



NRL Center for Corrosion Science and Engineering

Concentrating high densities of
ambient plankton for use in
ballast water treatment testing

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Background - IMO Ballast Convention

- 2004 – International Maritime Organization (IMO) adopted an International Convention for the **Control and Management of Ships' Ballast Water and Sediments.**
 - preventing the spread of non-indigenous species
 - setting standards for ballast water treatment systems
 - outlines methods for testing and implementing compliant treatment systems



Technology Verification

- EPA's Environmental Technology Verification (ETV) program developed a draft protocol for **verifying efficacy of ballast water management systems.**

- Testing conditions must meet
 - IMO standards for discharge water
 - IMO requirements for challenge water



IMO Challenge Water Requirements

- Required parameters for the test water treated by a system:
 - Physical and chemical conditions: temperature, salinity, pH, dissolved organic matter
 - Particles: particulate organic matter, mineral matter, organisms



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 - Particles: particulate organic matter, mineral matter, **organisms**



IMO Challenge Water Requirements

- Minimum criteria for living organisms (ETV):

Organism Size Class	Concentration	Diversity
$\geq 50 \mu\text{m}$	10^5 organisms/ m^3	5 species across 3 phyla
$\geq 10 \mu\text{m}$ and $< 50 \mu\text{m}$	10^3 organisms/ml	5 species across 3 phyla
$< 10 \mu\text{m}$	10^2 heterotrophic bacteria/ml	5 species across 3 phyla

Ambient organisms must comprise **75-95%** of the total organisms in the challenge water (5-25% test organisms).



$\geq 50 \mu\text{m}$ Plankton

- ETV calls for 450 m^3 of challenge water with 75,000 *ambient* organisms per m^3 .
 - 75 organisms l^{-1}
 - 3.38×10^7 organisms total



$\geq 50 \mu\text{m}$ Plankton

- ETV calls for 450 m³ of challenge water with 75,000 *ambient* organisms per m³.
 - 75 organisms l⁻¹
 - 3.38 x 10⁷ organisms total
- Assuming 50% mortality during fill:
 - 150 organisms l⁻¹
 - 6.76 x 10⁷ organisms total



To fill 450 m³ with 150 organisms l⁻¹

If [Ambient] is... (# l ⁻¹)	Then inject (# organisms)	Filter this much seawater (m ³)	How long will it take?
125	1.14 x 10 ⁷	91.2 m ³	2 hours
75	3.38 x 10 ⁷	450 m ³	10 hours
25	5.64x 10 ⁷	6900 m ³ 1.8 x 10 ⁶ gal	50 hours

At 200 gpm



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Summer densities: 75-180 organisms l⁻¹ (n=7 samples)

Winter densities: 50-65 organisms l⁻¹ (n= 3 samples)

At 200 gpm



Facility Location



Ballast Water Treatment Test Facility

Naval Research Laboratory
Key West, FL



Ballast Tank
Control Tank
Discharge Tank





Facility Location



Ballast Water Treatment Test Facility

Naval Research Laboratory
Key West, FL



Plankton $\geq 50 \mu\text{m}$

Summer densities: 75-180 organisms l^{-1}

Winter densities: 50-65 organisms l^{-1}

Extend testing season

Decrease reliance on blooms



Summer Ambient Densities

■ July 2008: 75-180 organisms l⁻¹

Crustaceans:

