Supporting Information for

Ballast water exchange plus treatment lowers species invasion rate in freshwater ecosystems

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Table S1. Sample size of voyages (n = 2,980) for each salinity combination within a given shipping pathway. Sample year indicates the timespan for which transit data were available for each region.

Recipient Port Salinity	Source Port Salinity	All Shipping Pathways	Great Lakes-St. Lawrence River International	Pacific International	Atlantic International	Arctic International	Arctic Domestic
	Fresh	87	67	9	11	0	0
Fresh	Brackish	77	58	17	2	0	0
	Marine	324	186	136	2	0	0
	Fresh	27	0	0	27	0	0
Brackish	Brackish	40	0	1	39	0	0
	Marine	59	0	26	33	0	0
	Fresh	458	0	105	329	4	20
Marine	Brackish	638	0	153	478	7	0
	Marine	1,270	0	940	307	18	5
		Sample Year	2006	2008	2006	2015	2015

Table S2. Number of empirical ballast water samples available with estimates of zooplankton abundance and species richness for each shipping pathway. Note that due to limited biological data, the Arctic domestic pathway used zooplankton data from ships arriving to the Arctic from Atlantic Canada, and from internal Great Lakes-St. Lawrence River transits.

Shipping Pathway	Number of Samples
Pacific International	50
Atlantic International	39
Great Lakes-St. Lawrence River International	19
Arctic International	31
Arctic Domestic	74

Table S3. Model parameters used to estimate the mean number of nonindigenous zooplankton species establishing in Canadian ecosystems.

		Shipping Pathway					
Model Parameter		Great Lakes-St. Lawrence River International	Pacific International	Atlantic International	Arctic International	Arctic Domestic* Atlantic	Arctic Domestic* GLSLR
Sample Concentration (Negative Binomial Distribution)	*size*	0.6297	0.2783	0.8268	0.2894	1.5618	0.4034
	μ	752.00	8861.66	13099.23	1661.77	77349.90	123550.70
Population Concentration Error		Poisson					
Proportion Nonindigenous (Beta)	α	0.7515	0.2302	0.1842	0.0973	1.0696	0.2411
	β	0.4004	2.9896	14.1509	0.4625	7.9209	1.1468
All Trips							
Probability Single Propagule Establishes (Beta)	α	0.005					
	β	5					
Allee Effect	c	1					

*The Arctic domestic pathway used zooplankton data from ships arriving to the Arctic from Atlantic Canada, and from internal Great Lakes-St. Lawrence River transits.

Table S4. Sensitivity analysis results.

			Transit Frequency		Mean Plankton Concentration μ		Mean Nonindigenous β		$\alpha = 0.005$	Allee Effect
Management Scenario	Null	Randomized Port Pairings	+25%	-25%	+25%	-25%	+25%	-25%	All Species	$c = 2$
NM	1.85	1.86	2.00	1.76	2.13	1.73	2.03	1.76	**54.63**	**3.98**
E	1.87	1.89	1.99	1.74	2.13	1.72	2.02	1.70	**54.32**	**3.92**
T (PE)	0.80	0.81	0.89	0.73	0.86	0.78	0.87	0.74	**22.29**	**1.78**
E+T (PE)	0.75	0.77	0.81	0.71	0.82	0.79	0.83	0.68	**20.83**	**1.69**
T (FE)	0.06	0.06	0.07	0.06	0.07	0.07	**0.08**	0.05	**0.48**	0.05
E+T (FE)	0.05	0.06	0.06	0.06	0.06	**0.07**	**0.07**	**0.03**	**0.35**	**0.03**

The response variable is the mean number of species per year among all Canadian ports (fresh, brackish, and marine) examined in this study. The management methods assessed are no management (NM), exchange only (E), treatment only (T), and exchange plus treatment (E+T). Ballast water treatment systems were either partially effective on half of the transits (PE) or fully effective on all transits (FE). An outcome with less or greater than 1:1 response indicates the model is insensitive or very sensitive to changes to a parameter. Outcomes with large deviations (>25% change) relative to the null are in bold.

