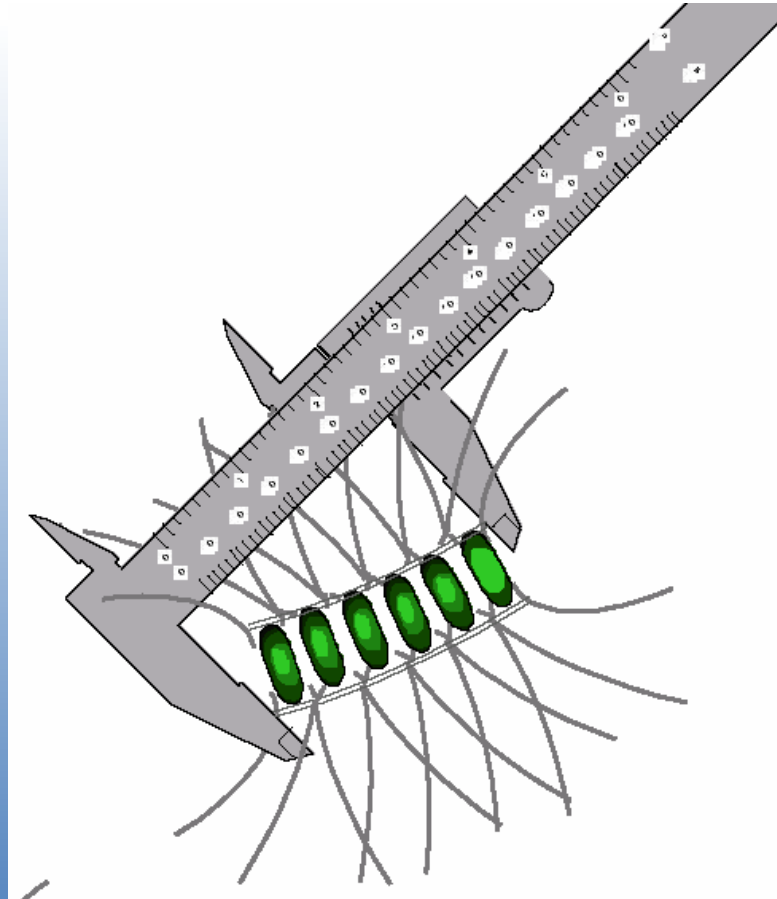


# “The Golden Bear Research Center (GBRC): Insight into Ballast Type Approval and Treatment Efficacy”

Nick Welschmeyer, Moss Landing Marine Laboratories, CA (CSU)  
and Golden Bear Research Center, Cal Maritime (CSU)

Presented: Sept. 26, 2018, Prevention First, Long Beach CA



**Golden Bear Research Facility (GBRC)**  
**California Maritime Academy CSU, Vallejo CA**  
**Moss Landing Marine Laboratories, SJSU, Moss Landing CA**



**Bill Davidson, Director and Chief Engineer**  
**Rich Muller, Associate Director**  
**Chris Brown, Scientific Program Manager**  
**Dr. Nick Welschmeyer, Lead Scientist**  
**Stephen Loiacono, Science Coordinator**  
**Nilo Alvarado, Research Technician**  
**Sean Fitch, Research Technician**

# QUESTION:

## HOW ARE WE DOING IN BALLAST WATER TREATMENT?

Let's see how ballast treatment success compares with other applications in pollution\* and public health\*\*

\* Bloomberg Report 2013;

\*\*World Health Organization

# Treatment Efficacy for a Ballast Tank:

What goes in vs. What goes out

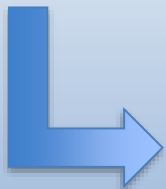
If Discharge is reduced to 1% of Uptake:

