

Mid-ocean exchange and Ballast Water Treatment Projects Canadian Update

Propagule pressure study (CAISN)

Ballast sediment/slurry study

Ballast water treatment study -1
natural populations of phytoplankton

Ballast water treatment study -2
invertebrate larvae cultures



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Ballast water is recognized as a major vector for AIS

Ballast water management – key marine commerce issue re safety, energy use

Mid ocean exchange – main management tool, recognized by Transport Canada in regulations

Marine Invaders of the Pacific Northwest



Numerous species are invaders to the west coast of North America. Some non-native species have become important in mariculture, such as the Manila clam and Pacific oyster. Other non-native species become invasive – they have negative impacts on native species and the environment.

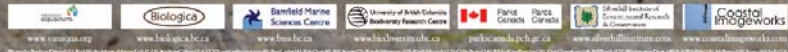
Shipping, aquaculture and aquaria trade releases are the primary vectors of introduced marine species. Warming conditions have allowed for the establishment and spread of many warm water species. Many southern species are to be expected with warming waters.

Education about marine invaders can bring awareness to the problems they can cause. Some common invaders to Pacific Northwest shores are shown below. This poster can be used as an identification guide to help you identify invaders. If you notice a new marine invader we would be interested to know!

Please contact us at invasivespeciesawareness@gmail.com



1. Soft-shell Clam (*Mya arenaria*)
2. Manila Clam (*Venerupis philippinarum*)
3. Green Mussel (*Mytilus peruvianus*)
4. Dwarf Belpash (*Gastrea japonica*)
5. Common Atlantic Slippershell (*Crepidula fornicata*)
6. Orange Striped Green Anemone (*Diadema lineatum*)
7. Venetian Clam (*Ventrella japonica*)
8. Violet Tunicates (*Botryllodes ocellatus*)
9. *Proplydia japonica*
10. Atlantic Oyster (*Crassostrea virginica*)
11. Pacific Oyster (*Crassostrea gigas*)
12. European Flat Oyster (*Ostrea edulis*)
13. Eastern Mudflat (*Hyasina obtusata*)
14. Japanese Wireweed (*Gelidium mitsumai*)
15. European Green Crab (*Carcinus maenas*)
16. New Zealand Mudsnail (*Hydrobia ulvae*)
17. Atlantic Oyster Drill (*Urosalpinx cinerea*)
18. Japanese Rockshell (*Crucianella muriei*)
19. Japanese Mud Snail (*Bohadsia sinuata*)
20. Moon-cow Snail (*Mytiloides japonica*)
21. Glub Tunicate (*Styela clava*)

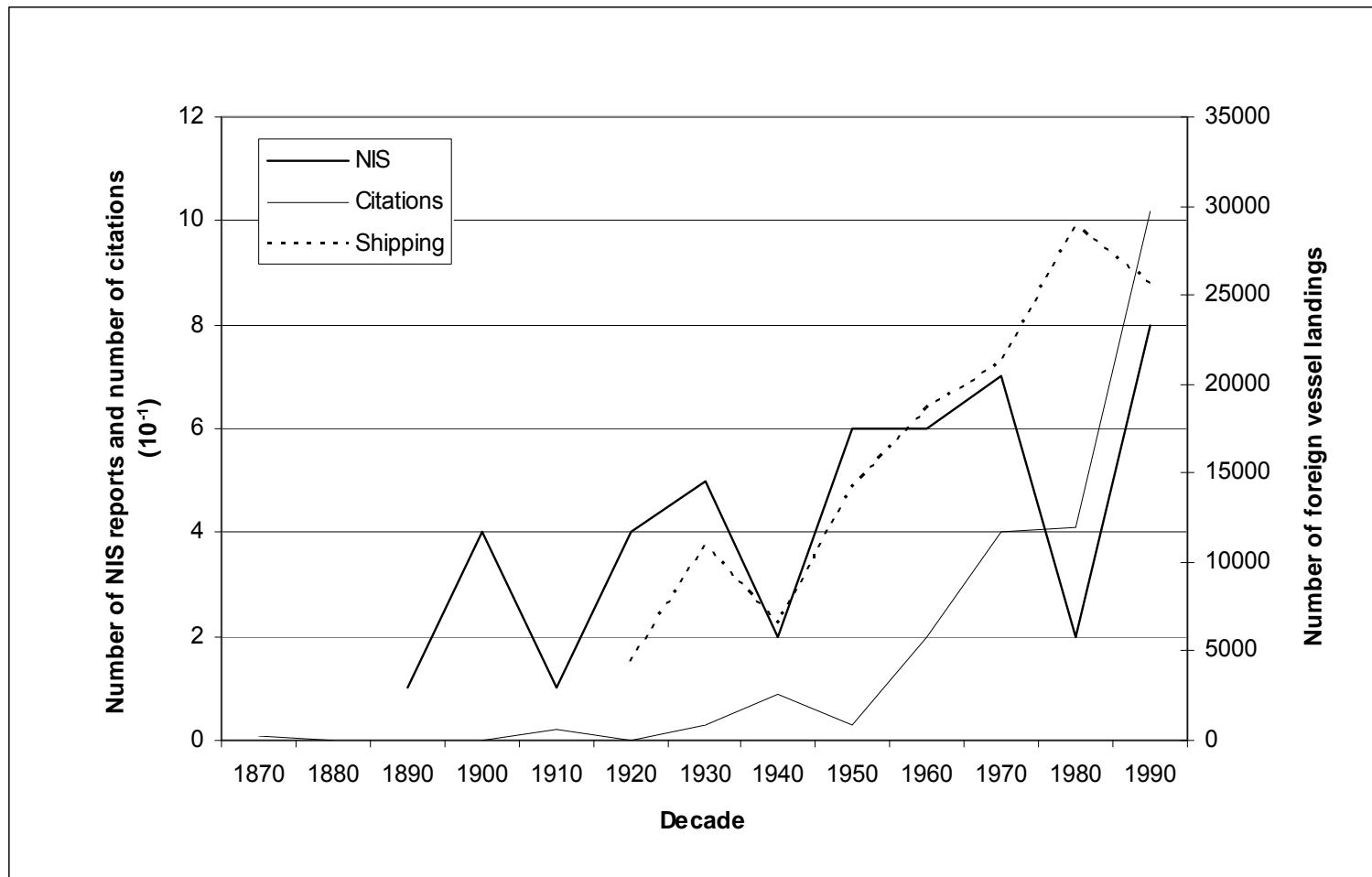


Photos by: 1. David H. Secor; 2. David H. Secor; 3. David H. Secor; 4. David H. Secor; 5. David H. Secor; 6. David H. Secor; 7. David H. Secor; 8. David H. Secor; 9. David H. Secor; 10. David H. Secor; 11. David H. Secor; 12. David H. Secor; 13. David H. Secor; 14. David H. Secor; 15. David H. Secor; 16. David H. Secor; 17. David H. Secor; 18. David H. Secor; 19. David H. Secor; 20. David H. Secor; 21. David H. Secor

Poster developed by Laura White

STRAIT OF GEORGIA

Decadal trends in number of reports of exotic species, number of Literature citations (an indication of “searching” effort), and ship arrivals to Vancouver (Levings et al 2004)



DEEP SEA SHIPS AS VECTORS FOR INVASIVE SPECIES

Preliminary estimates of propagule pressure from ballast water organisms in Vancouver Harbour

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Donald Humphrey (MSc student UBC)
Claudio DiBacco (PI, UBC and co-supervisor)
Veronica Lo (MSc student UBC)
Kai Chan (UBC co-supervisor)**

**Support staff
Beth Piercey, Meighen Whitehead, Sarah Ballard**



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WHAT IS CAISN?

