Optimizing methods to estimate zooplankton concentration based on generalized patterns of patchiness inside ballast tanks and ballast water discharges

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Research Problem

- Zooplankton populations can be spatially heterogeneous and stratified in ship ballast tanks and ballast discharge
- Sampling protocols for monitoring Regulation D-2 should be “representative of the whole discharge of ballast water from any single/combination of tanks being discharged”
- Sampling methods should therefore take heterogeneity into account, for accurate estimation of tank average

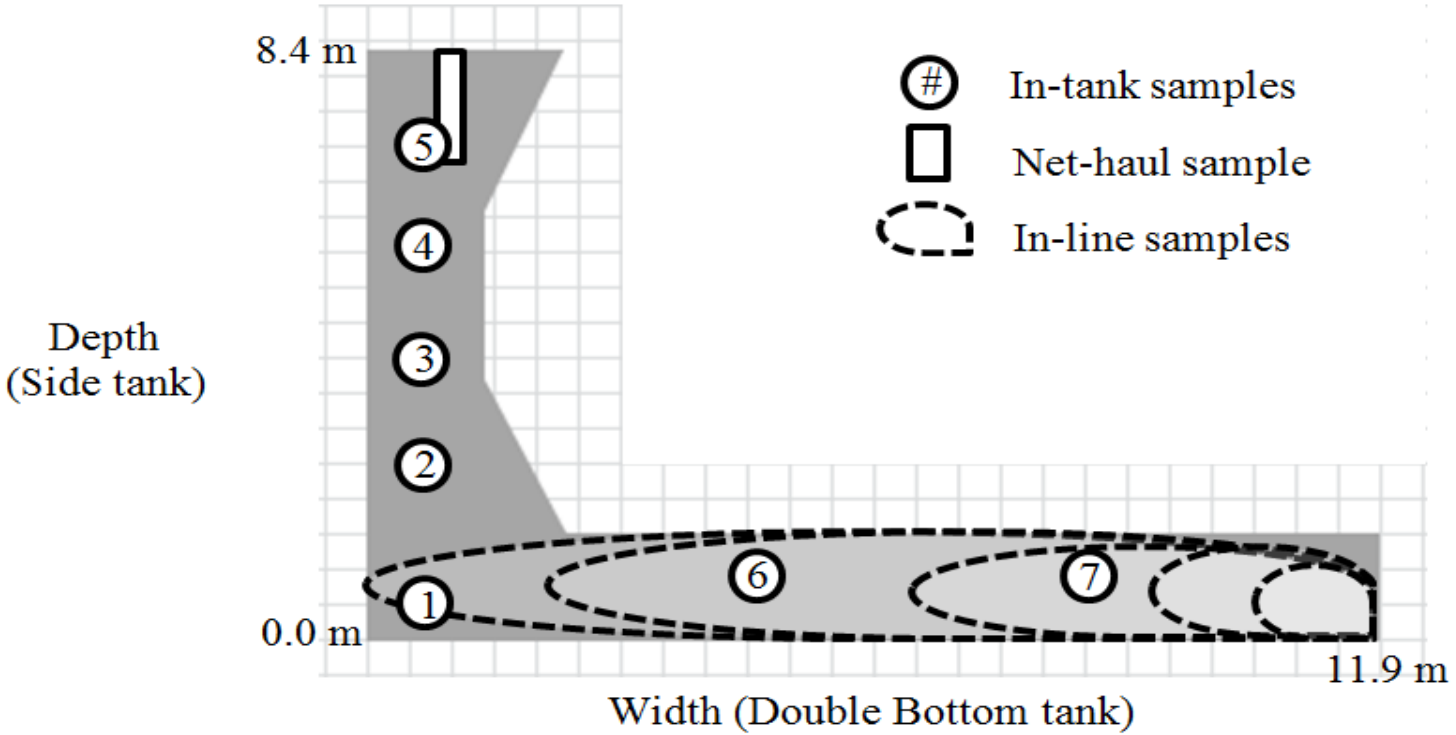
Background Info

- Very limited data on spatial structure of plankton in ballast tanks – some evidence for trends by depth for some taxa (Murphy et al. 2002)
- Recent inline sampling studies report zooplankton concentration varies depending on timing/sequence of sample collection (Gollasch & David 2013)
- If there are trends and patchiness in-tank and during inline discharge, estimates ignoring depth/sequence may lead to large errors (uncertainty)