=100x reduction

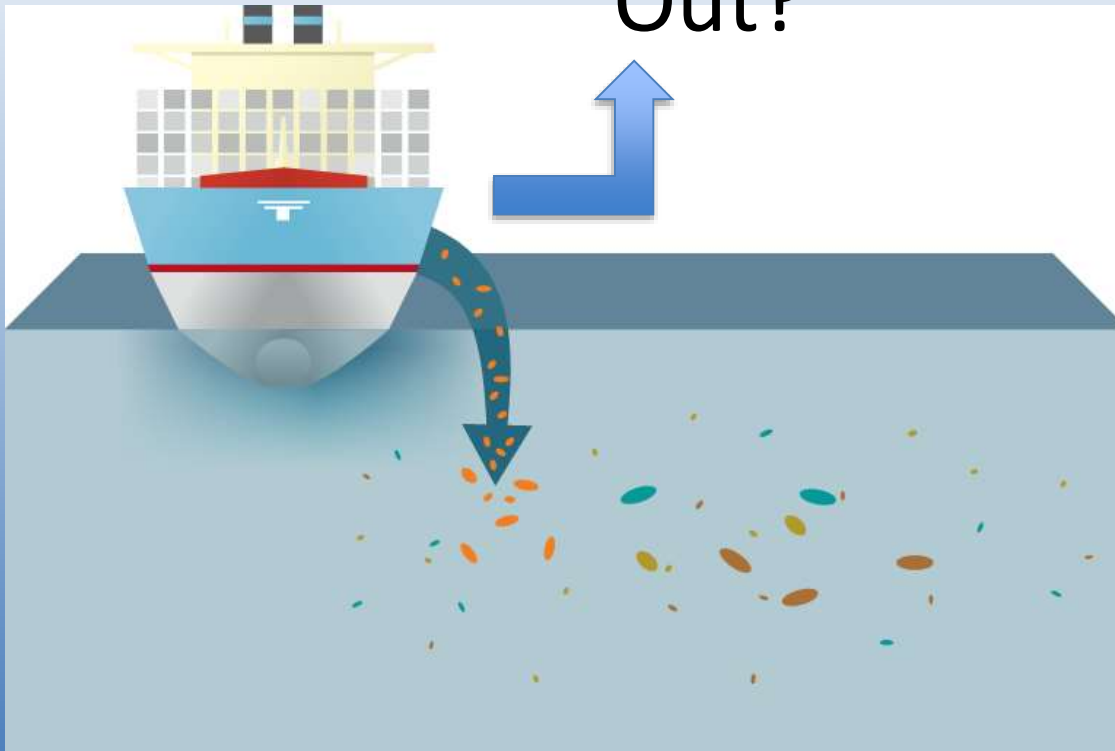
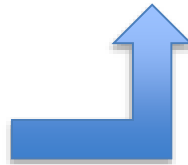
=2 log reduction

= 99% reduction

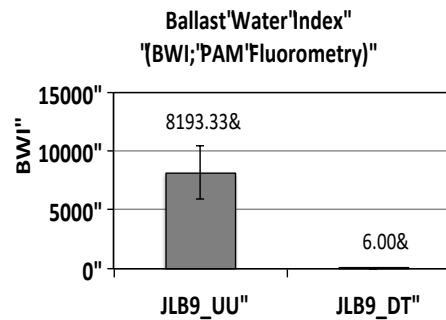
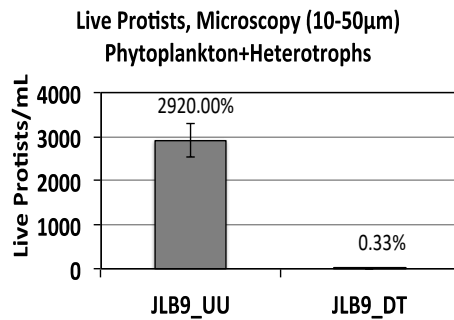
In



Out?