- Canadian Aquatic Invasive Species Network (CAISN)
- 5 year program (2006-2011)
- \$5 M cooperative research venture
- Funded by NSERC, DFO, Transport Canada, and other agencies concerned with AIS.

THREE GEOGRAPHIC NODES

- West Coast, Great Lakes, and East Coast.
- DFO and University laboratories (BC, AB, ON, QC, NB, NF)
- DFO Principal Investigators (Pacific Region)
 - Glen Jamieson, Colin Levings, Tom Therriault.



◀ Zebra mussels not propellers



CAISN Null hypothesis

No difference in actual propagule pressure (“introduction effort”) between 3 shipping routes

Sampling

Zooplankton, diatoms, dinoflagellates, bacteria, viruses

Data

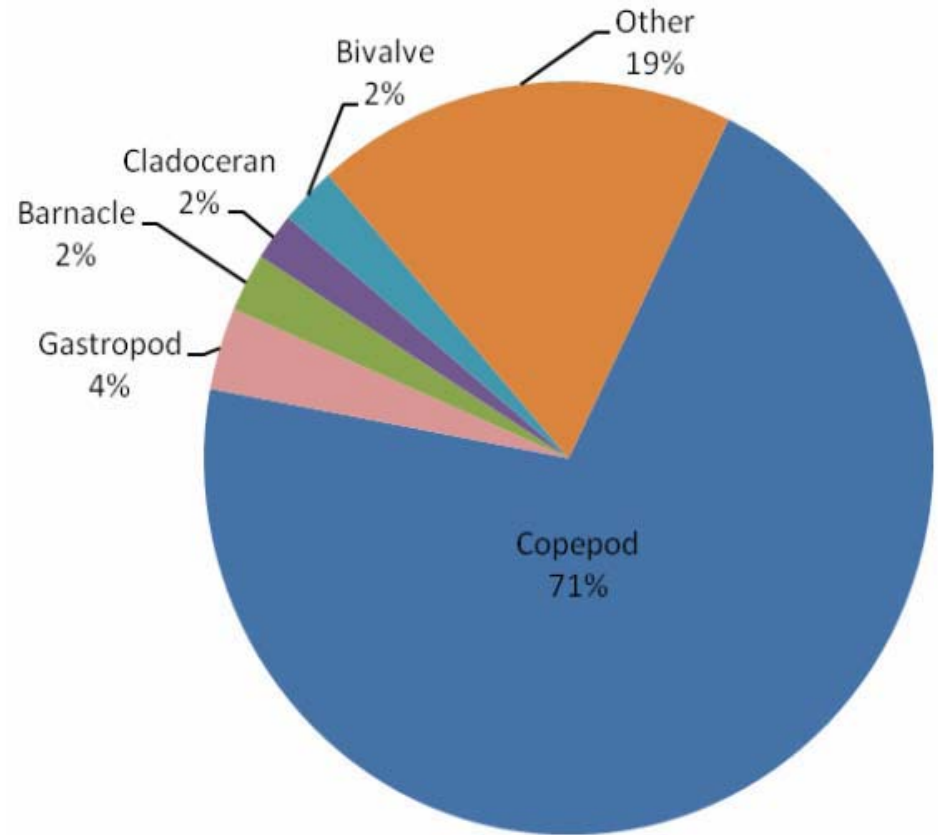
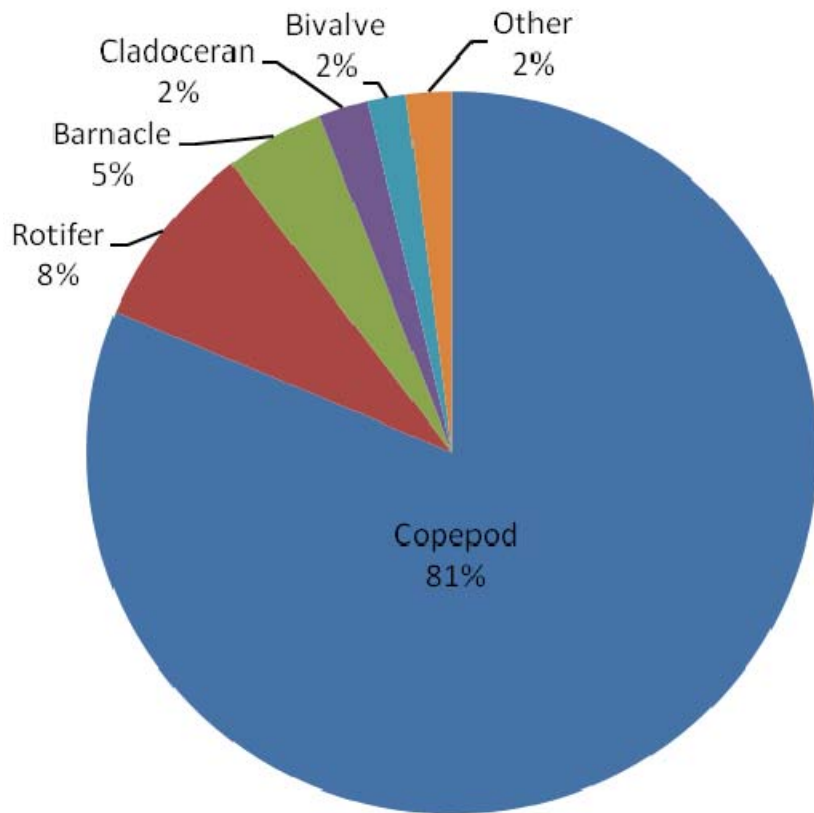
-2006-2007 results on zooplankton sampling presented for Pacific region today

- Similar sampling program carried out in 2008 – results currently being worked up



Zooplankton diversity in ballast water over all vessels and regions

Range of Zooplankton abundance: 3 - 63,562 m⁻³



AIS found in ballast water on ships in Vancouver (2006-2007)

Copepods:

Pseudodiaptomus marinus, P. forbesii, P. inopinus
(Humphrey et al)

Sinocalanus doerri, Limnoithona sinesis, Acartia
(Acartiura), Omorii, Oithona davisae
(Levings et al 2004)

Potential propagule pressure (PPP)

