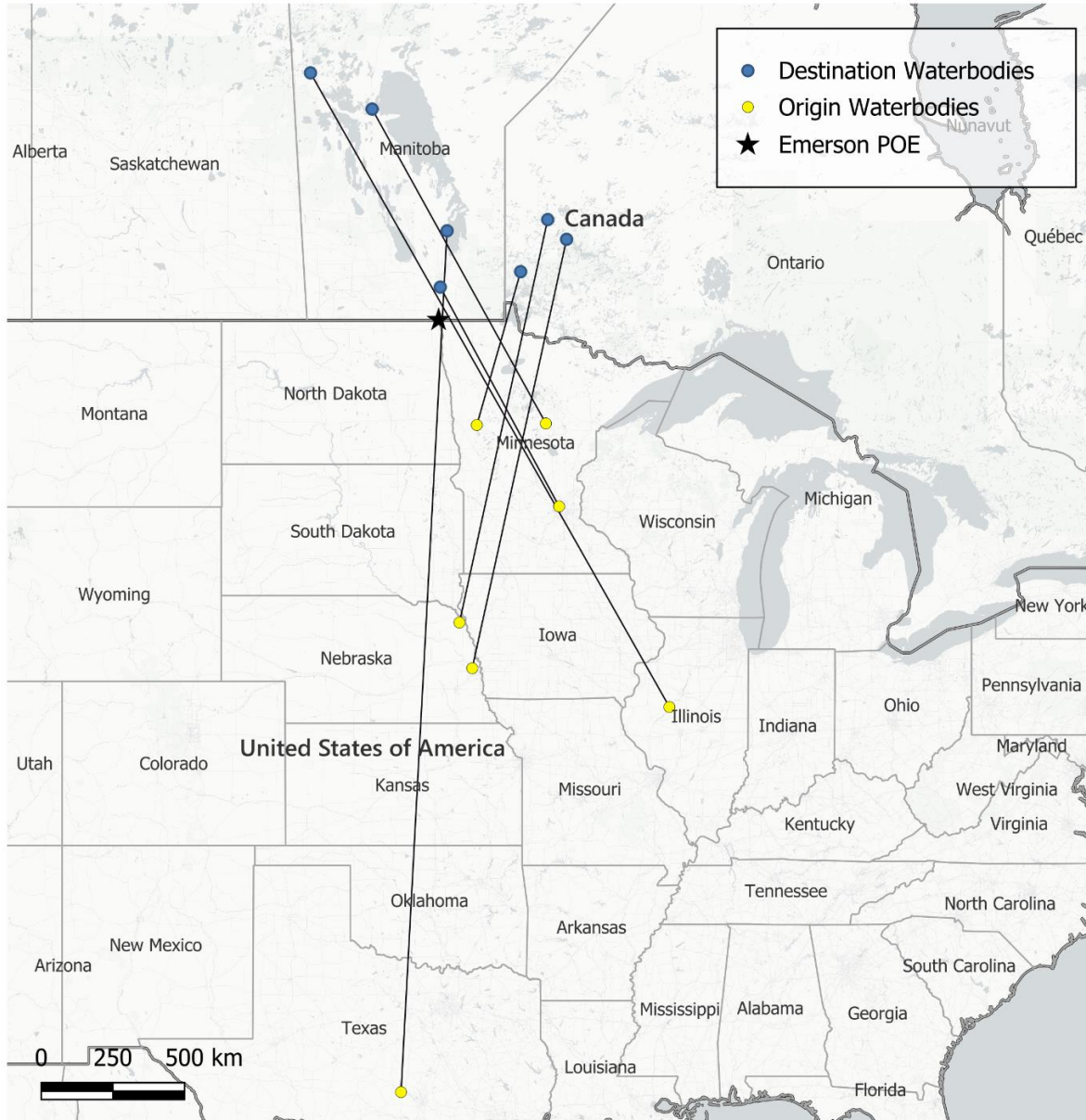


**Figure 11.** Origin (yellow) and destination (blue) waterbodies for watercraft inspected at the Emerson POE (black star) during the 2023 season.



**Figure 12.** Projected travel distances of boaters passing through the Emerson POE in 2023. Shortest routes were generated in ArcGIS Pro (n = 467).