Figure S1. The Canadian geographical regions with the shipping ports examined in this study. The four Canadian regions of interest are the Pacific, Atlantic, Great Lakes-St. Lawrence River (GLSLR), and Arctic. The Great Lakes-St. Lawrence River region includes all freshwater ports upstream of and including Québec City. The destination ports (n = 72) included in this study are displayed by the markers where their color and size represent their salinity category and number of arrivals, respectively.

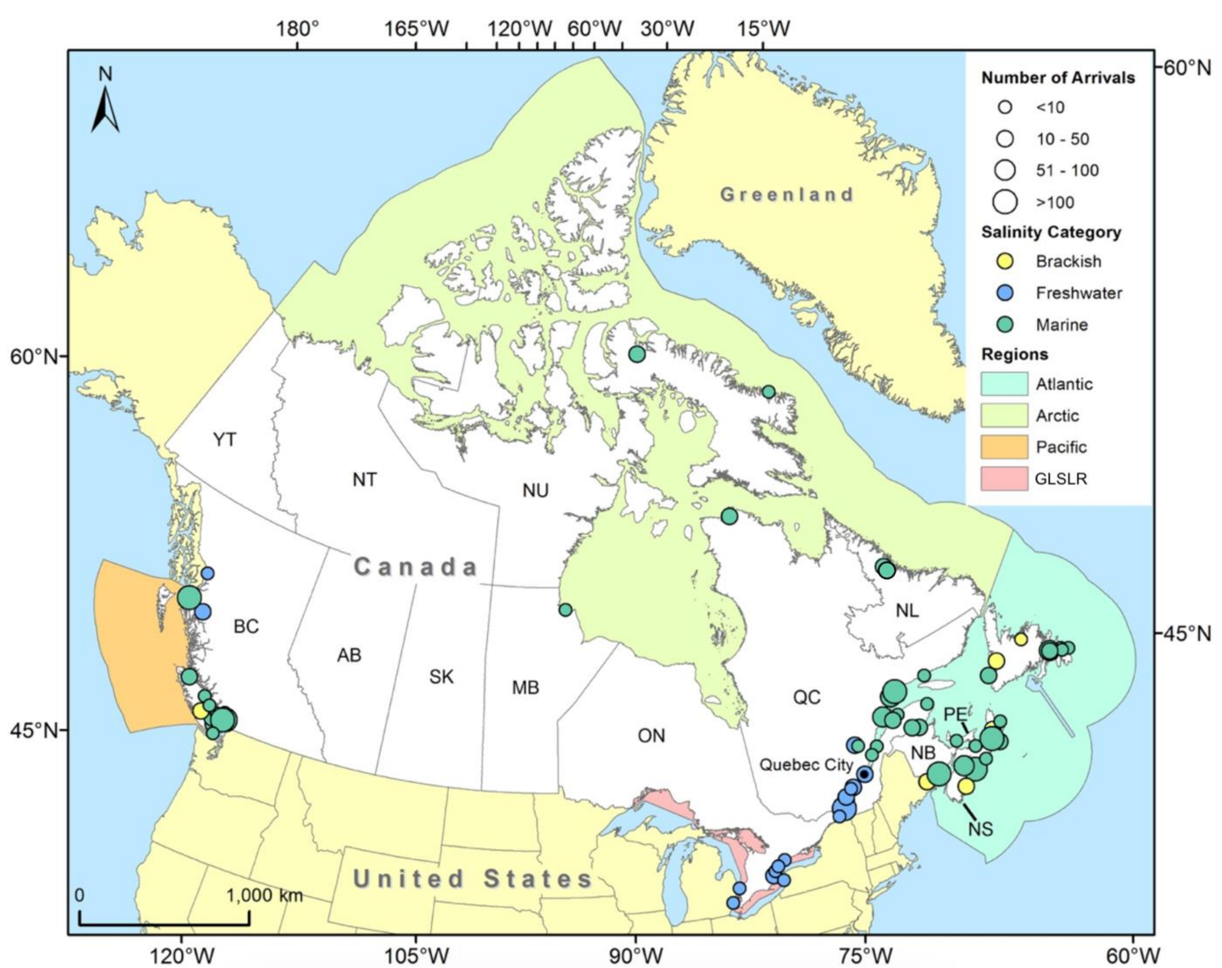

Figure S2. Probability distribution describing the zooplankton sample concentration (individuals per m^3) among ship transits within each shipping pathway. The Arctic domestic pathway used zooplankton data from ships arriving to the Arctic from Atlantic Canada (bottom right panel), and from internal Great Lakes-St. Lawrence River (GLSLR) transits (bottom left panel). The black lines represent the probability density function.