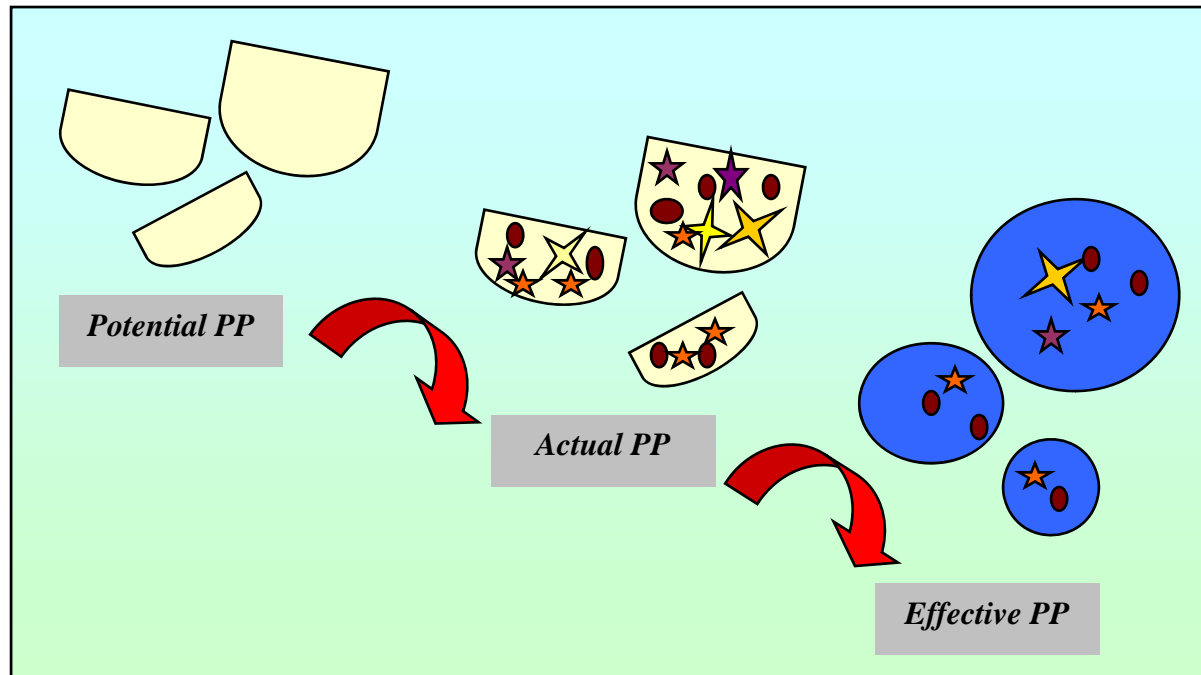
uses ship characteristics as a proxy for the direct sampling of propagules (e.g., volume of ballast water, length)

Actual propagule pressure (APP)

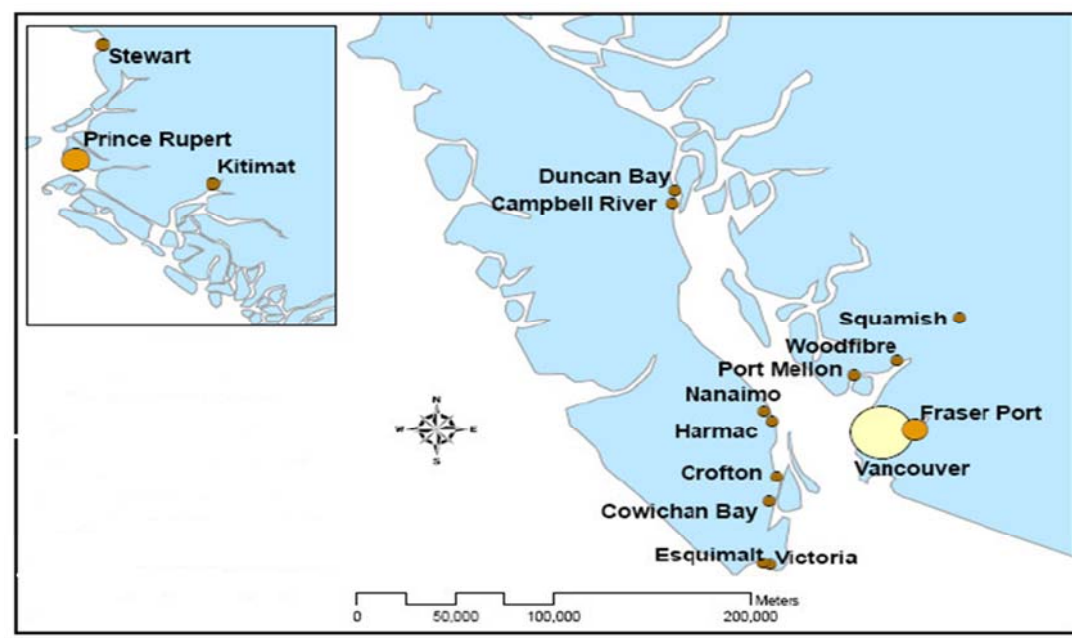
where the number and identity of propagules released are sampled directly

Effective propagule pressure (EPP)

defined as the number of propagules that actually survive after their release in the receiving area



Ballast discharge volumes in BC ports for potential PP (Lo et al in prep)



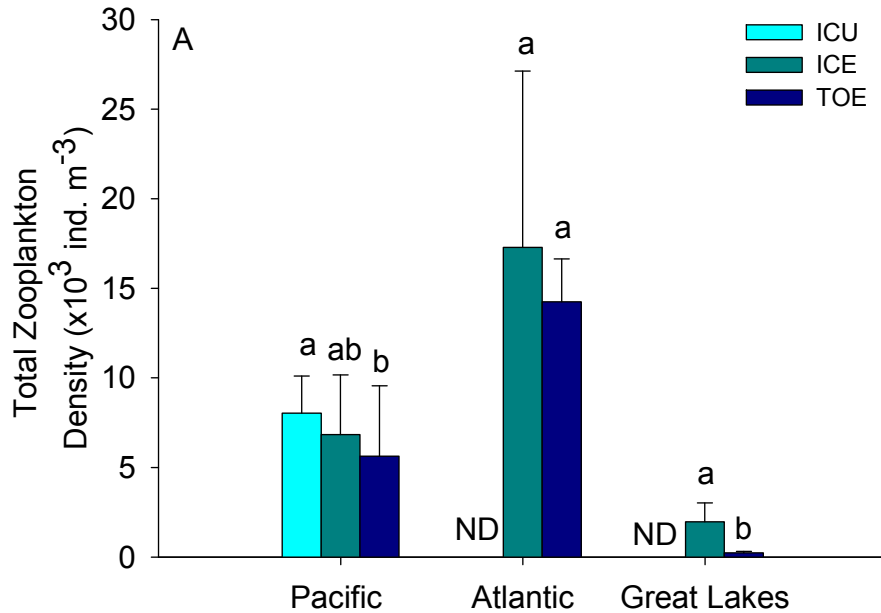
Actual Propagule Pressure (Humphrey et al in prep)

APP = (density of organism) x (ballast volume discharged) x (release events)

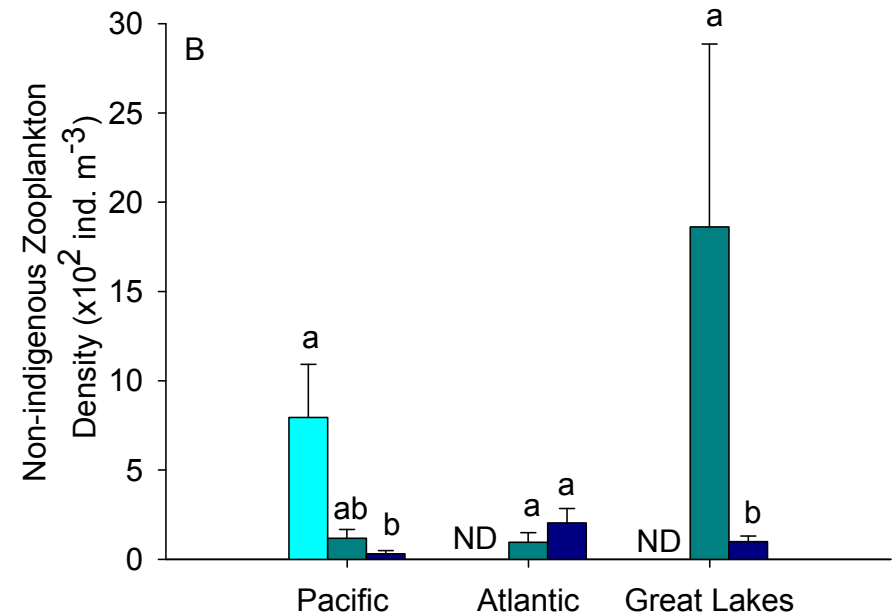
$$\text{APP} = (\text{No.m}^{-3}) \times (\text{tonnage ship}^{-1}) \times (\text{No.ship yr}^{-1})$$