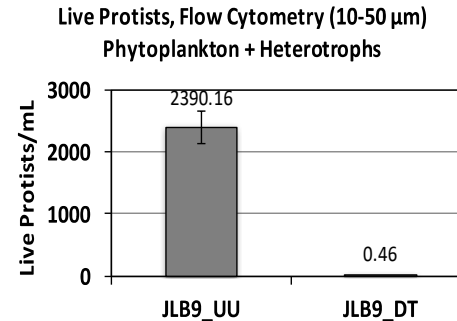
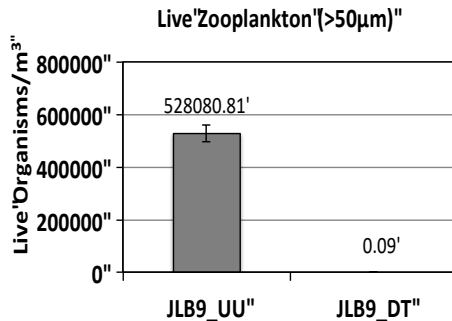


8849x



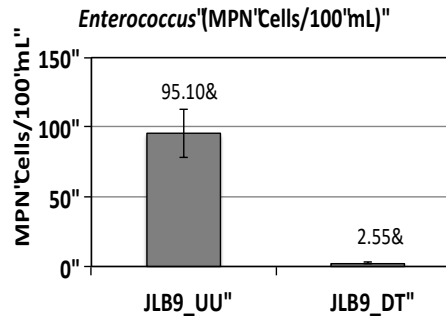
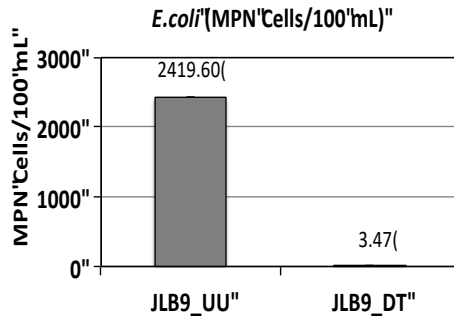
1366x

578667x



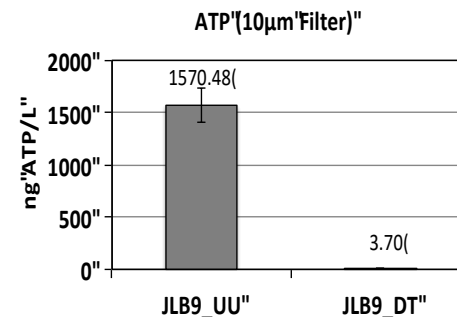
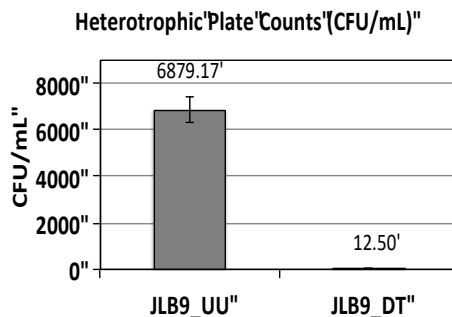
5196x