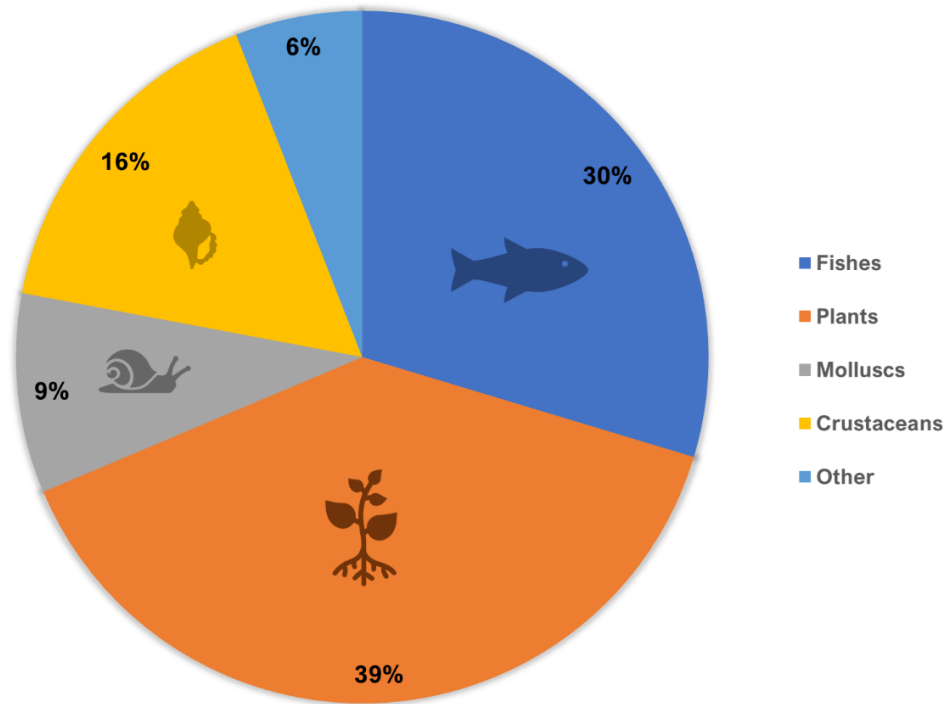
For the seven high risk watercraft that were confirmed to be transporting invasive mussels, their waterbodies of last launch were located in Minnesota (3 watercraft), Nebraska (2), Illinois (1), and Texas (1; Figure 13). Only three of the reported waterbodies of last launch for these seven watercraft were known to be positive for Zebra Mussel. For destination waterbodies, only six watercraft were reportedly heading to a waterbody, with one watercraft heading to a private residence. The recorded destination waterbodies were Lake Winnipeg, Cedar Lake, and the Saskatchewan River in Manitoba and Lac Seul, Big Sand Lake, and Red Lake in Ontario. Although Lake Winnipeg and Cedar Lake have established populations of Zebra Mussel, the Saskatchewan River and the three Ontarian destination waterbodies are not yet known to have established populations of Zebra Mussel and could have been at risk of a novel introduction had these watercraft not been intercepted at the Emerson POE. All seven of these high risk watercraft were refused entry or successfully decontaminated to prevent the spread of invasive mussels into Canadian waters.



**Figure 13.** Origin (yellow) and destination (blue) waterbodies for invasive mussel watercraft inspected at the Emerson POE (black star) during the 2023 season.

### AIS Interceptions

Of the 249 AIS established in the origin waterbodies encountered during this study (USGS 2023), a total of 118 were identified as species that could be introduced into Manitoba via overland watercraft transport (Figure 14). Many of these species are resistant to desiccation and can reproduce asexually, with few individuals required to create a viable population. The watercraft inspected during this season could have had an environment conducive to the survival of these AIS and several watercraft indeed harbored some of these invaders (e.g., Zebra Mussel). This AIS species list (see Appendix 3) is by no means comprehensive, derived from only 467 of the possible 847 data points with modelling criteria that are simple and generalized.



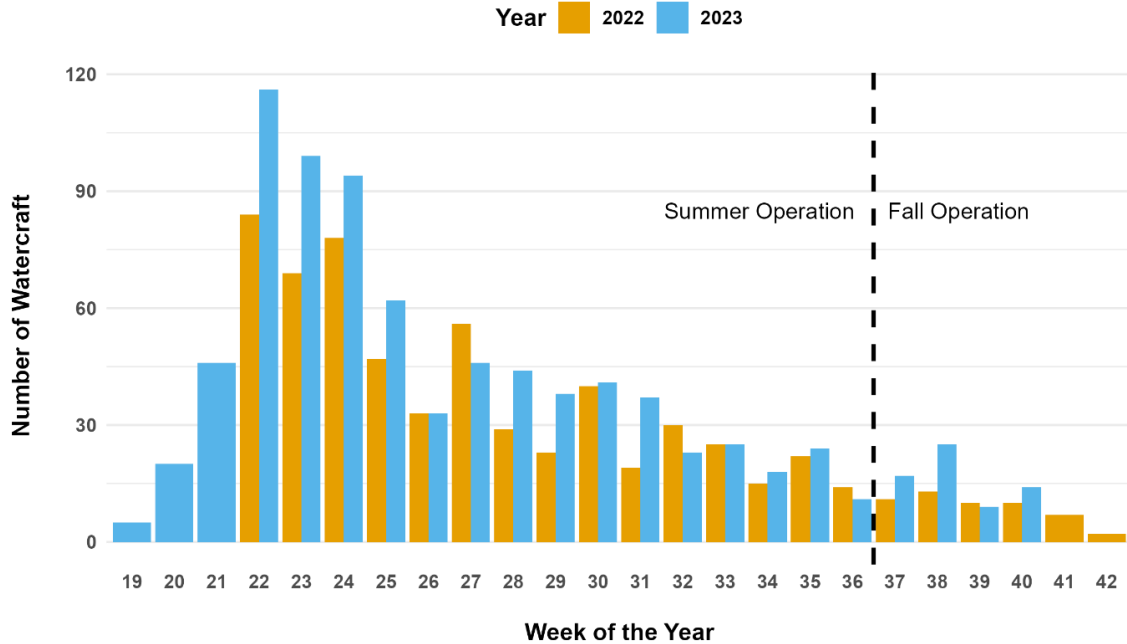
**Figure 14.** AIS by taxa in origin watersheds with access to the stowaway pathway and broad environmental tolerance in Manitoba, Canada.

When considering waterbodies with established populations of Zebra Mussel, 45% of watercraft reported to have last launched in a waterbody positive for Zebra Mussel. Of these watercraft, 51% were non-CDD, highlighting a subset of 195 watercraft with the potential to be high risk for transporting various life stages of Zebra Mussel (see Appendix 4).