Comparison of zooplankton densities associated with exchange treatments across 3 Canadian regions

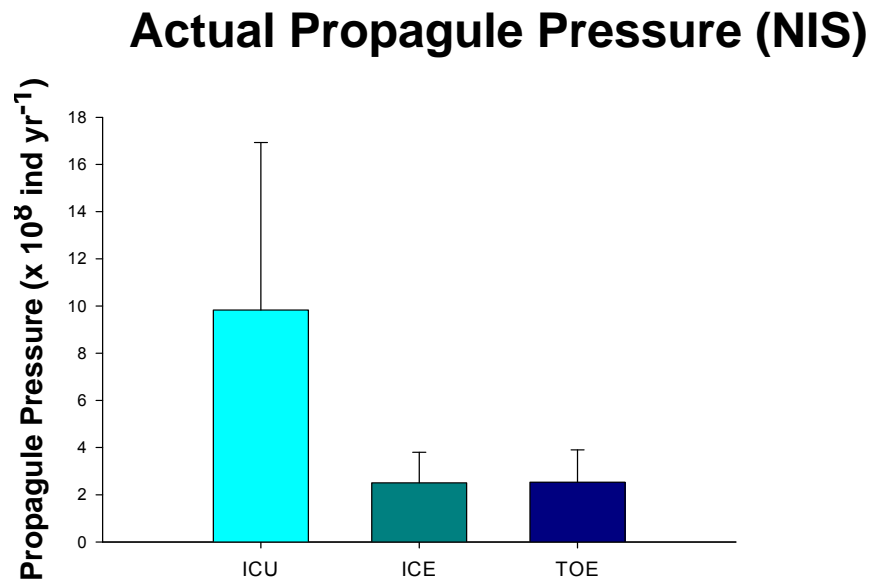
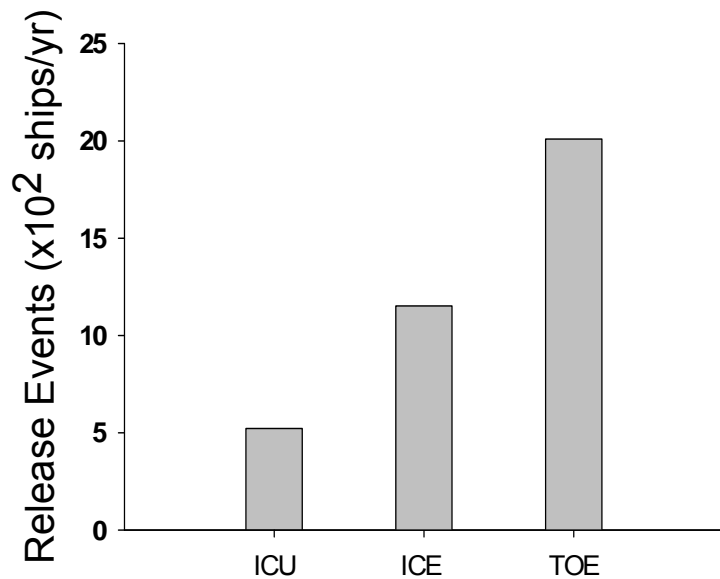
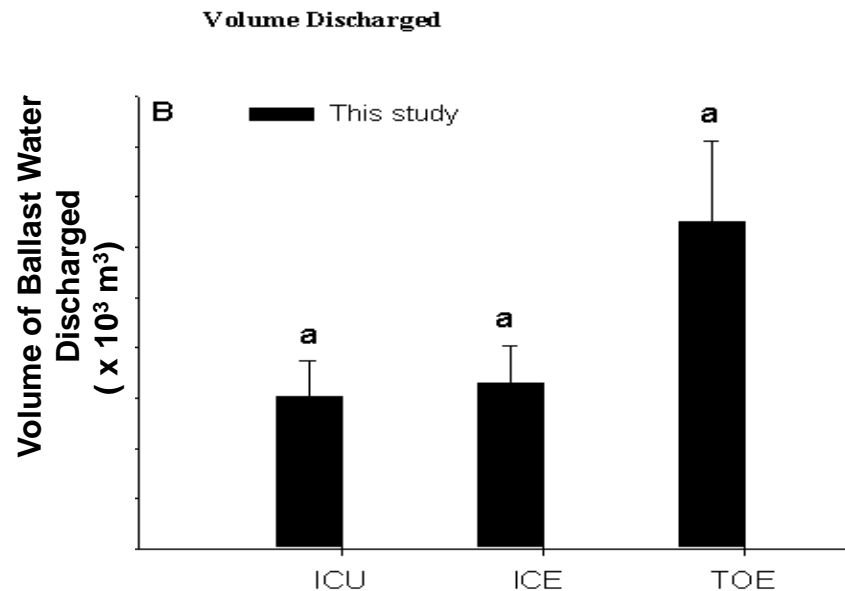
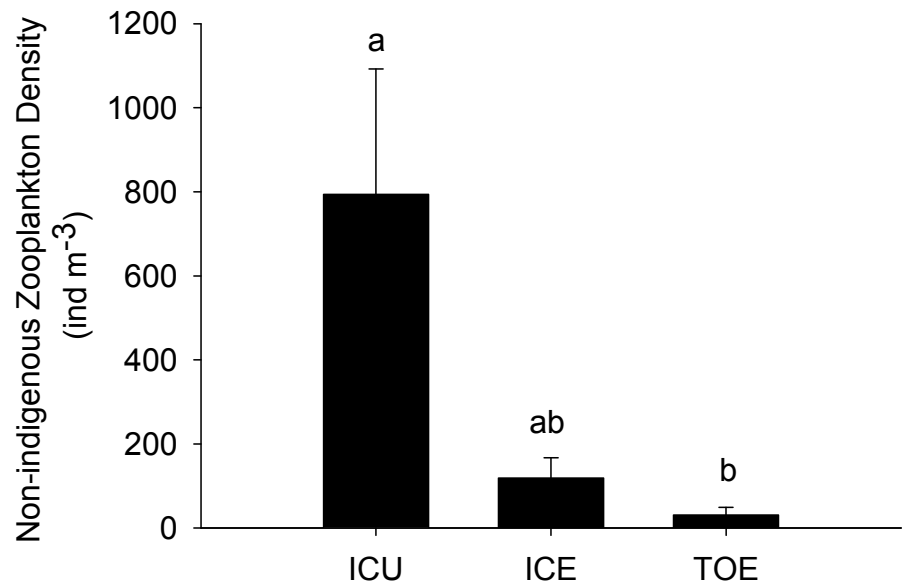
Total zooplankton



