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Research to understand efficacy of ballast water management systems in the Great Lakes and St. Lawrence River

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Scientific testing on operational ships

- To examine if ballast water managed using BWMS meets Regulation D-2
- Opportunistic sampling mainly in Vancouver and North American Great Lakes since 2017
- In-line continuous sampling and immediate analysis

Organism Size Class	Regulation D-2 Limit
≥50 µm **('large')**	<10 m^3
≥10 - 50 µm **('small')**	<10 mL^1
Indicator Microbes	*Not Assessed*

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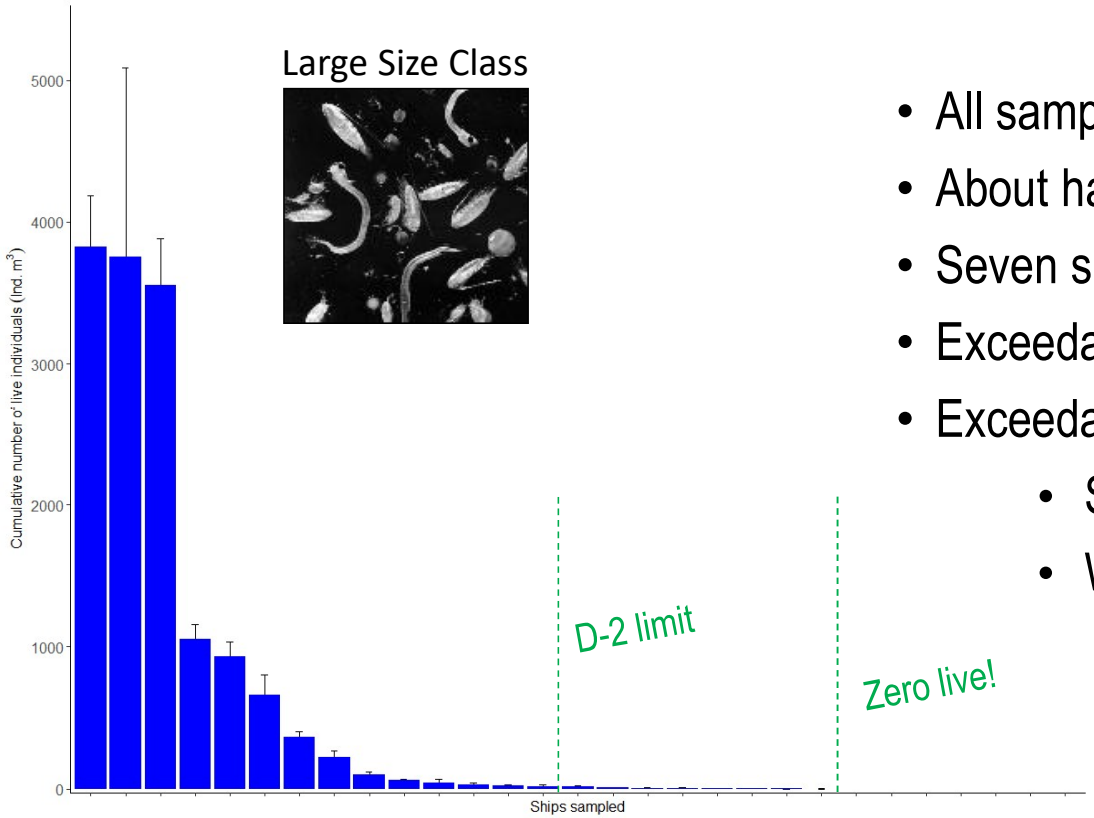
Discharge sampling results (2017-2018)



- All samples met D-2 limit for small size class (n=31)
- About half met D-2 limit for large size class (48%, n=29)
- Seven samples with zero live individuals observed
- Exceedances skewed, ranging from 29 - 3822 ind. per m^3
- Exceedances could be explained for three tests:
  - Subset of UV lamps at low intensity (x2)
  - Wrong chlorine dose / software updates needed

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Casas-Monroy & Bailey 2021; Bailey *et al.* 2022