### Multiyear Snapshot

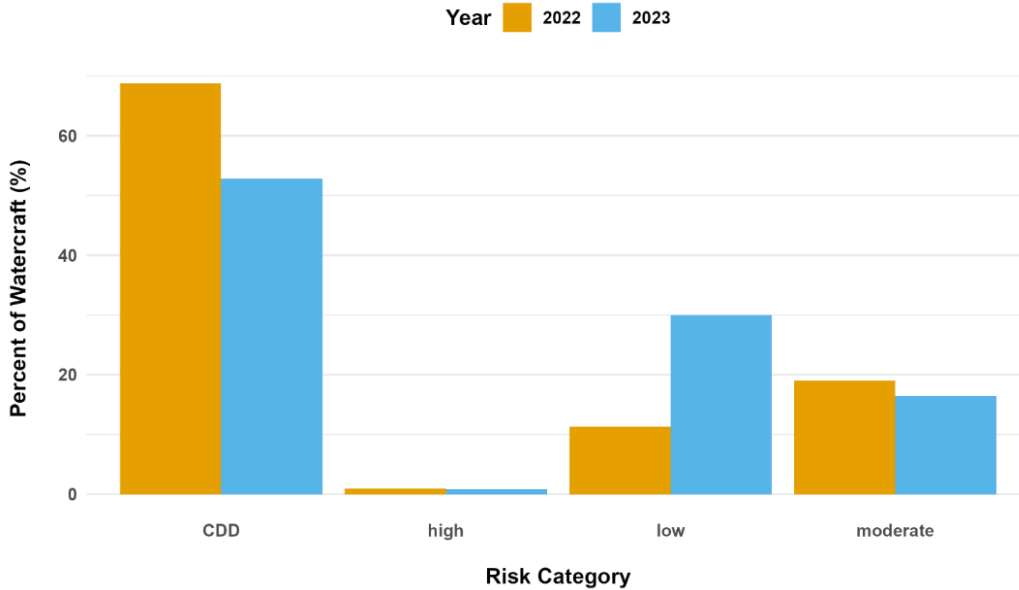
There are some notable differences between the first two seasons of the watercraft inspection and decontamination program (Brougham et al. 2025). Despite the significant reduction in hours of operation, 2023 still saw 33% more watercraft than 2022. One primary difference between the two years of operation that may have contributed to this increase in boat traffic was the lifting of COVID-19 travel restrictions for travellers entering Canada at highway POEs, which occurred on October 1, 2022 (PHAC 2022).

Beyond the overall lower numbers of watercraft inspected in 2022, there was little difference in watercraft traffic trends between years. When comparing weekly watercraft traffic, the pattern is similar between years, both sharing their peak on week 22 (Figure 15). However, in 2022, operation began on the busiest week of the season (week 22), which makes it difficult to infer the watercraft traffic trends for earlier in that season. An earlier operational start date of May 12 in 2023, to coincide with the beginning of the open water season, allowed DFO to track the increase in watercraft traffic up to the peak in week 22, which indicates that week 22 may be the true peak for both seasons.



**Figure 15.** Total number of watercraft inspected by week of the year in 2022 (orange) and 2023 (blue).

In terms of the proportion of CDD watercraft, the 2023 season had 16% less CDD watercraft than the 2022 pilot season (Figure 16). Although the proportion of CDD watercraft declined between years, 28% more watercraft were low risk and 26% less watercraft were moderate risk in 2023, meaning that a higher proportion of watercraft required a decontamination in 2022 than in 2023. For high risk watercraft, there was a 1% decrease in 2023. In contrast, the proportion of watercraft with invasive mussels actually increased by 1%, from 2% in 2022 to 3% in 2023.



**Figure 16.** Percent of watercraft per risk category in 2022 (orange) and 2023 (blue).

## CONCLUSION

Results from the 2023 watercraft inspection and decontamination season continue to demonstrate that a proportion of watercraft entering Canada through the Emerson, Manitoba POE do not meet the CDD requirements set out in CBSA's Memorandum D19-8-5. With the proportion of CDD watercraft dropping from 68% in 2022 to 53% in 2023, DFO saw an increase in the risk from these watercraft during the program's second season.

In contrast, CBSA recorded that 98% of watercraft had been reported by boaters as CDD. This 45% difference in reported versus observed compliance highlights the importance of physical watercraft inspections at highway POEs. This difference could also be indicative of a gap in understanding by boaters as to what it means for a watercraft to be CDD. This finding paired with the high numbers of watercraft coming from midwestern U.S. states (Minnesota, Nebraska, South Dakota, North Dakota, and Iowa) provides DFO with a potential target audience for awareness materials on what to expect when travelling into Canada with a watercraft.

Assessments of the reasons for watercraft failure can also provide insight into areas to focus outreach around CDD requirements. The most common reasons for inspection failure were consistently the presence of standing water and/or unremoved drain plugs. This finding highlights a gap in compliance by boaters encountered at the Emerson POE and an opportunity for outreach. Ensuring watercraft are clean and free of AIS is the first and most important step, however, it appears that many boaters encountered by DFO at the Emerson POE may not understand the importance of drying all standing water and ensuring that any drain plugs are removed prior to travel. Additionally, failure was often detected in the bilge and engine areas of watercraft. Educating boat users on the importance of checking every compartment and draining their engine prior to leaving a waterbody may help bridge this compliance gap. The reasons for inspection failure are also helpful indicators for training seasonal staff.