Misc. nauplii

Adult copepods and
copepodites

Dinoflagellates

Ciliates

Rotifers

Annelids

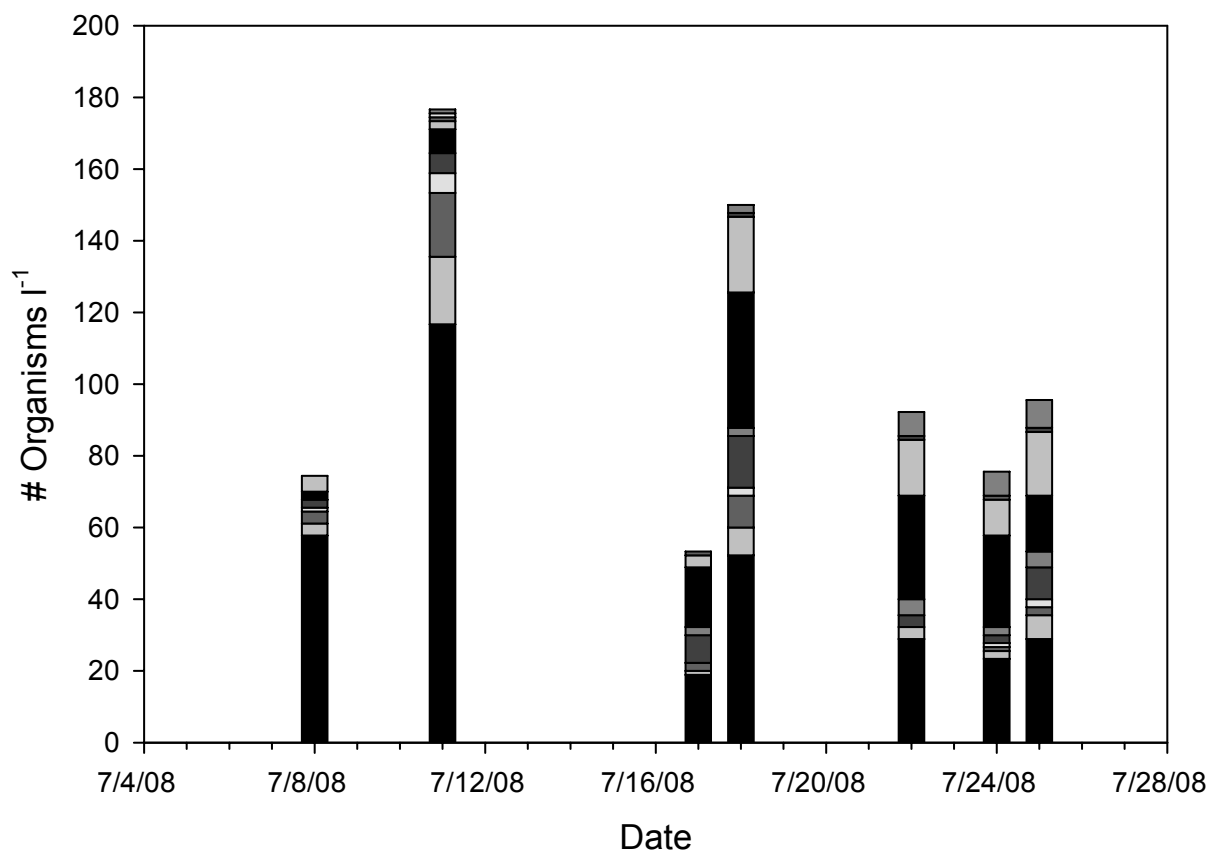
Nemertean

Flat Worms

Molluscs

(Trochophores
and Veligers)