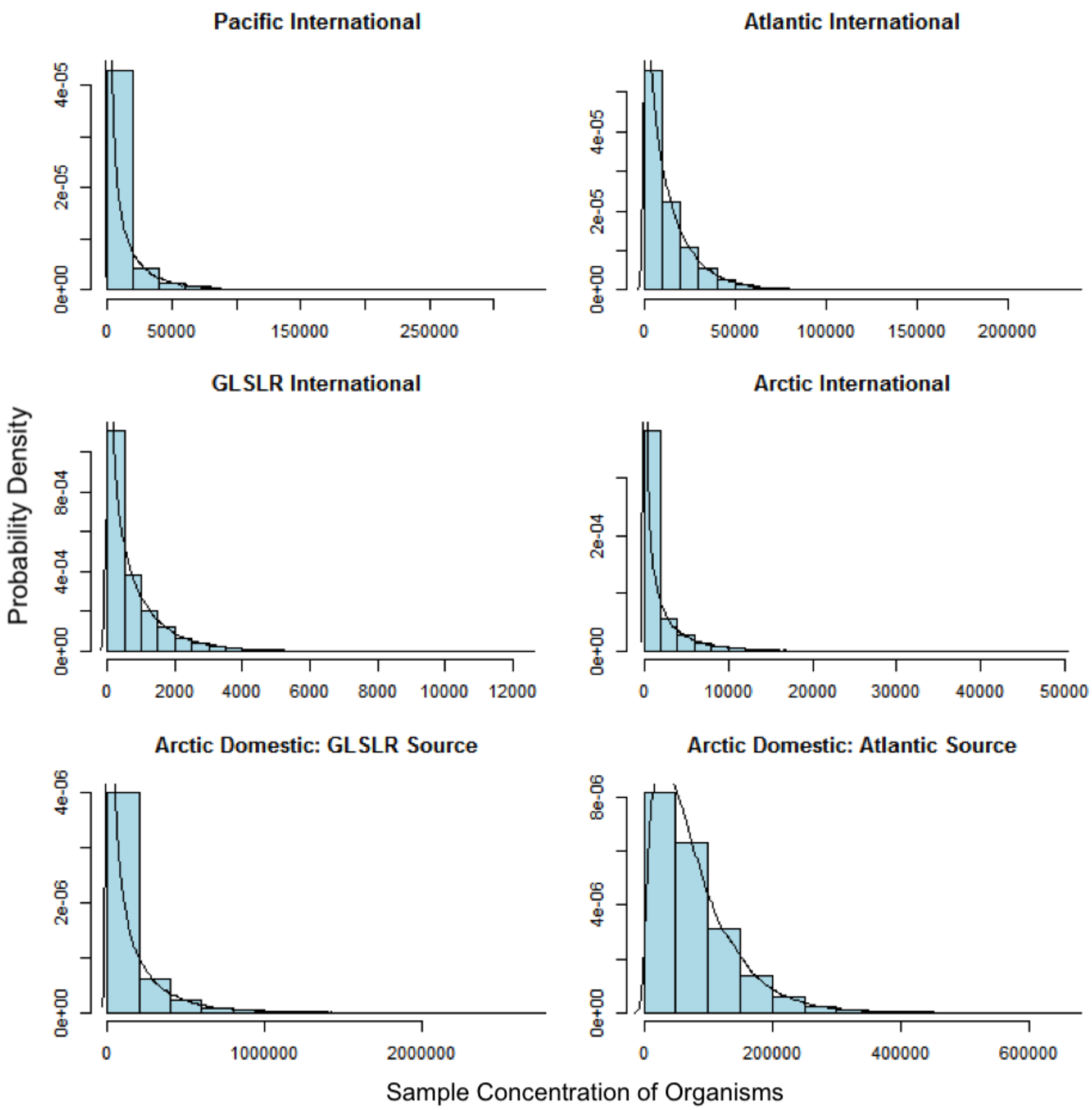

Figure S3. An example C_p | C_s distribution describing the population concentration of zooplankton in a single ship, with a sample concentration of 10,000 zooplankton per m^3.