Invasive mussels were detected on seven watercraft throughout the 2023 season. Detections of these high risk watercraft occurred on six weekends throughout the summer. As was the case with results from the 2022 season, increased numbers of watercraft passing through the Emerson POE did not necessarily correlate with increased numbers of watercraft with invasive mussels. Six of the seven watercraft with invasive mussels were detected on weeks with relatively low numbers of watercraft passing through DFO's inspection station. This result highlights the importance of physical inspections even on non-peak weekends. Additionally, the increase in invasive mussels later in the season could be correlated with the seasonality of boat usage. As the season progressed, more watercraft were being detected with invasive mussels, likely due to increased usage of watercraft by water users. In addition, 45% of watercraft had been reported to have last launched in a waterbody invaded by Zebra Mussel.

Travel distances for boaters ranged from 267 km to 4,922 km in 2023 with an average distance of 1,441 km. Watercraft travelled from across the U.S., with an emphasis on the midwestern states, to come into Canada with their watercraft. The distances travelled by these boaters is not often captured in literature, since most of those recorded trips tend to be under 200km (Drake 2017). This subset provides an opportunity for further study regarding the patterns of compliance and movement for long-haul boating trips across North America. To expand this

dataset, data collection from other POEs across the Canadian-U.S. international border would be required to assess the volume of watercraft travelling into Canada through highway POEs.

Based on the origin locations of all inspected watercraft, 118 established AIS could be transported by non-CDD watercraft. For Zebra Mussel invaded waterbodies, 45% of watercraft were reportedly coming to Canada after launching in a waterbody known to have established populations of the high risk invader. The 51% of these watercraft that were non-CDD represent a subset of watercraft at risk of spreading viable Zebra Mussel into Canada, if not properly decontaminated prior to launching. As was the case in 2022, this high-level review of potential stowaway species intercepted by the Emerson inspection and decontamination station highlights the abundance of species that may be transported into Canada via international travellers with watercraft. This analysis illustrates the importance of promoting AIS awareness and CDD measures to better prevent AIS from becoming established in Canadian waters.

Findings from the Emerson watercraft inspection and decontamination station in 2023 provide a first step to understanding the risk that highway POEs pose to Canadian waters by monitoring boater compliance with requirements set out under Memorandum D19-8-5 and the *Aquatic Invasive Species Regulations*. With results indicating a high volume of seasonal watercraft traffic travelling through the Emerson POE, a proportion of which are non-CDD or even carrying prohibited species, continued operations of physical watercraft inspection and decontamination at this POE is recommended. Understanding the true risk of highway POEs to the broader Ontario and Prairie Region, and Canada as a whole, will require additional data from other POEs on the volume of watercraft entering Canada and the CDD compliance of these watercraft.

## **ACKNOWLEDGEMENTS**

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Finally, a special thanks to Roxie Remillard and the entire CBSA team at the Emerson, Manitoba international POE for their ongoing support and partnership on this watercraft inspection and decontamination program.

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# APPENDIX 1. DFO-CBSA WATERCRAFT DATA COLLECTION FORM



Fisheries and Oceans Canada / Pêches et Océans Canada

Inspection ID: EM/BO – DDMMYY – ###

## Watercraft Cross-Border Transportation Form

Section A: Triage Questions – Completed by CBSA			
Date:	Time In:	POE:	Number of Boats:
When was the last time the boat was in the water: <input type="checkbox"/> 30 days or less <input type="checkbox"/> More than 30 days ago			
If 30 days or less; what was State or Province of last use? _____			
Is this State or Province free of AIS (refer to list on reverse)? <input type="checkbox"/> Yes <input type="checkbox"/> No			
Is the watercraft CLEAN, DRAIN, and DRY? <input type="checkbox"/> Yes <input type="checkbox"/> No			
Are all drain plugs removed on the watercraft? <input type="checkbox"/> Yes <input type="checkbox"/> No			
Is any person in possession of live bait? (In the vehicle, watercraft, etc.) <input type="checkbox"/> Yes <input type="checkbox"/> No			
Section B: Secondary Inspection – Completed by DFO			Commercial Shipment: <input type="checkbox"/> Yes <input type="checkbox"/> No
Traveller Name:		Phone:	Vehicle Plate:
Trailer Plate:	Registration No.:		Plate State/Prov:
Destination Waterbodies:			
Nearest Town:		State/Prov:	
Purpose of Trip: <input type="checkbox"/> Angling <input type="checkbox"/> Boating <input type="checkbox"/> Hunting <input type="checkbox"/> Other: _____			
Length of Stay <input type="checkbox"/> < 1 week <input type="checkbox"/> 1-2 weeks <input type="checkbox"/> > 2 weeks <input type="checkbox"/> Indefinitely			
Watercraft Type: <input type="checkbox"/> Outboard Motor <input type="checkbox"/> Pontoon <input type="checkbox"/> Simple Boat – No Motor			
Ballast Tanks? <input type="checkbox"/> Inboard Motor <input type="checkbox"/> Jet Boat <input type="checkbox"/> Inboard Outboard (I/O)			
<input type="checkbox"/> PWC / Jetski <input type="checkbox"/> SUP Paddleboard <input type="checkbox"/> Ski / Wakeboard Boat			
<input type="checkbox"/> Sailboat <input type="checkbox"/> Canoe or Kayak <input type="checkbox"/> Other: _____			
Was the watercraft inspected for AIS on this <u>current</u> trip? <input type="checkbox"/> Yes, inspected in: _____ <input type="checkbox"/> No			
Any watercraft seals or receipts observed? <input type="checkbox"/> Yes, from: _____ <input type="checkbox"/> No			
Have you been inspected at this station before? <input type="checkbox"/> Yes, this year <input type="checkbox"/> Yes, past year: _____ <input type="checkbox"/> No			
When was the last time the boat was in the water: <input type="checkbox"/> 30 days or less <input type="checkbox"/> More than 30 days ago			
If 30 days or less; was the State of Province of last use free of AIS? (see list on reverse) <input type="checkbox"/> Yes <input type="checkbox"/> No			
Last Waterbody:		Nearest Town:	State/Prov:
Watercraft Residence (State/Prov):			
Resale or Rental? <input type="checkbox"/> Yes, rental <input type="checkbox"/> Yes, purchased in U.S. <input type="checkbox"/> Yes, being sold in Canada <input type="checkbox"/> No			
Inspection Outcome			
Clean, Drain, Dry? <input type="checkbox"/> Yes <input type="checkbox"/> No*		Reason for Failure: <input type="checkbox"/> Not Clean <input type="checkbox"/> Not Drain <input type="checkbox"/> Not Dry	
*Complete Section C on reverse		<input type="checkbox"/> Suspected/Confirmed AIS: _____	
Action Taken: <input type="checkbox"/> Decontamination* <input type="checkbox"/> Refused Entry <input type="checkbox"/> Other: _____			
Notes:			
Specimen Sample No.: <u>EM / BO – DDMMYY – ### – A</u>		eDNA Sample No.: <u>EM / BO – DDMMYY – ### – A</u>	
Officer / Interviewer:		Inspection Staff:	