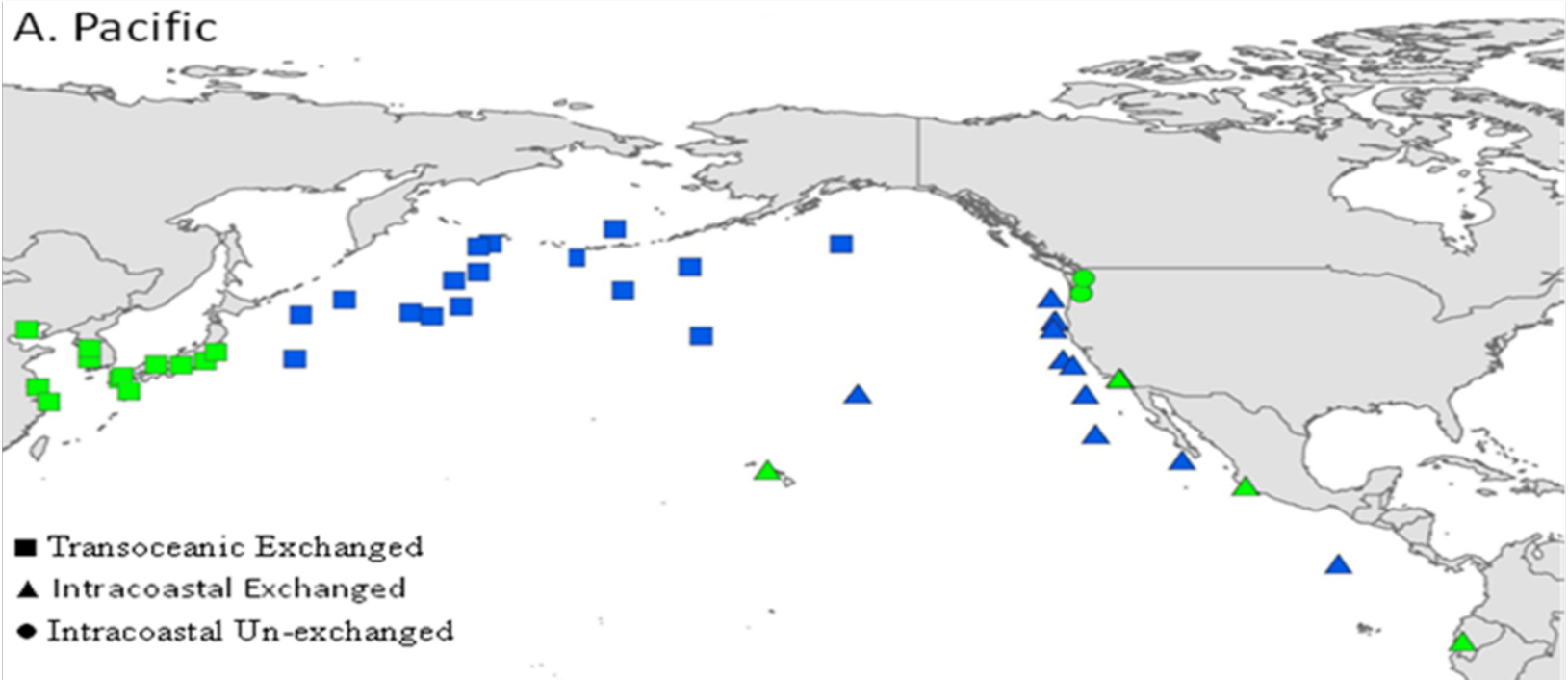
Non-indigenous zooplankton



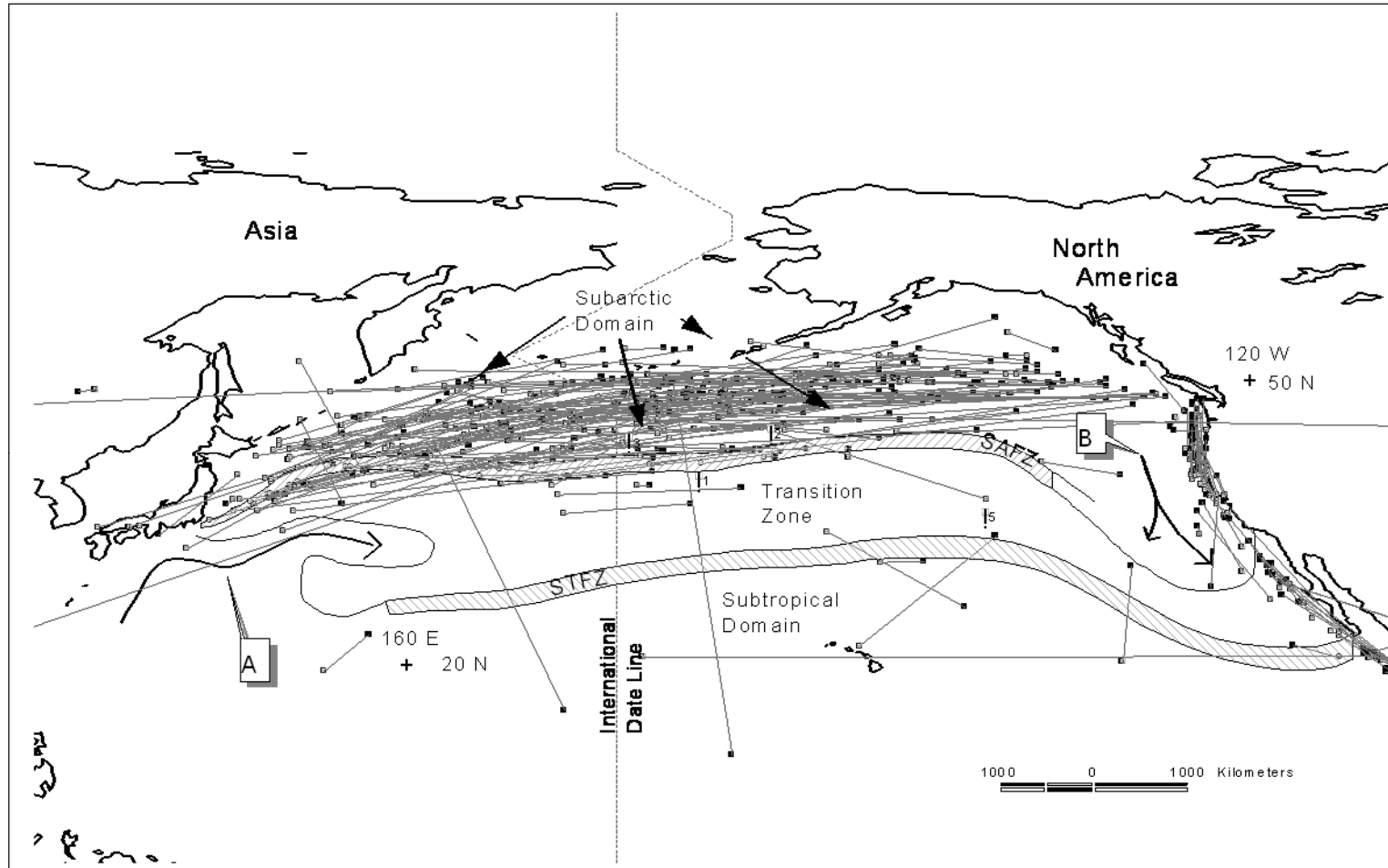
Coastal unexchanged (ICU) = 13 ships
Coastal exchange (ICE) = 11 ships
TransPacific exchange (TOE) = 11 ships
(Humphrey et al. In preparation)