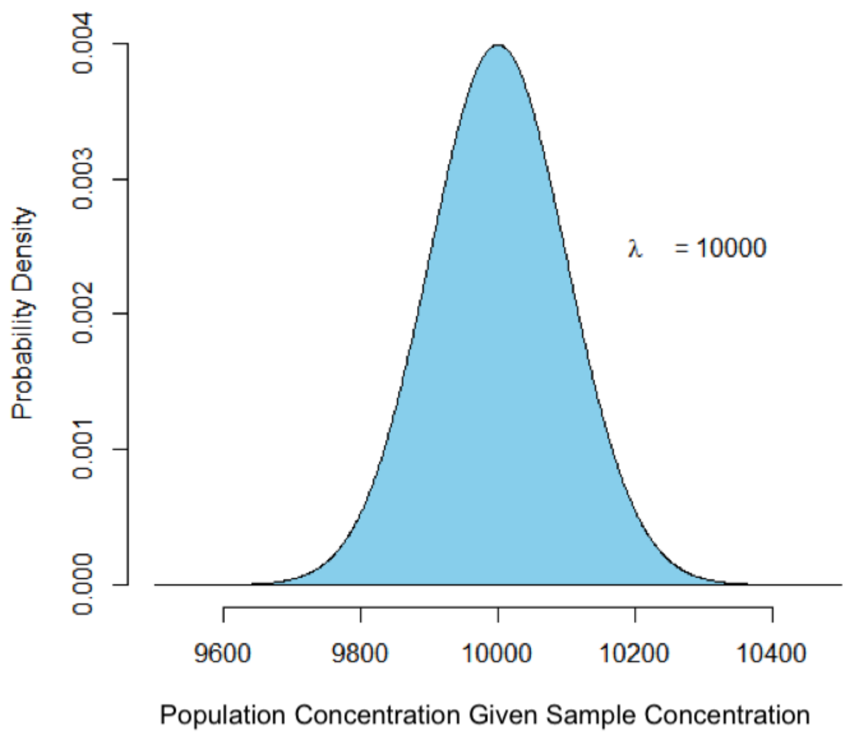

Figure S4. Probability distributions describing the proportion of nonindigenous zooplankton out of the total organism concentration among ship trips within each shipping pathway. The Arctic domestic pathway used zooplankton data from ships arriving to the Arctic from Atlantic Canada (bottom right panel), and from internal Great Lakes-St. Lawrence River (GLSLR) transits (bottom left panel). The black lines represent the probability density function.