Figure A1.1. DFO-CBSA inspection and data collection form from the 2023 season (page 1).



## Watercraft Cross-Border Transportation Form

States without Zebra Mussel				
Alaska	Hawaii	New Mexico	Oregon	
North Carolina	Idaho	New Jersey	Rhode Island	Georgia
Delaware	Maine	New Hampshire	South Carolina	Montana
Florida	Wyoming	Nevada	Washington	

Section C: Failed Inspection Details				
H	E		A	D
hull and trailer	engine compartment		anchor, gear, and interior	drain plugs removed
<input type="checkbox"/> <b>Not Clean</b>	<input type="checkbox"/> AIS: _____	<input type="checkbox"/> Aquatic Plants	<input type="checkbox"/> Live well	<input type="checkbox"/> Hull
	<input type="checkbox"/> Aquatic Organisms	<input type="checkbox"/> Mud and/or Dirt (aquatic)	<input type="checkbox"/> Bilge	<input type="checkbox"/> Gear
			<input type="checkbox"/> Engine	<input type="checkbox"/> Gen. Interior: _____
			<input type="checkbox"/> Trailer	<input type="checkbox"/> Other: _____
<input type="checkbox"/> <b>Not Drain</b>	<input type="checkbox"/> Main (bilge)	<input type="checkbox"/> Live well	<input type="checkbox"/> Other: _____	
<input type="checkbox"/> <b>Not Dry</b> (standing water)	<input type="checkbox"/> Livewell	<input type="checkbox"/> Bilge	<input type="checkbox"/> Gen. Interior: _____	
	<input type="checkbox"/> Engine	<input type="checkbox"/> Gear	<input type="checkbox"/> Other: _____	
Section D: Decontamination Details				
Decontamination Completed By: _____			Decontamination Direction No.: _____	
Watercraft Seal: <input type="checkbox"/> Yes, Green: _____ <input type="checkbox"/> Yes, Black: _____ <input type="checkbox"/> No				
Full Decontamination? <input type="checkbox"/> Yes <input type="checkbox"/> No		If no, select all areas that <u>were</u> decontaminated:		
		<input type="checkbox"/> Hull	<input type="checkbox"/> Anchor, rope, & rigging	
		<input type="checkbox"/> Trailer	<input type="checkbox"/> Live wells	
		<input type="checkbox"/> Engine Flush	<input type="checkbox"/> Transom wells	
		<input type="checkbox"/> Gimbal Area	<input type="checkbox"/> Fishing equipment	
		<input type="checkbox"/> Water related gear	<input type="checkbox"/> Ballast Tanks	
Decontamination Notes (e.g., if not fully decontaminated, why?): _____ _____				

Figure A1.2. DFO-CBSA inspection and data collection form from the 2023 season (page 2).

## APPENDIX 2. STATE AND PROVINCE ABBREVIATIONS

**Table A2.1.** U.S. states and their abbreviations.

<b>State</b>	<b>Abbreviation</b>	<b>State</b>	<b>Abbreviation</b>
Alabama	AL	Montana	MT
Alaska	AK	Nebraska	NE
Arizona	AZ	Nevada	NV
Arkansas	AR	New Hampshire	NH
California	CA	New Jersey	NJ
Colorado	CO	New Mexico	NM
Connecticut	CT	New York	NY
Delaware	DE	North Carolina	NC
District of Columbia	DC	North Dakota	ND
Florida	FL	Ohio	OH
Georgia	GA	Oklahoma	OK
Hawaii	HI	Oregon	OR
Idaho	ID	Pennsylvania	PA
Illinois	IL	Puerto Rico	PR
Indiana	IN	Rhode Island	RI
Iowa	IA	South Carolina	SC
Kansas	KS	South Dakota	SD
Kentucky	KY	Tennessee	TN
Louisiana	LA	Texas	TX
Maine	ME	Utah	UT
Maryland	MD	Vermont	VT
Massachusetts	MA	Virginia	VA
Michigan	MI	Washington	WA
Minnesota	MN	West Virginia	WV
Mississippi	MS	Wisconsin	WI
Missouri	MO	Wyoming	WY

**Table A2.2.** Canadian provinces referenced in this report and their abbreviations.

<b>State</b>	<b>Abbreviation</b>	<b>State</b>	<b>Abbreviation</b>
Alberta	AB	Ontario	ON
British Columbia	BC	Quebec	QC
Manitoba	MB	Saskatchewan	SK
Nunavut	NU	-	-

### APPENDIX 3. AQUATIC INVASIVE SPECIES LIST

**Table A3.1.** List of stowaway pathway invasive fishes found in origin watersheds (USGS NAS) that could be found above 40°N. Includes listing under Canadian AIS legislation (AISR = Federal *Aquatic Invasive Species Regulations*; MB = Manitoba's *Aquatic Invasive Species Regulation*; SK = *The Saskatchewan Fisheries Regulations*; AB = Alberta's *Fisheries Act*).