697x



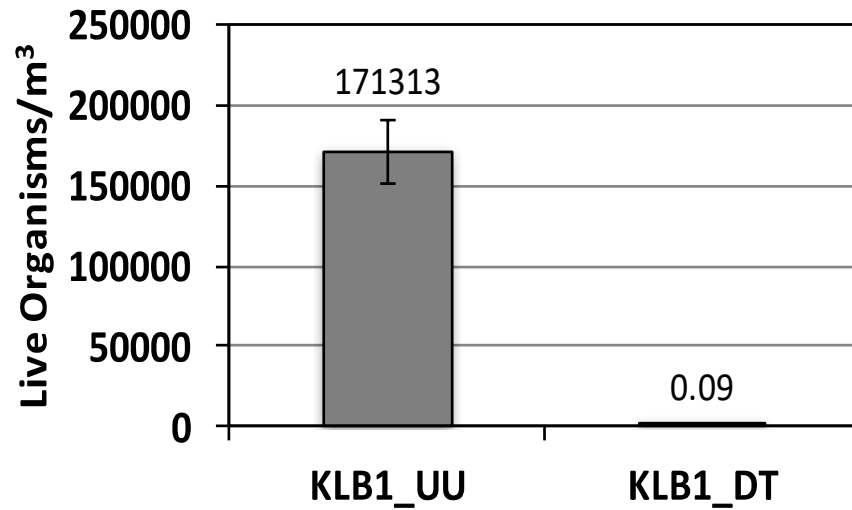
37x

550x

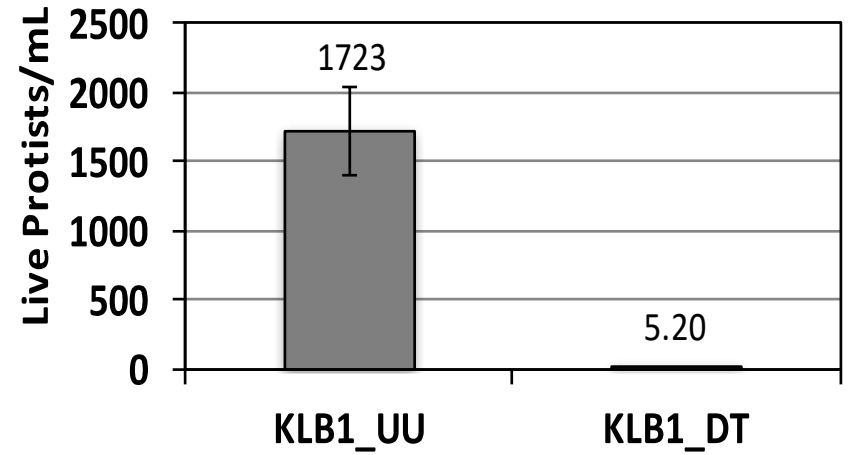


424x

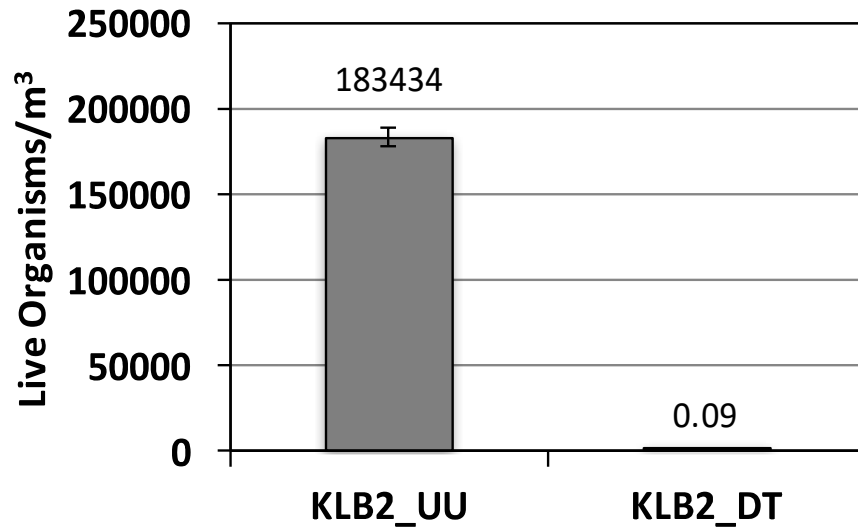
Live Zooplankton (>50  $\mu\text{m}$ )