Diatoms

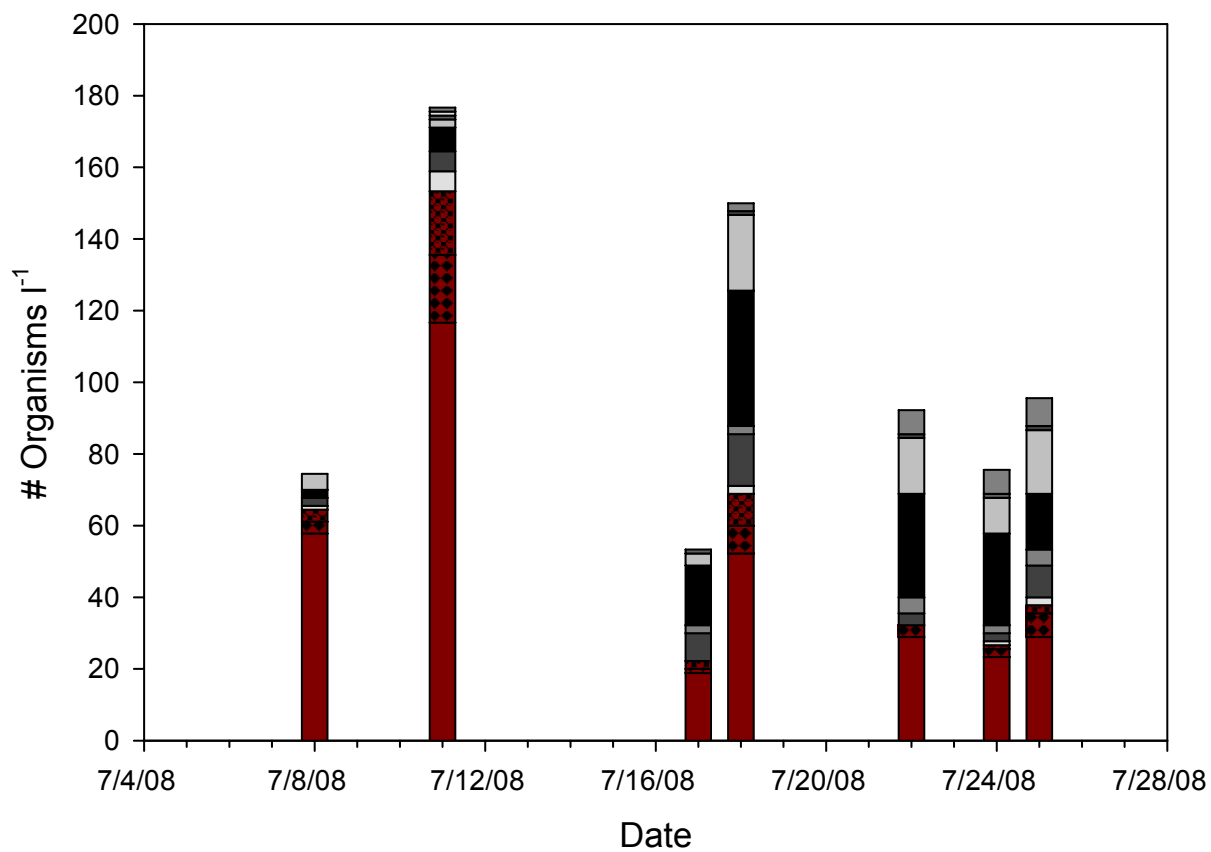




Summer Ambient Densities

- July 2008: 75-180 organisms l⁻¹

Crustaceans:
24-153 organisms l⁻¹

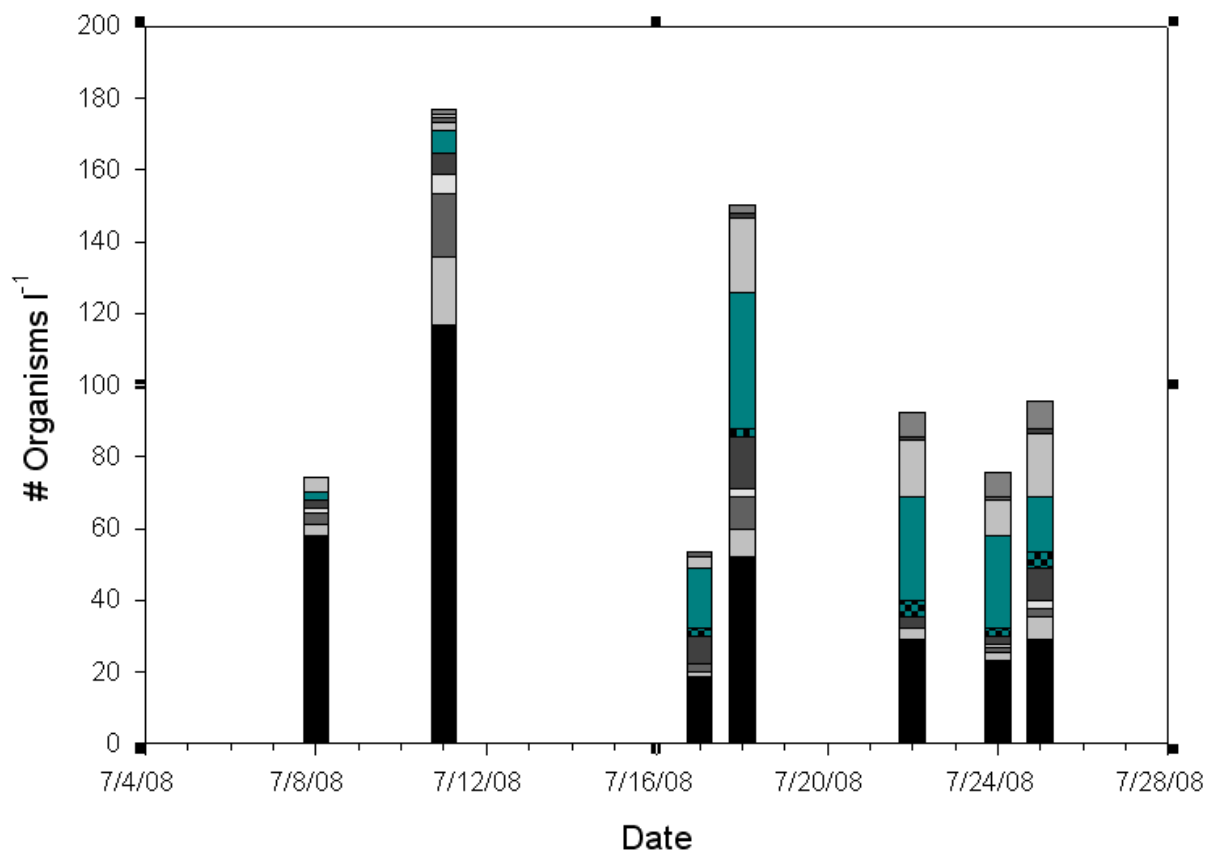




Summer Ambient Densities

- July 2008: 75-180 organisms l⁻¹

Polychaetes:
2-38 organisms l⁻¹





The Quest Begins

- How do we concentrate tens of millions of zooplankters:
 - Quickly
 - And without killing them



In situ vs. in tank



10'x10'x12'
25 um plankton net



In situ vs. in tank



10'x10'x12'
25 um plankton net



In situ vs. in tank



10'x10'x12'
25 um plankton net



In situ collection of plankton



- 4" hose
- 200 and 400 gpm
- At 400 gpm,
16.7 gpm m⁻²





One-hour *in situ* trial

- **25-35%** relative retention of organisms (compared to ambient plankton sample taken with a sieve)

organisms l^{-1} filtered from ambient seawater using **large plankton net**

organisms l^{-1} filtered from 20 l ambient seawater using **a sieve**

X 100



One-hour *in situ* trial

- 25-35% relative retention of organisms (compared to ambient plankton sample taken with a sieve)