Ships arriving to Vancouver from ports north of Cape Blanco (northern California) are exempt from mid-ocean exchange regulation



Positions of mid ocean ballast water exchange for Vancouver-bound ships (Levings et al 2004)






Other sampling conducted through CASIN

- 1) Microbiota in water (bacteria, viruses, dinoflagellates, algae)**
- 2) Sediment in ballast tanks (invertebrates, algae, dinoflagellates)
(Beth boarded about 300 ships (2006-2008))**
- 3) Hull fouling (invertebrates and algae – Meighen boarded ~ 50 ships)**
- 4) Port sampling to assess Effective Propagule Pressure
(Tom T and Chuck Fort)**

Conclusions, management implications, and next steps

- Identification of soft bodied larvae a problem
- coastal leap frogging of AIS a management challenge (Transport Canada was alerted before and current study is further support to resolve)
- ecosystem effects of AIS in ports receiving heavy APP 

Further acknowledgements: the shipping industry, Officers and crews of the ships



APEC project

- **Both sediment and slurry samples collected**
 - Sediments processed through CAISN project
 - Slurry samples processed through APEC project
- **Incubations (5 psu and 32 psu) at 16 °C**
 - phytoplankton and invertebrate assessments
- **Most Probable Number (MPN) assessment for phytoplankton**
 - Problematic species – chain-forming and spine-forming species

Sutherland, T.F., Levings, C.D., Elliott, C.C., W.W. Hesse

2001

Effect of a ballast water treatment system on survivorship of natural populations of marine plankton.

Marine Ecology Progress Series, 2010: 139 – 148.



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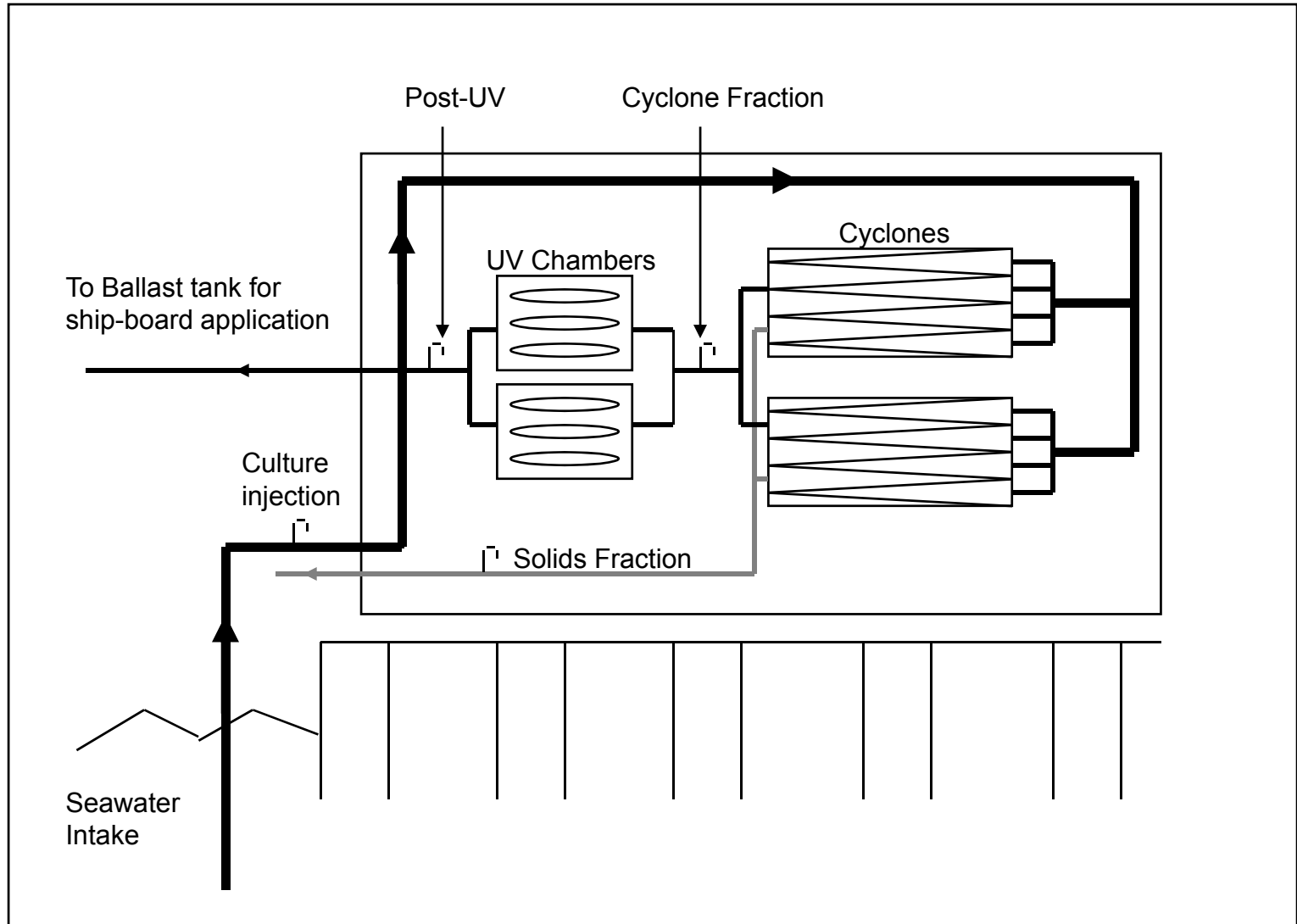
Ballast Water Treatment System

- Fully self-contained Ballast Water Process System
- Pre-treatment module (cyclonic separation)
- Secondary Treatment phase (Ultraviolet sterilization)