Scientific Name	Common Name	AISR	MB	SK	AB
<i>Alosa pseudoharengus</i>	Alewife	MB	X	-	X
<i>Ameiurus catus</i>	White Catfish	MB	X	-	-
<i>Aphredoderus sayanus</i>	Pirate Perch	-	-	-	-
<i>Astyanax mexicanus</i>	Mexican Tetra	-	-	-	-
<i>Carassius auratus</i>	Goldfish	-	-	-	-
<i>Chrosomus oreas</i>	Mountain Redbelly Dace	-	-	-	-
<i>Ctenopharyngodon idella</i>	Grass Carp	-	-	-	-
<i>Cyprinodon variegatus</i>	Sheepshead Minnow	-	-	-	-
<i>Dorosoma cepedianum</i>	Gizzard Shad	-	-	-	-
<i>Dorosoma petenense</i>	Threadfin Shad	-	-	-	-
<i>Fundulus catenatus</i>	Northern Studfish	-	-	-	-
<i>Fundulus zebrinus</i>	Plains Killifish	-	-	-	-
<i>Gambusia affinis</i>	Western Mosquitofish	MB	X	-	X
<i>Gambusia holbrooki</i>	Eastern Mosquitofish	-	-	-	-
<i>Gasterosteus aculeatus</i>	Threespine Stickleback	MB	X	-	-
<i>Hypentelium nigricans</i>	Northern Hog Sucker	-	-	-	-
<i>Hypophthalmichthys molitrix</i>	Silver Carp	Canada	X	X	X
<i>Hypophthalmichthys nobilis</i>	Bighead Carp	Canada	-	X	X
<i>Labidesthes sicculus</i>	Brook Silverside	-	-	-	-
<i>Lepomis auritus</i>	Redbreast Sunfish	-	-	-	-
<i>Lepomis cyanellus</i>	Green Sunfish	MB	X	-	X
<i>Lepomis gulosus</i>	Warmouth	-	-	-	-
<i>Menidia beryllina</i>	Inland Silverside	-	-	-	-
<i>Micropterus punctulatus</i>	Spotted Bass	-	-	-	-
<i>Misgurnus anguillicaudatus</i>	Pond Loach	MB	X	-	X
<i>Morone americana</i>	White Perch	MB	X	-	X
<i>Morone mississippiensis</i>	Yellow Bass	ON, MB	X	X	X
<i>Morone saxatilis</i>	Striped Bass	-	-	-	-
<i>Mylopharyngodon piceus</i>	Black Carp	-	-	-	-
<i>Neogobius melanostomus</i>	Round Goby	-	-	-	-
<i>Nocomis micropogon</i>	River Chub	-	-	-	-
<i>Notropis boops</i>	Bigeye Shiner	-	-	-	-
<i>Oreochromis aureus</i>	Blue Tilapia	-	-	-	-
<i>Percina macrolepida</i>	Bigscale Logperch	-	-	-	-
<i>Scardinius erythrophthalmus</i>	Rudd	ON, MB	X	-	X

**Table A3.2.** List of stowaway pathway invasive plants found in origin watersheds (USGS NAS) that could be found above 40°N. Includes listing under Canadian AIS legislation (AISR = Federal *Aquatic Invasive Species Regulations*; MB = Manitoba's *Aquatic Invasive Species Regulation*; SK = *The Saskatchewan Fisheries Regulations*; AB = Alberta's *Fisheries Act*).

Scientific Name	Common Name	AISR	MB	SK	AB
<i>Alopecurus geniculatus</i>	Water Foxtail	-	-	-	-
<i>Arundo donax</i>	Giantreed	-	-	-	-
<i>Butomus umbellatus</i>	Flowering Rush	-	X	-	X
<i>Cabomba caroliniana</i>	Carolina Fanwort	-	-	-	-
<i>Callitriche stagnalis</i>	Pond Water-Starwort	-	-	-	-
<i>Carex acutiformis</i>	Lesser Pond Sedge	-	-	-	-
<i>Ceratopteris thalictroides</i>	Watersprite	-	-	-	-
<i>Colocasia esculenta</i>	Wild Taro	-	-	-	-
<i>Cotula coronopifolia</i>	Common Brassbuttons	-	-	-	-
<i>Egeria densa</i>	Brazilian Waterweed	-	X	-	X
<i>Eichhornia crassipes</i>	Common Water-Hyacinth	-	X	-	-
<i>Glyceria maxima</i>	Reed Mannagrass	-	-	-	-
<i>Heteranthera limosa</i>	Mud Plantain	-	-	-	-
<i>Hydrilla verticillata</i>	Hydrilla	-	X	-	X
<i>Hydrocharis morsus-ranae</i>	European Frogbit	-	X	-	X
<i>Hydrocotyle ranunculoides</i>	Floating Marsh Pennywort	-	-	-	-
<i>Iris pseudacorus</i>	Yellow Iris	-	X	-	X
<i>Landoltia punctata</i>	Dotted Duckweed	-	-	-	-
<i>Ludwigia grandiflora</i>	Large-Flower Primrose-Willow	-	-	-	-
<i>Ludwigia hexapetala</i>	Six Petal Water Primrose	-	-	-	-
<i>Ludwigia peploides</i>	Floating Primrose-Willow	-	-	-	-
<i>Ludwigia peruviana</i>	Peruvian Primrose-Willow	-	-	-	-
<i>Lycopus europaeus</i>	European Bugleweed	-	-	-	-
<i>Lysimachia nummularia</i>	Creeping Jenny	-	-	-	-
<i>Lysimachia punctata</i>	Large Yellow Loosestrife	-	-	-	-
<i>Lythrum hyssopifolia</i>	Hyssop Loosestrife	-	-	-	-
<i>Lythrum salicaria</i>	Purple Loosestrife	-	X	-	X
<i>Marsilea mutica</i>	Australian Water-Clover	-	-	-	-
<i>Marsilea quadrifolia</i>	European Water-Clover	-	-	-	-
<i>Mentha aquatica</i>	Water Mint	-	-	-	-
<i>Murdannia keisak</i>	Marsh Dewflower	-	-	-	-
<i>Myriophyllum aquaticum</i>	Parrot Feather	-	X	-	-
<i>Myriophyllum spicatum</i>	Eurasian Watermilfoil	-	X	-	X
<i>Najas marina</i>	Holly-Leaf Waternymph	-	-	-	-
<i>Najas minor</i>	Brittle Waternymph	-	X	-	-
<i>Nymphoides peltata</i>	Yellow Floating-Heart	-	X	-	X
<i>Oenanthe javanica</i>	Java Waterdropwort	-	-	-	-
<i>Panicum repens</i>	Torpedo Grass	-	-	-	-
<i>Phragmites australis australis</i>	Common Reed	-	X	-	X