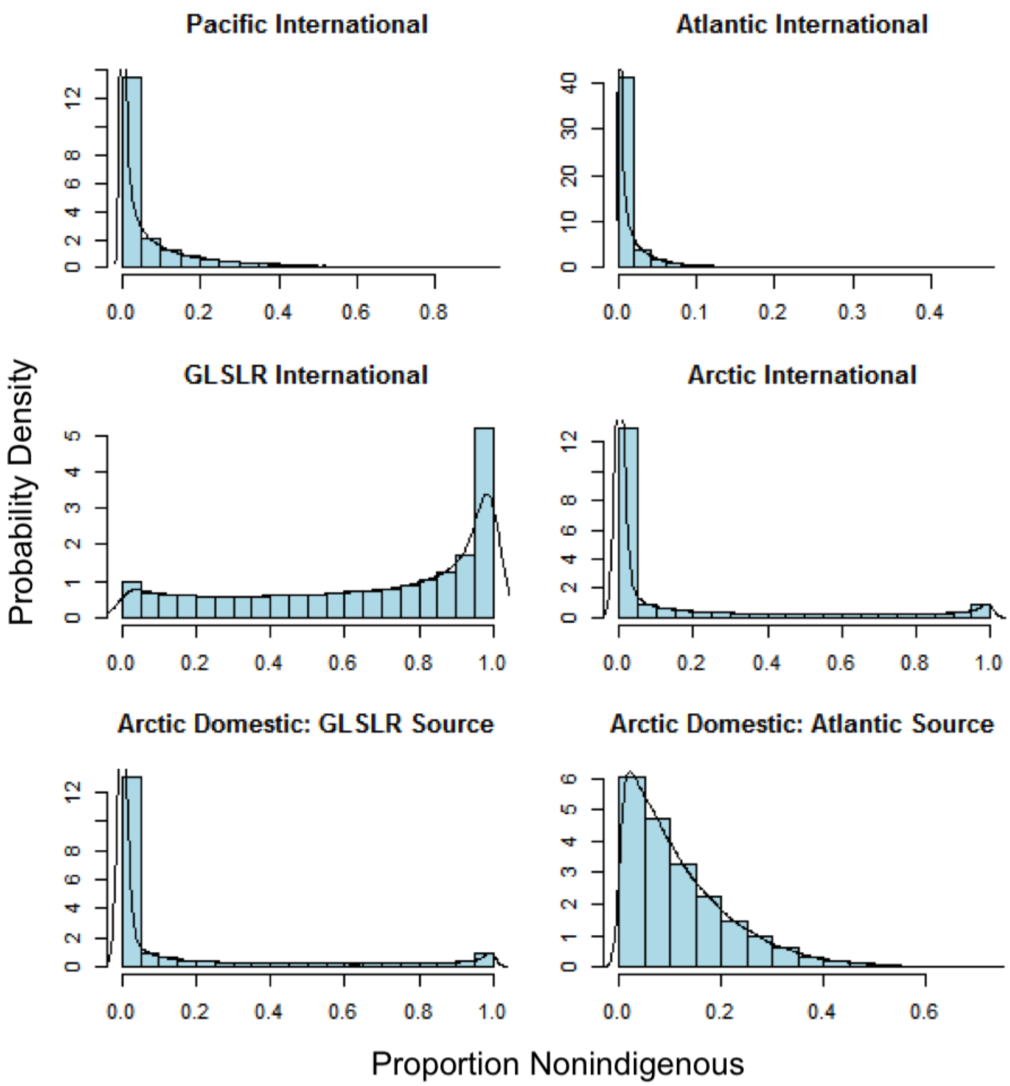

Figure S5. Environmental distance curve. P(Y=1) represents the probability of survival in the recipient environment given the temperature match between the source and recipient environments.