Research Objectives

- to examine spatial heterogeneity of zooplankton in ballast water
- to model and estimate the average concentration of zooplankton across the entire ballast tank
- to determine under which contexts different sampling methods are most representative (yield the most accurate estimate of the tank average)

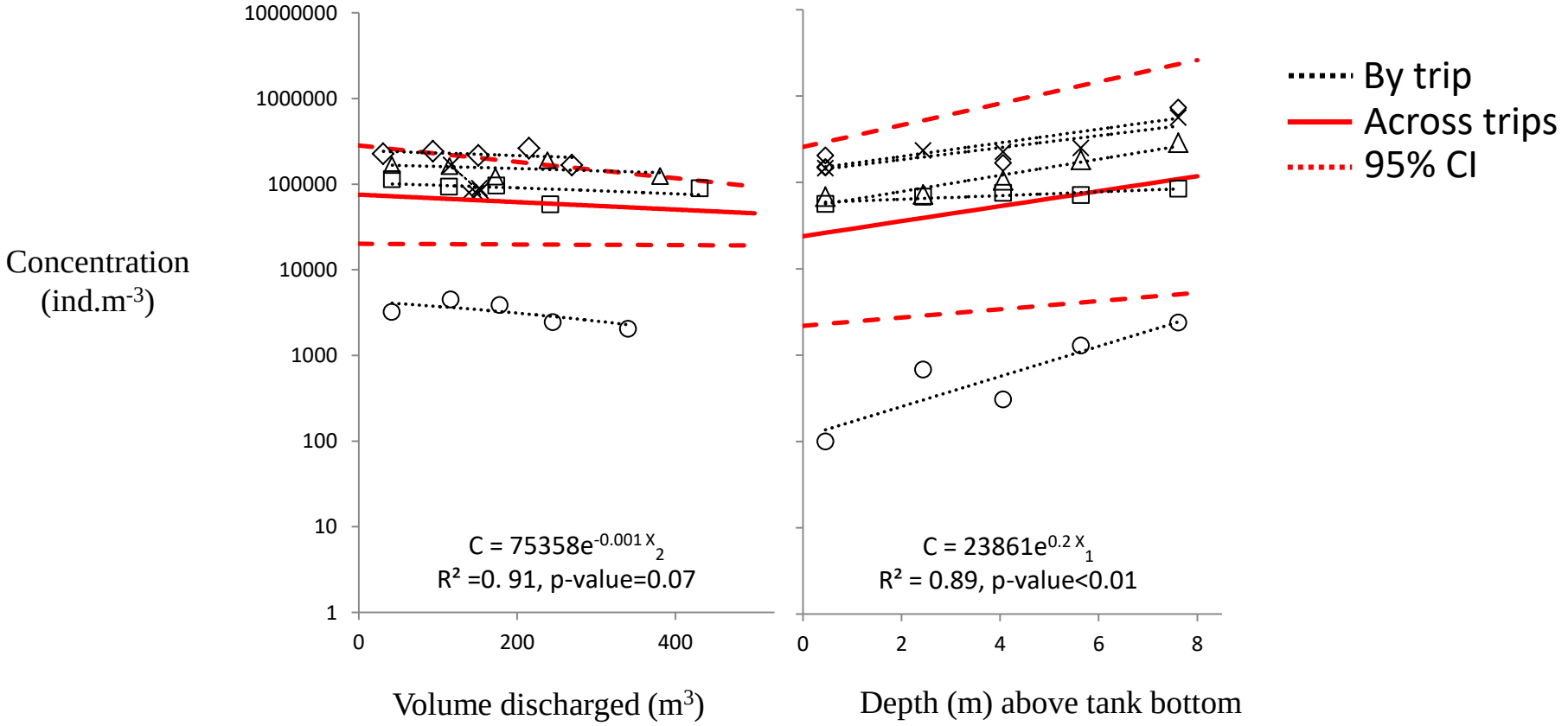
Sampling Locations – M/V Tim S Dool



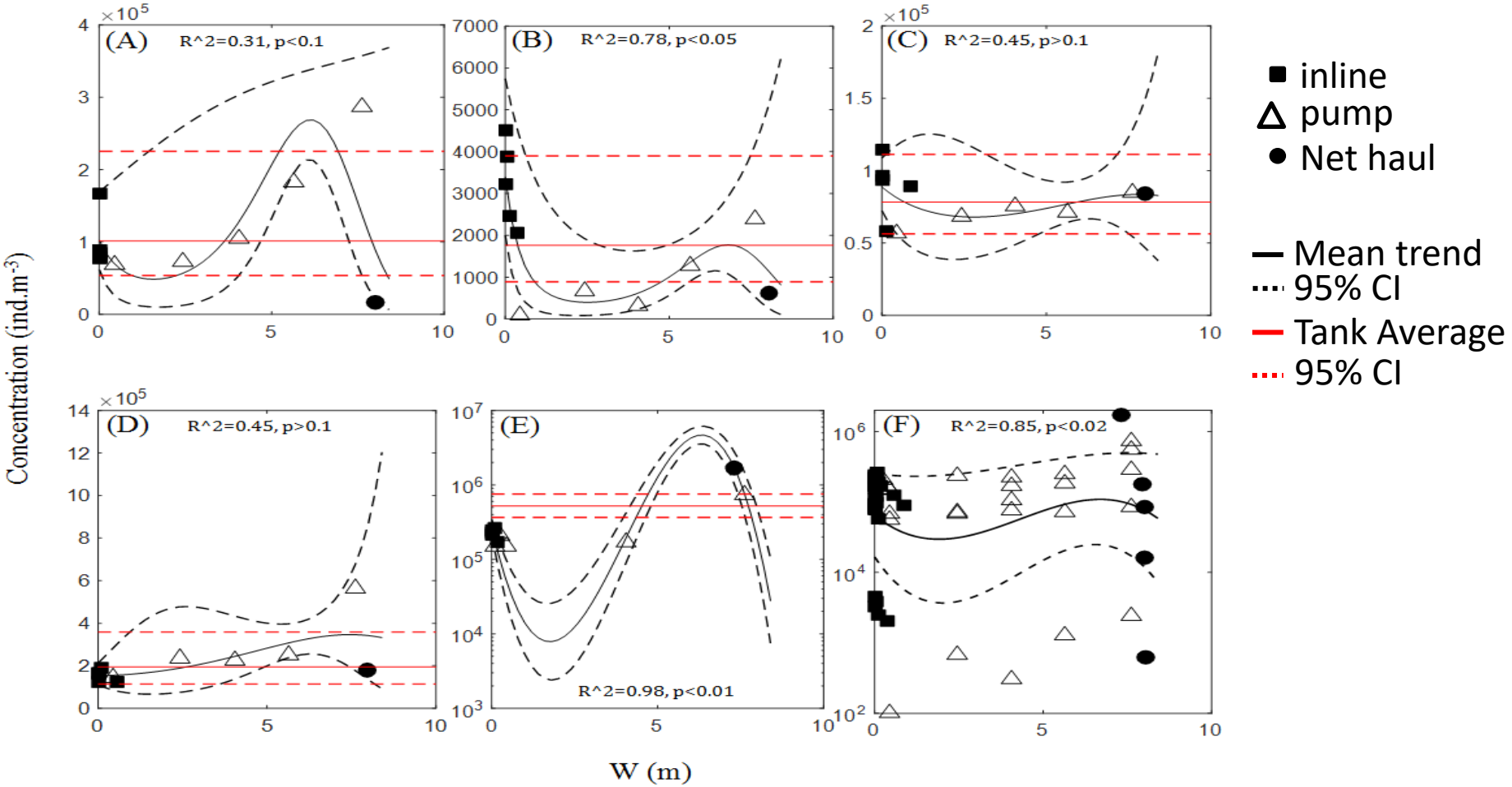
Analytical Methods

- Data from 5 trips (different ballast sources, age, season, etc.)
- Modeled data to look for trends by volume-discharged and tank depth
- Combined all data (net, pump, inline) to generate tank average
- Modeled standardized errors in each sample estimate w.r.t. tank averages
- Estimated bias, variance of errors and their MSE
    - bias - over or underestimations;
    - variance - variability;
    - MSE – accuracy (lower MSE = better estimate of tank average)