<i>Pistia stratiotes</i>	Water Lettuce	-	X	-
<i>Potamogeton crispus</i>	Curly-Leaf Pondweed	-	X	X
<i>Rorippa sylvestris</i>	Keek	-	-	-
<i>Salvinia minima</i>	Water Spangles	-	-	-
<i>Schoenoplectiella mucronata</i>	Bog Bulrush	-	-	-
<i>Typha domingensis</i>	Southern Cattail	-	-	-
<i>Veronica beccabunga</i>	European Speedwell	-	-	-

**Table A3.3.** List of stowaway pathway invasive molluscs found in origin watersheds (USGS NAS) that could be found above 40°N. Includes listing under Canadian AIS legislation (AISR = Federal *Aquatic Invasive Species Regulations*; MB = Manitoba's *Aquatic Invasive Species Regulation*; SK = *The Saskatchewan Fisheries Regulations*; AB = Alberta's *Fisheries Act*).

Scientific Name	Common Name	AISR	MB	SK	AB
<i>Bithynia tentaculata</i>	Faucet Snail	MB	X	X	X
<i>Cipangopaludina chinensis</i>	Chinese Mystery Snail	MB	X	X	X
<i>Cipangopaludina japonica</i>	Japanese Mystery Snail	-	-	-	-
<i>Corbicula fluminea</i>	Basket Clam	MB	X	X	X
<i>Corbicula largillierti</i>	Yangtze Basket Clam	-	-	-	-
<i>Dreissena bugensis</i>	Quagga Mussel	Canada	X	X	X
<i>Dreissena polymorpha</i>	Zebra Mussel	Canada	X	X	X
<i>Eupera cubensis</i>	Mottled Fingernail Clam	-	-	-	-
<i>Pomacea canaliculata</i>	Channeled Applesnail	-	X	X	X
<i>Potamopyrgus antipodarum</i>	New Zealand Mudsnail	MB	X	X	X
<i>Viviparus georgianus</i>	Banded Mystery Snail	-	-	-	-

**Table A3.4.** List of stowaway pathway invasive crustaceans found in origin watersheds (USGS NAS) that could be found above 40°N. Includes listing under Canadian AIS legislation (AISR = Federal *Aquatic Invasive Species Regulations*; MB = Manitoba's *Aquatic Invasive Species Regulation*; SK = *The Saskatchewan Fisheries Regulations*; AB = Alberta's *Fisheries Act*).

Scientific Name	Common Name	AISR	MB	SK	AB
<i>Apocorophium lacustre</i>	Scud	-	-	-	-
<i>Argulus japonicus</i>	Japanese Fishlouse	-	-	-	-
<i>Bythotrephes longimanus</i>	Spiny Waterflea	MB	X	X	X
<i>Caecidotea racovitzai</i>	<i>Caecidotea racovitzai</i>	-	-	-	-
<i>Crangonyx pseudogracilis</i>	Northern River Crangonyctid	-	-	-	-
<i>Daphnia lumholtzi</i>	African Spiny Waterflea	-	-	-	-
<i>Echinogammarus ischnus</i>	<i>Echinogammarus ischnus</i>	-	X	-	-
<i>Eriocheir sinensis</i>	Chinese Mitten Crab	Part 3	-	X	-
<i>Eubosmina coregoni</i>	Baltic Long-nosed Waterflea	-	X	-	-
<i>Eurytemora affinis</i>	<i>Eurytemora affinis</i>	-	-	-	-
<i>Exopalaemon modestus</i>	Siberian Prawn	-	-	-	-
<i>Faxonius luteus</i>	Golden Crayfish	-	-	-	-
<i>Faxonius neglectus neglectus</i>	Ringed Crayfish	-	-	-	-
<i>Faxonius propinquus</i>	Northern Clearwater Crayfish	-	-	-	-

<i>Faxonius rusticus</i>	Rusty Crayfish	-	-	-	-
<i>Hemimysis anomala</i>	Bloody Red Shrimp	Part 3	X	-	-
<i>Procambarus acutus</i>	White River Crayfish	-	-	-	-
<i>Procambarus clarkii</i>	Red Swamp Crayfish	MB	X	-	-
<i>Rhithropanopeus harrisii</i>	Harris Mud Crab	-	-	-	-

**Table A3.5.** List of stowaway pathway AIS that don't belong to the following four taxa (i.e., other taxa) that were found in origin watersheds (USGS NAS) and that could be found above 40°N. Includes listing under Canadian AIS legislation (AISR = Federal *Aquatic Invasive Species Regulations*; MB = Manitoba's *Aquatic Invasive Species Regulation*; SK = *The Saskatchewan Fisheries Regulations*; AB = Alberta's *Fisheries Act*).