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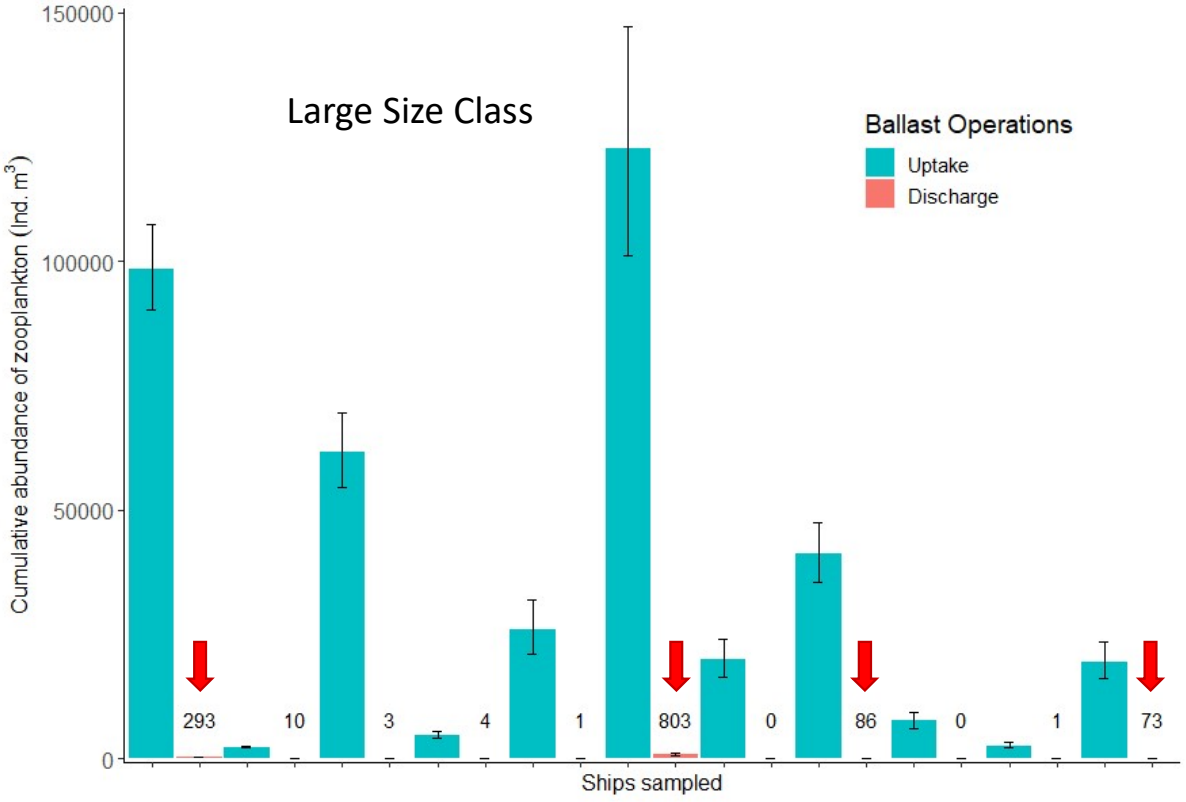
Before/after BWMS sampling (2019, 2022)



Data from Bailey *et al.* 2022

- Paired design to assess BWMS 'efficacy'
- Three UV- and one chlorine-BWMS
- All discharge samples met D-2 limit for small size class (n=11)
- Four discharge samples clearly exceed D-2 limit for large size class
- Large effect of treatment: abundances reduced ~99% compared to uptake

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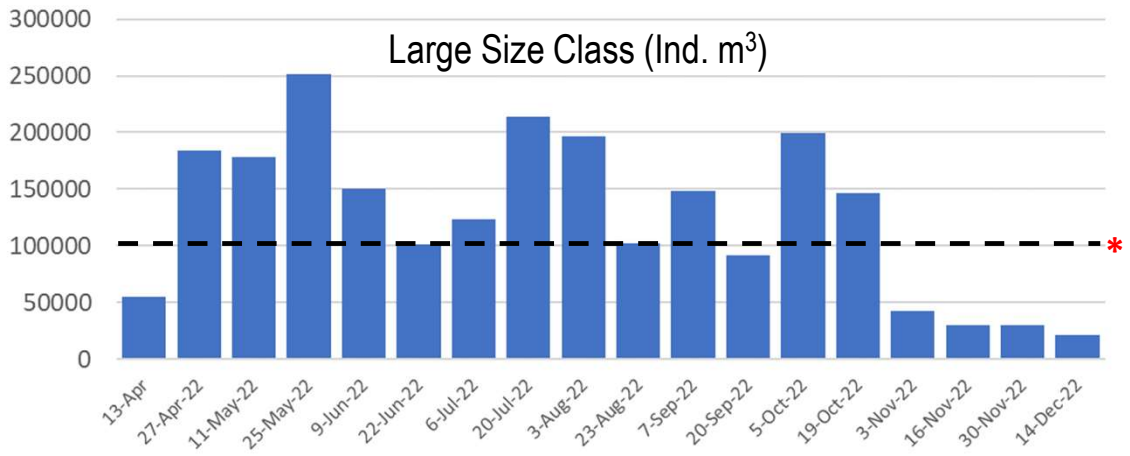
Sampling in Hamilton Harbour (2022)

- Hamilton Harbour considered challenging anecdotally
- Challenging Water Quality refers to ambient uptake water with parameters (e.g. high turbidity) that cause a properly installed/maintained BWMS to be temporarily inoperable
- Sampling April-October revealed low oxygen / high nutrients = high number of organisms



Bailey *et al.* unpublished

* Min. abundance for US type approval testing

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Assessing BWMS performance in 2023

- 10 paired samples of harbour water (during uptake) vs BW discharge
- For the small size class, 100% discharge samples below D-2 limit
- For the large size class, 10% of discharge samples below D-2 limit
- Reduction ranged from 76.8% to 99.9%

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Bailey *et al.* unpublished

Conclusions

- Before-after paired design more informative than discharge-only
- Compliance against the D-2 standard should be assessed for the ≥ 50 µm size class
- There are different kinds of water quality "challenge":
  - High turbidity = BWMS slows or becomes temporarily inoperable
  - High organism abundance = BWMS operates but fails to meet D-2

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Knowledge gaps

- BWMS performance issues
  - Defining the issues (e.g. filter clog, UV lamp burn out, low chlorine dosage) and driving factors (e.g. CWQ, cold temperature, maintenance)
  - Comprehensive systematic data about *when*, *where* and *how often* BWMS encounter performance issues

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Hamilton Harbour, Sept 2019

Relevant Publications:

Bailey et al. 2023. Efficacy of ballast water management systems operating within the Great Lakes and St. Lawrence River (2017-2022). Canadian Data Report of Fisheries and Aquatic Sciences 1376.

Bailey et al. 2022. First evaluation of ballast water management systems on operational ships for minimizing introductions of nonindigenous zooplankton. Marine Pollution Bulletin 182: 113947.

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