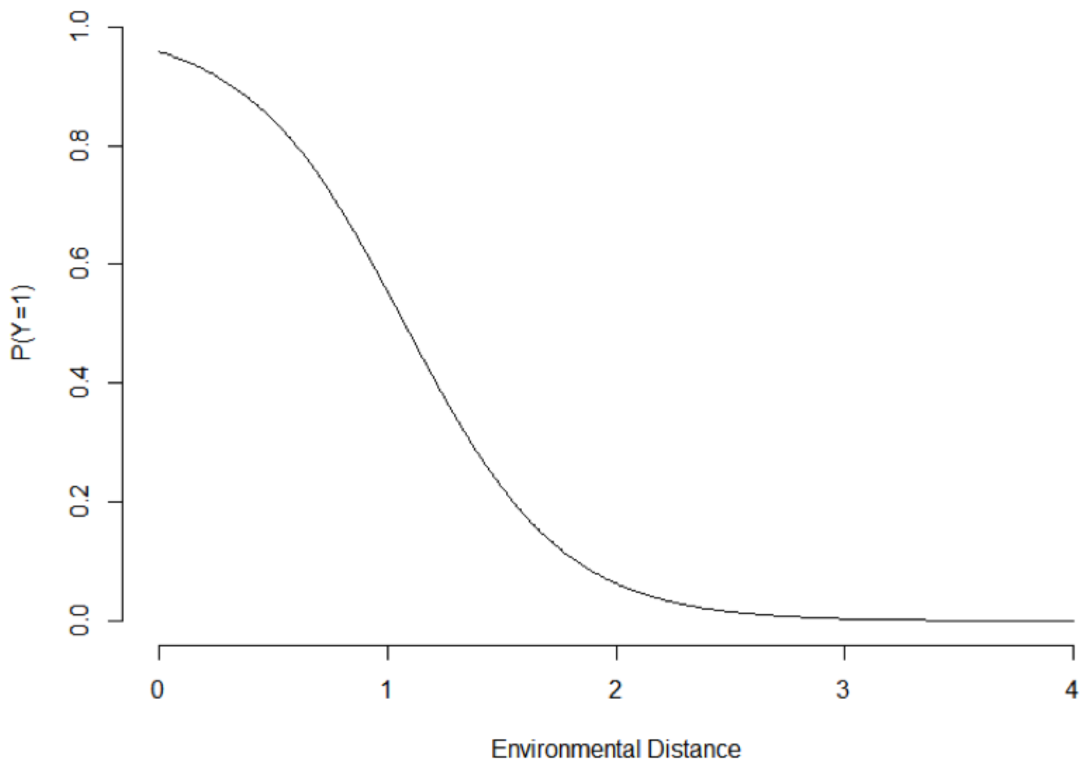

Figure S6. Examples of the probability of establishment based on the per-capita probability of establishment (α), initial organism concentration (individuals per m^3), and Allee effect (c).

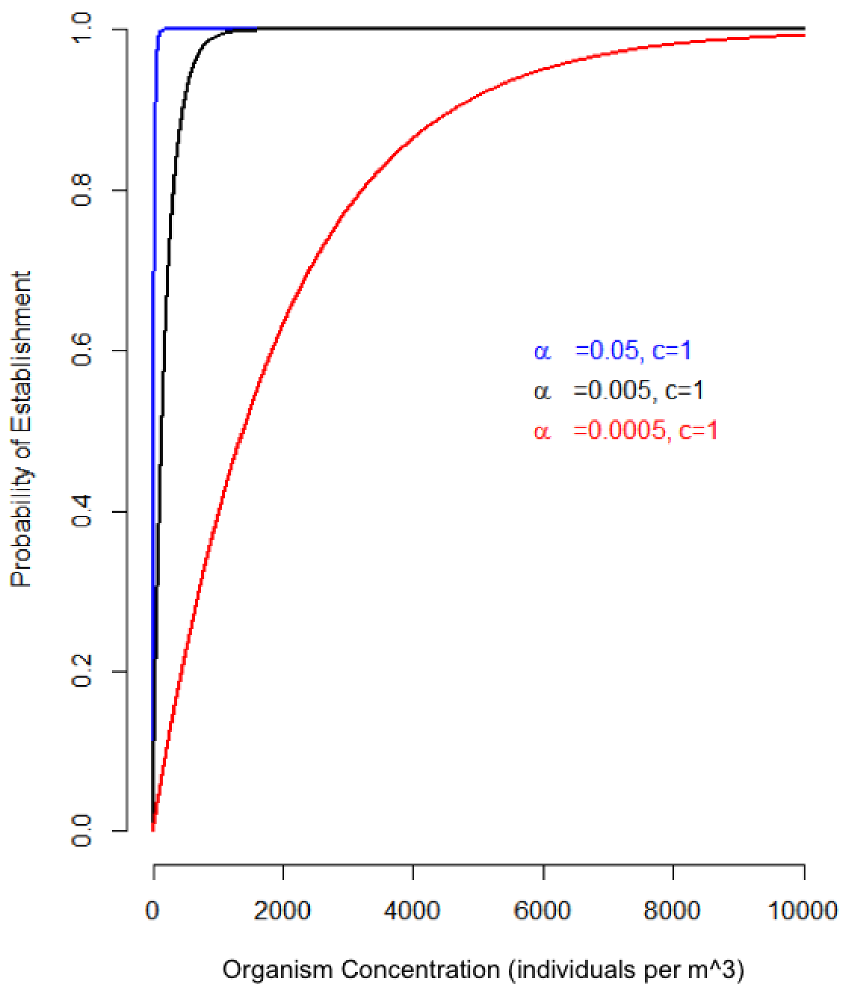

Figure S7. Probability distribution describing the per-capita probability of establishment (α) across multiple species in a ballast tank. This distribution was identical across all trips and shipping pathways.