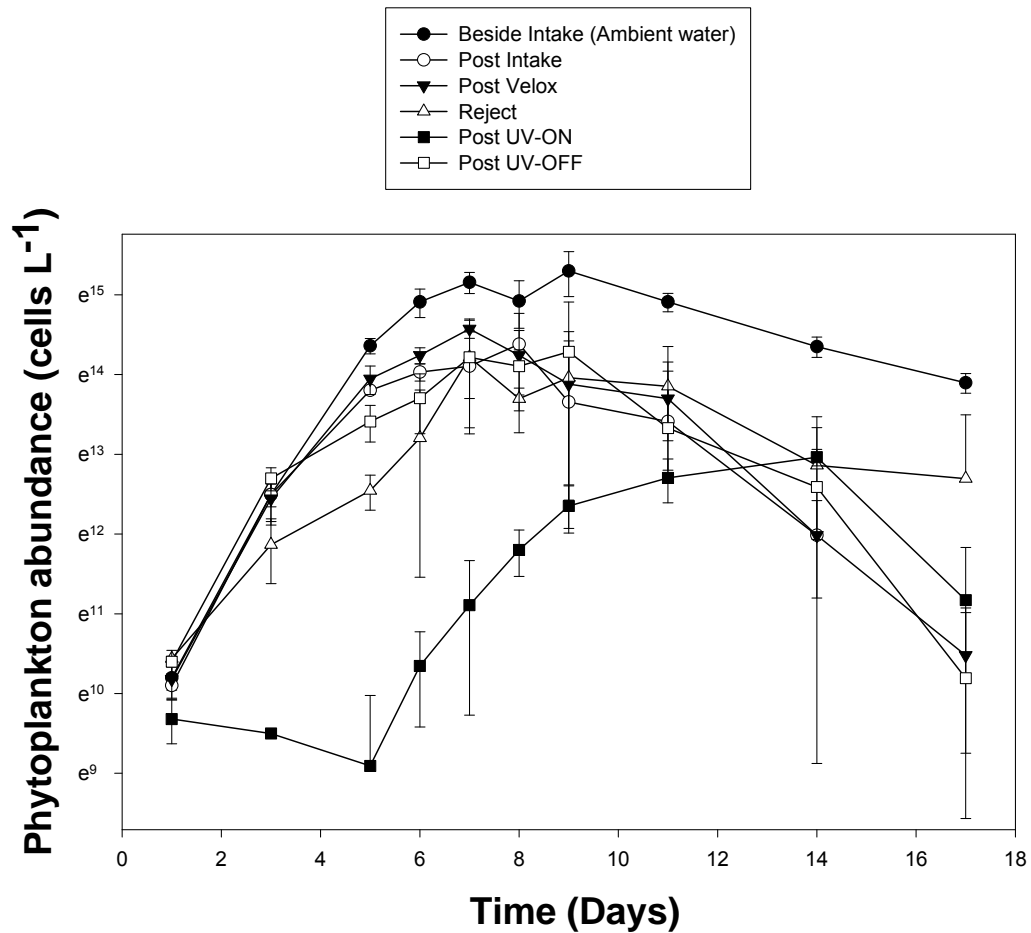
UV sterilization

Cyclonic separation

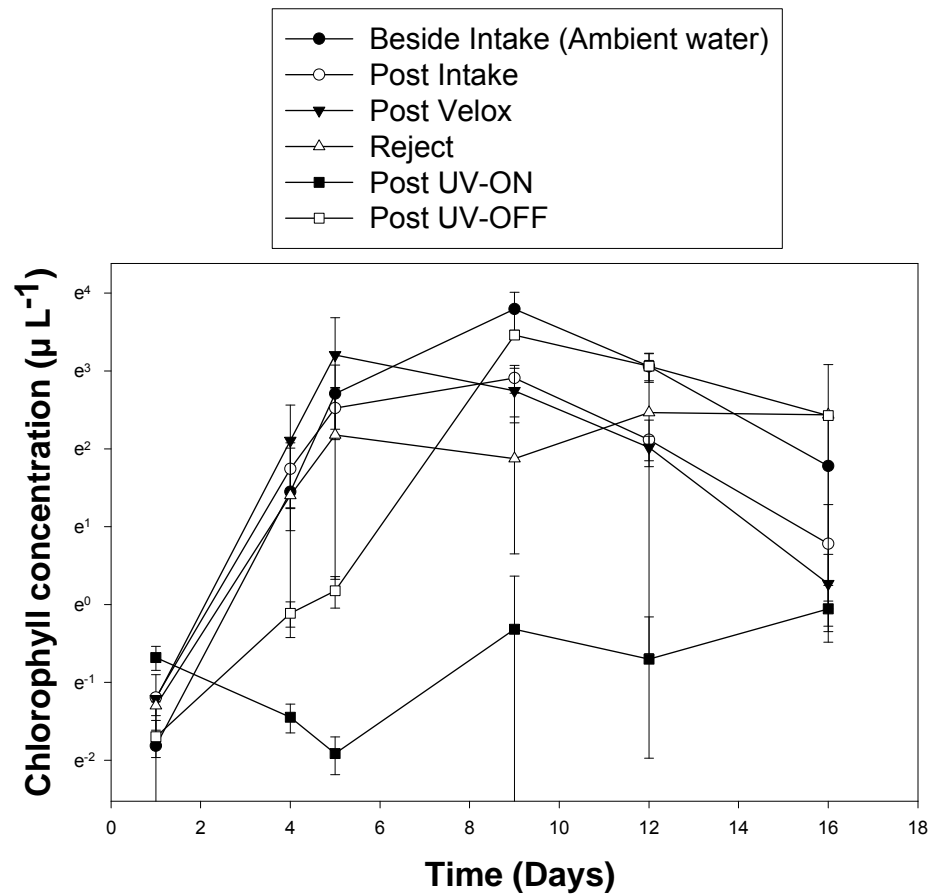


LAG PHASE, GROWTH PHASE AND RELATIVE ABUNDANCE

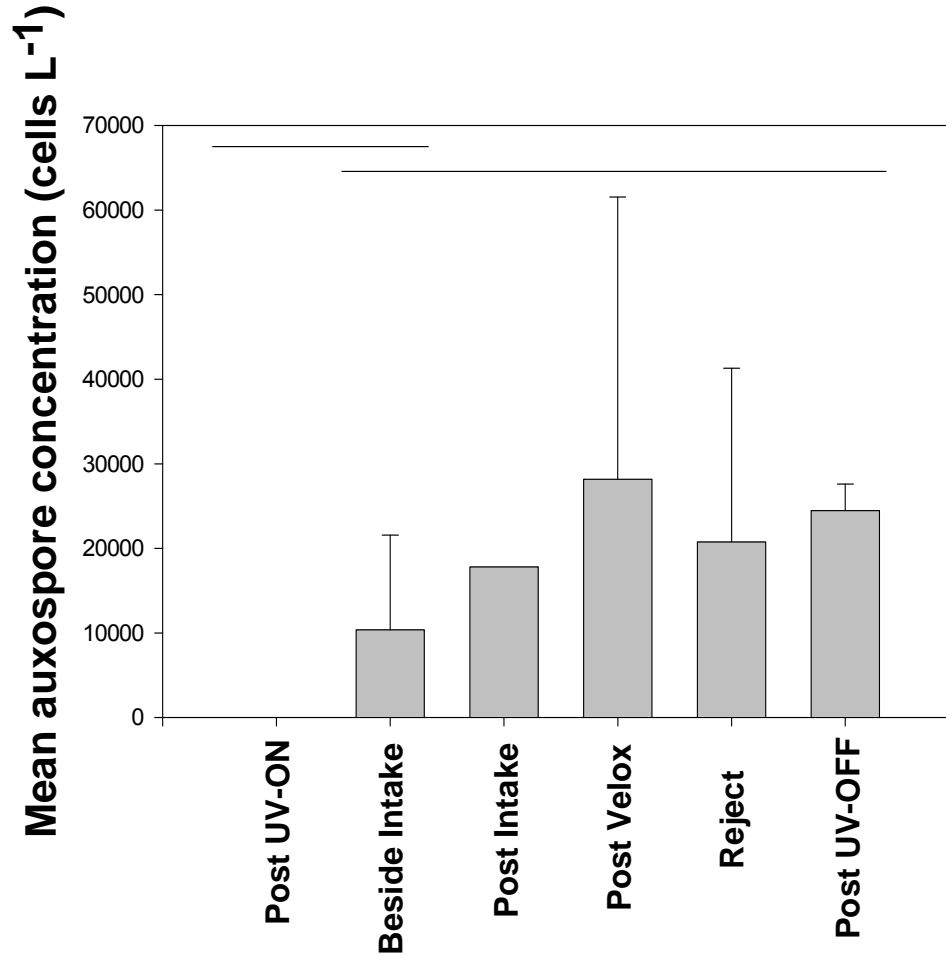
Chaetoceros gracile



RESULTS OF COMBINED UV-DARKNESS EXPERIMENT



AUXOSPORE FORMATION: REPRODUCTIVE POTENTIAL



Sutherland, T.F., C.D. Levings, S. Petersen, W.W. Hesse.