- Tried to run overnight...
 - ...Net ripped.
(Too much volume?)





Next Plan: Inline Filter Bags

- Two 50 μm filter bags in series
 - 16" long bags
 - 25 or 50 gpm

 - At 25 gpm,
125 gpm m^{-2}
 - At 50 gpm,
250 gpm m^{-2}





Next Plan: Inline Filter Bags

- Two 50 μm filter bags in series
 - 16" long bags
 - 25 or 50 gpm

62-99+% recovery
of organisms at
25 gpm

10-15% at 50 gpm

- Good recovery, but not big enough to be practical given our situation





In Parallel Filter Bags



- Four 50 μm bags + four 25 μm bags (32" long)
- 75 gpm for 1-3 hours (23.4 gpm m^{-2})



In Parallel Filter Bags



- Four 50 μm bags + four 25 μm bags (32" long)
- 75 gpm for 1-3 hours
- 25 μm bags overflowed



Go Big - Water Box

- Thirty-six 50 μm filter bags – 32” long
- 170 gpm for 5 hours
- 11.8 gpm m^{-2}





Water Box Results

- Mean ambient plankton (sieve): 60.5 l⁻¹
- Concentrated plankton (box): 17.9 l⁻¹ (29.6%)

- Mean ambient crustaceans (sieve): 43.0 l⁻¹
- Concentrated crustaceans (box): 11.6 l⁻¹ (26.88%)