Scientific Name	Common Name	AISR	MB	SK	AB
<i>Cordylophora caspia</i>	Freshwater Hydroid	-	-	-	-
<i>Craspedacusta sowerbii</i>	Freshwater Jellyfish	-	X	X	-
<i>Didymosphenia geminata</i>	Didymo	-	X	-	-
<i>Lophopodella carteri</i>	Asian Freshwater Bryozoan	-	-	-	-
<i>Nitellopsis obtusa</i>	Starry Stonewort	-	X	-	-
<i>Pectinatella magnifica</i>	Magnificent Bryozoan	-	-	-	-
<i>Urnatella gracilis</i>	Freshwater Goblet Worm	-	-	-	-

## APPENDIX 4. ZEBRA MUSSEL WATERBODY MAPPING

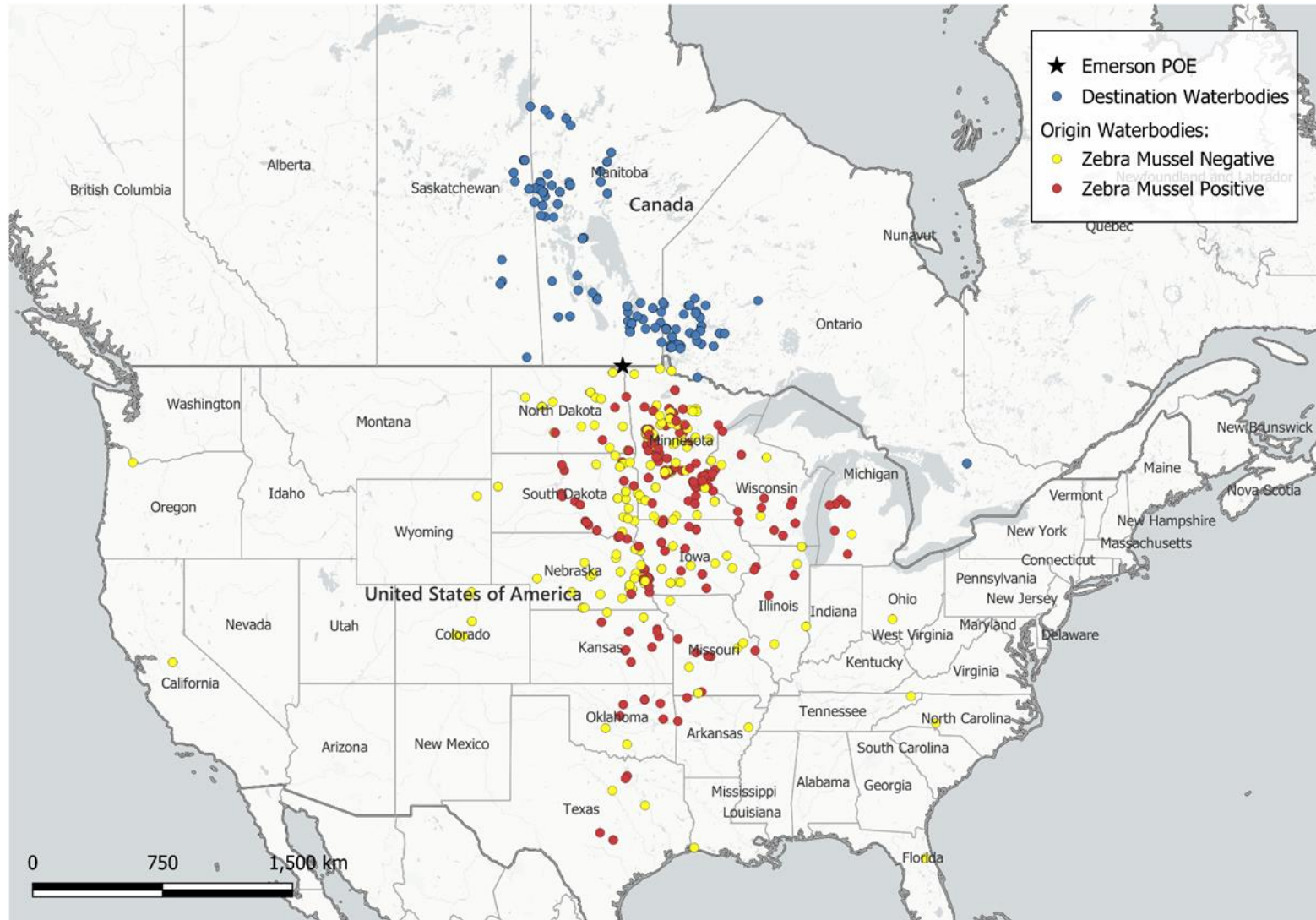


Figure A4.1. Destination waterbodies (blue) and origin waterbodies: positive for Zebra Mussel (red) and negative for Zebra Mussel (yellow).