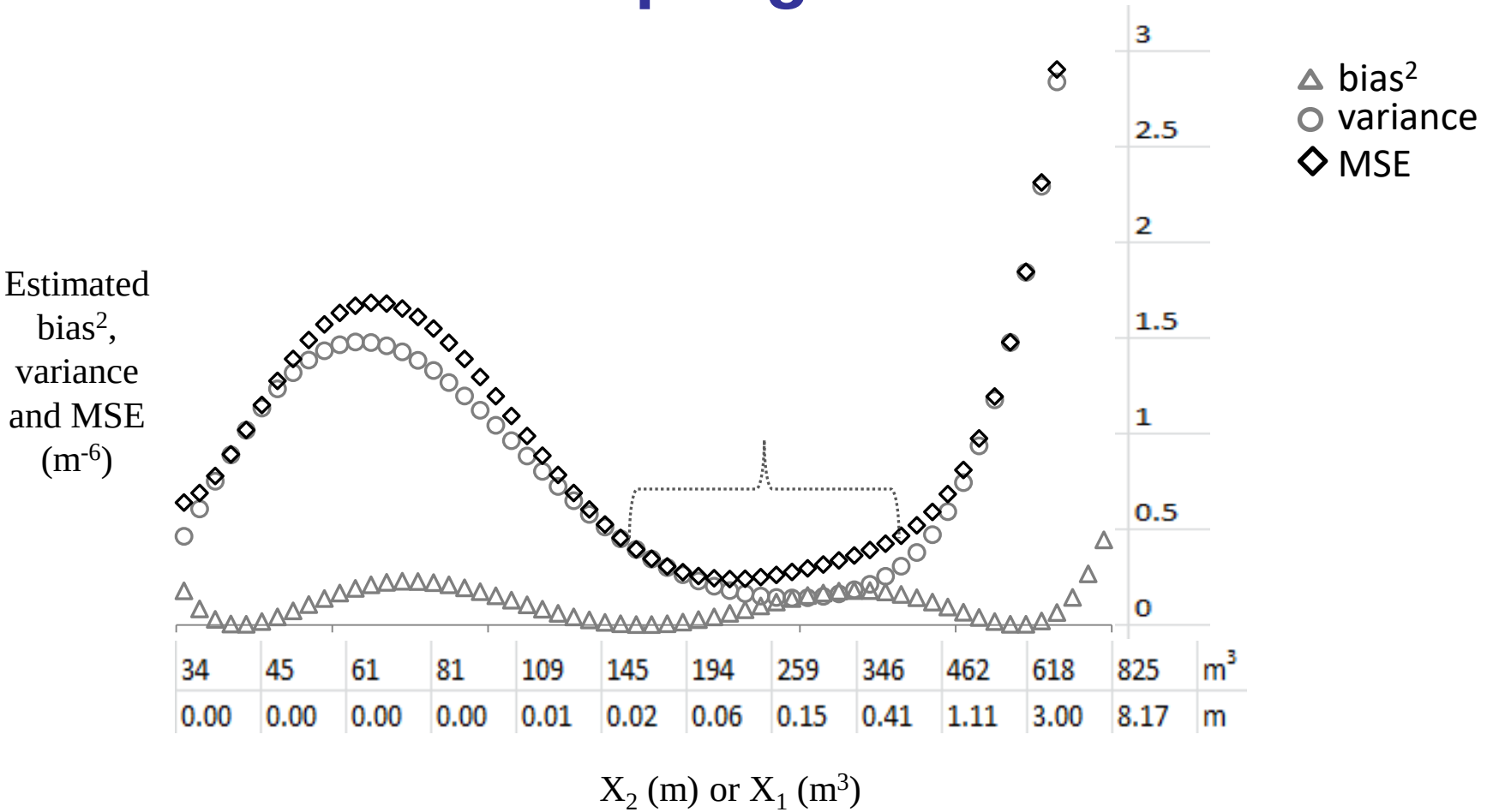
Trends by sequence / depth



Pooling data to generate tank average



Sampling Error



Conclusions

- Sample representativeness, as compared to the tank average, varied depending on the depth or sequence sampled
- In-line discharge samples provided the least biased and most precise estimate of average tank abundance (having lowest MSE) when collected during the time frame of 20-60% of the tank volume being discharged
- As net-haul estimates show positive bias, a net-haul estimate meeting D-2 standard appears to be a robust “pass”, while a failure would be uncertain

Next Steps

- Results were consistent across trips despite differences in ballast water source, season, and age…
- Additional research examining sample representativeness would be beneficial to confirm the trends we observed are generally applicable across
  - different types of ballast tanks
  - different sizes of ships
  - a broader selection of zooplankton communities
  - treated ballast water

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