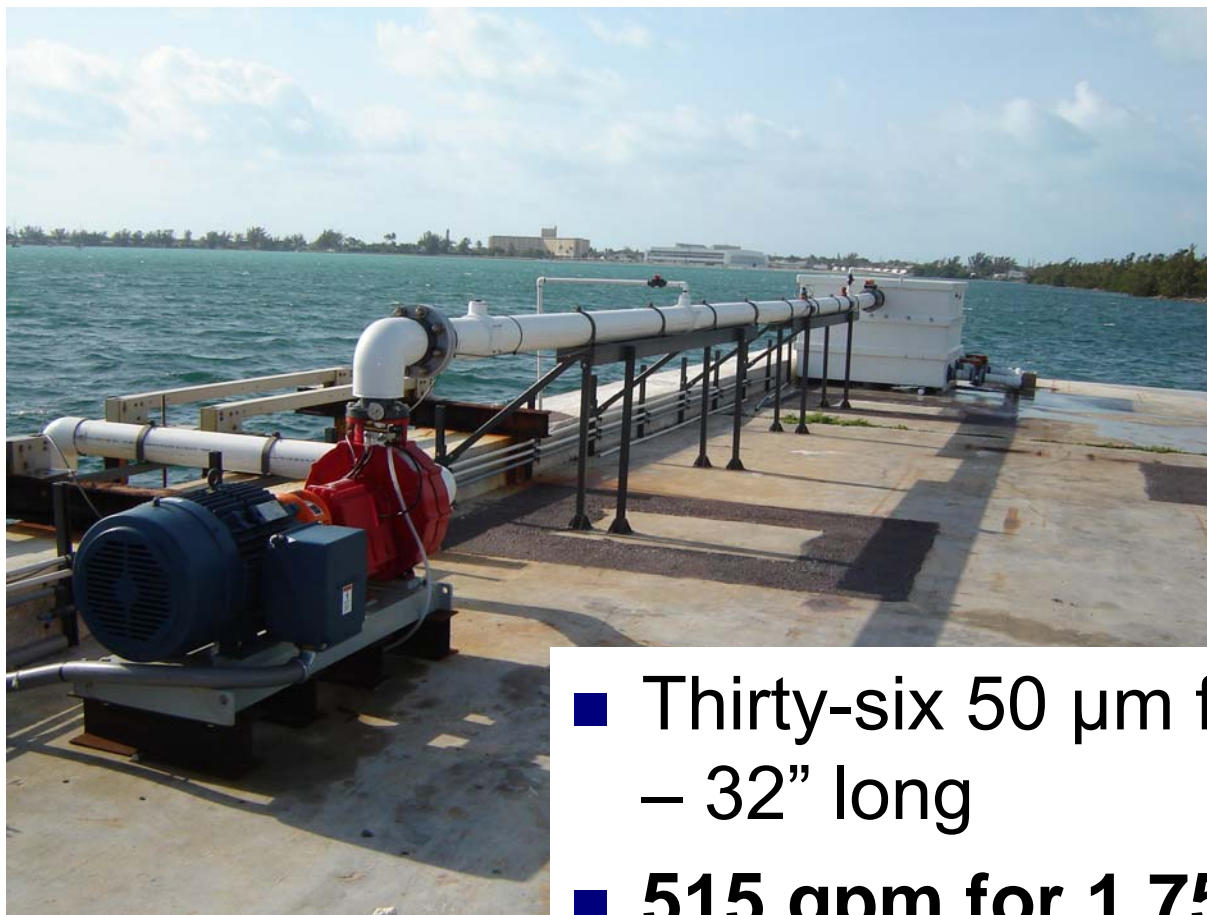
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At 200 gpm



New Pump for the Water Box



- Thirty-six 50 μm filter bags – 32" long
- 515 gpm for 1.75 hours
- 35.75 gpm m^{-2}



Water Box at 515 gpm

- Mean ambient plankton: 45.2 l⁻¹
- Concentrated plankton: 26.6 l⁻¹ (58.8%)

- Mean ambient crustaceans: 34.76 l⁻¹
- Concentrated crustaceans: 18.26 l⁻¹ (52.5%)



Water Box at 515 gpm

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- Concentrated plankton: 26.6 l⁻¹ (58.8%)

- Mean ambient crustaceans: 34.76 l⁻¹
- Concentrated crustaceans: 18.26 l⁻¹ (52.5%)

- This trial only ran for 105 minutes – less patchiness and variability



Summary

- Parallel filtration reduces flow per m^2 of mesh without decreasing surface area:volume.



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- Plankton retention efficiency drops off greatly between 125 and 250 gpm m^{-2} .



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- Parallel filtration reduces flow per m^2 of mesh without decreasing surface area:volume.
- Plankton retention efficiency drops off greatly between 125 and 250 gpm m^{-2} .
- Longer periods of concentrating plankton will introduce more patchiness and variability into estimates.



Future Plans

- Continue Water Box experiments:
 - Increasing run time (overnight)
 - Assess health of organisms



Future Plans

- Continue Water Box experiments:
 - Increasing run time (overnight)
 - Assess health of organisms
- Continue monitoring variability in ambient plankton community



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