2001

***Mortality of zooplankton and invertebrate larvae
exposed to cyclonic pre-treatment and ultraviolet radiation.***

Marine Technology Society Journal, 37 (2): 3-12.

***Fisheries and Oceans Canada
Velox Technology Inc.***

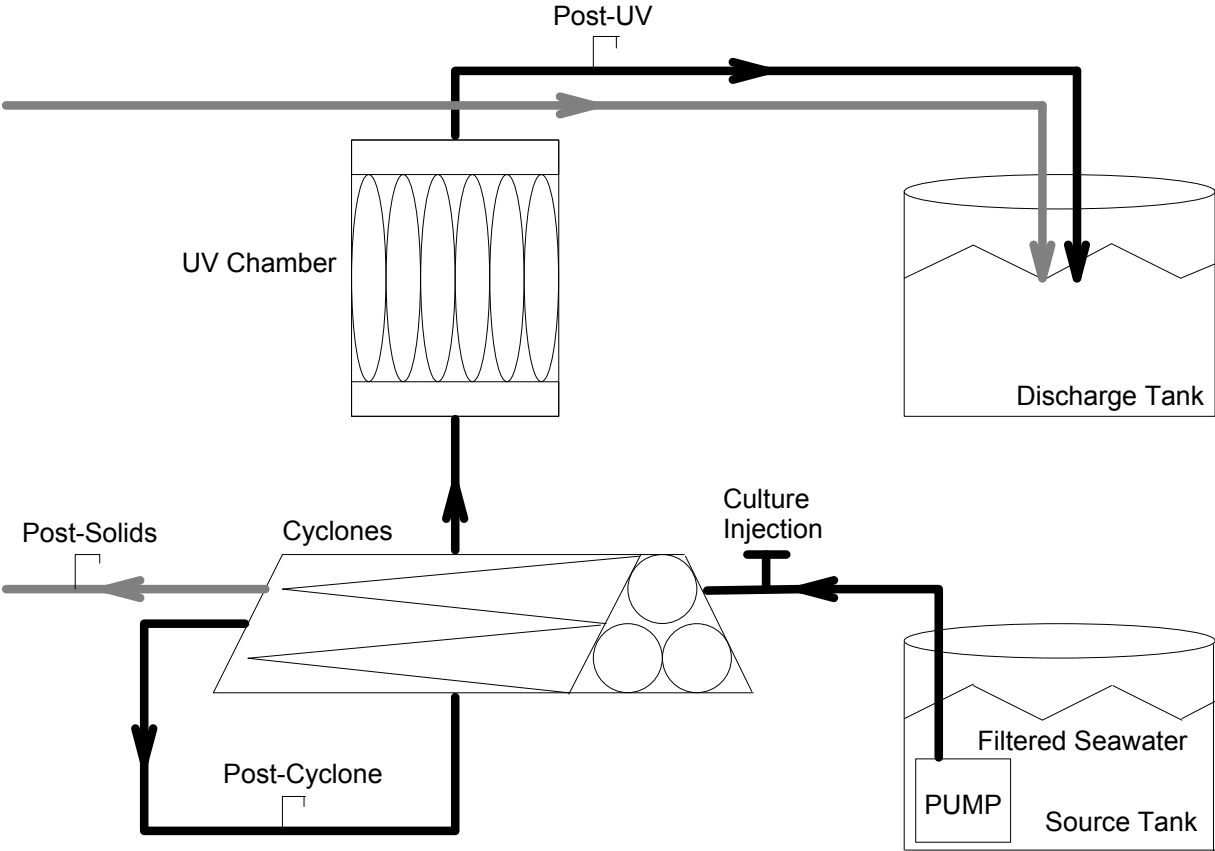
DFO-UBC Centre for Aquaculture and Environmental Research



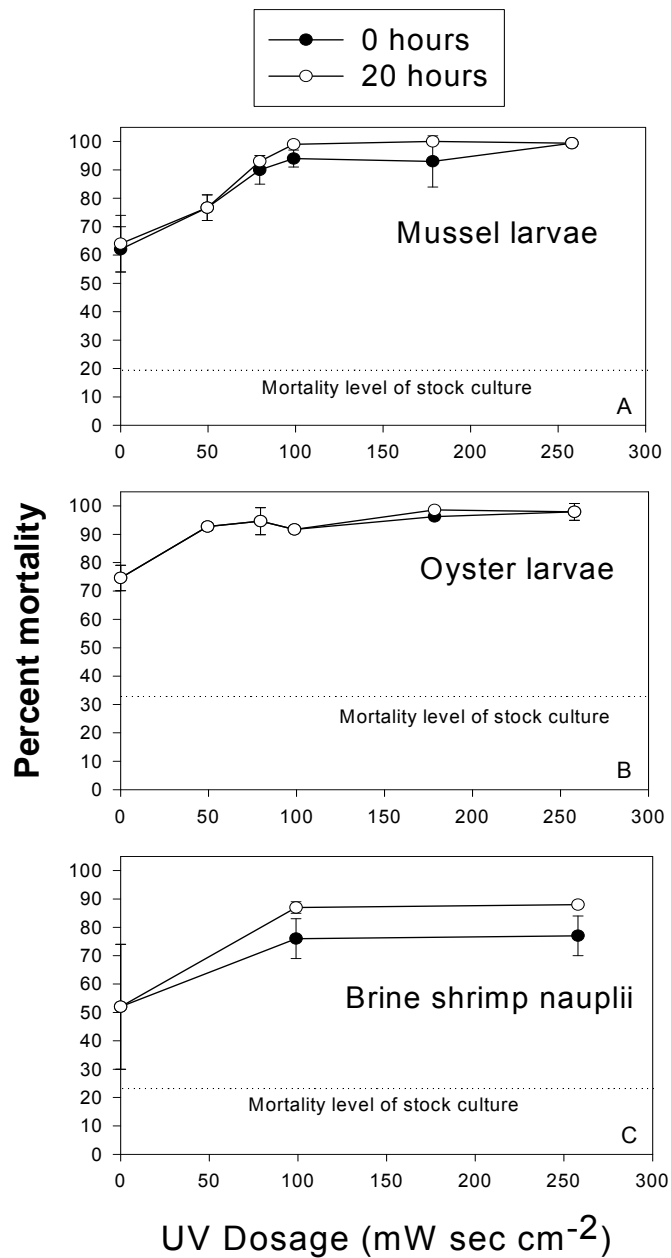
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Experimental Setup



Total System Mortality



Summary of treatment studies

Taxa-specific Tolerances to Treatment

- **Photoprotection of vital structures**
 - depends on reflection, refraction, or absorption of harmful wavelengths by outer tissues
 - depends on the presence of photoprotective compounds
- **Photoreactivation of damaged structures**
 - depends upon the ability to repair UV-induced damage to organism structures
 - will affect “effective propagule pressure”

Thank you