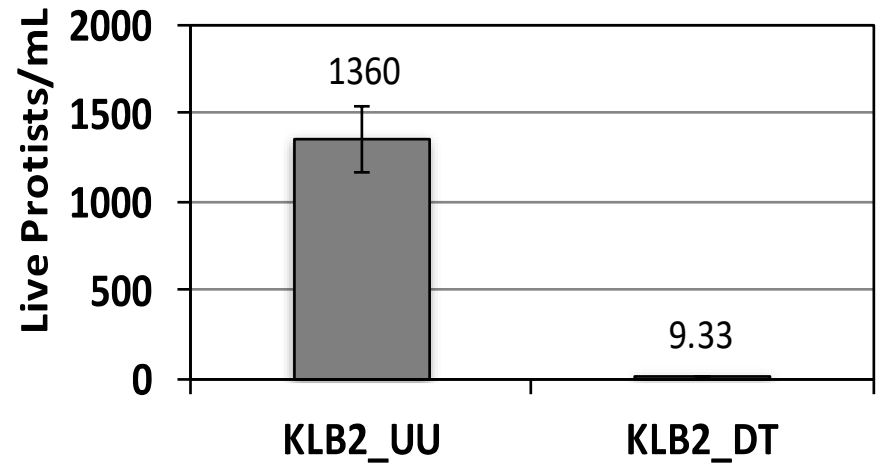
Live Protists, Epi Microscopy (10-50  $\mu\text{m}$ )  
Phytoplankton + Heterotrophs



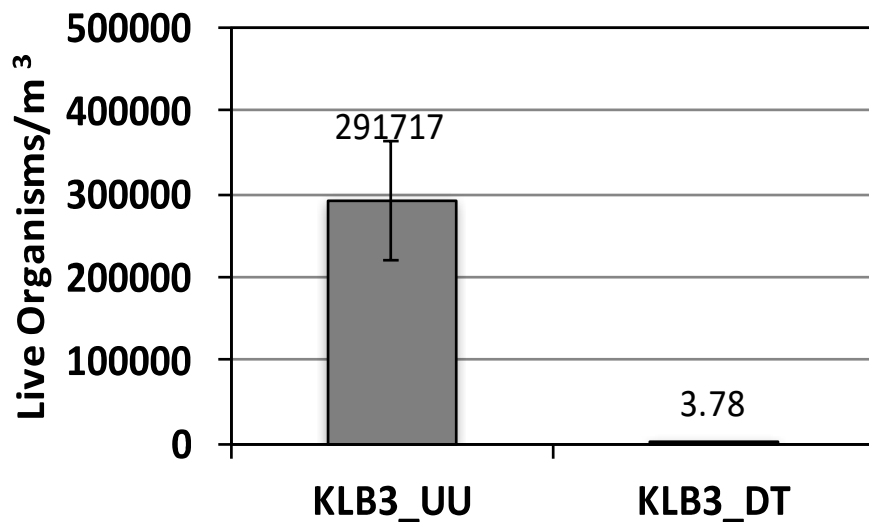
Live Zooplankton (>50  $\mu\text{m}$ )



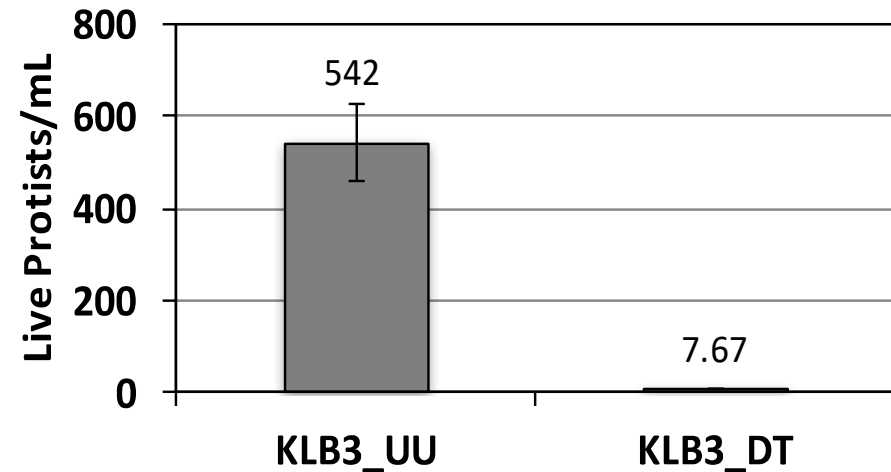
Live Protists, Epi Microscopy (10-50  $\mu\text{m}$ )  
Phytoplankton + Heterotrophs



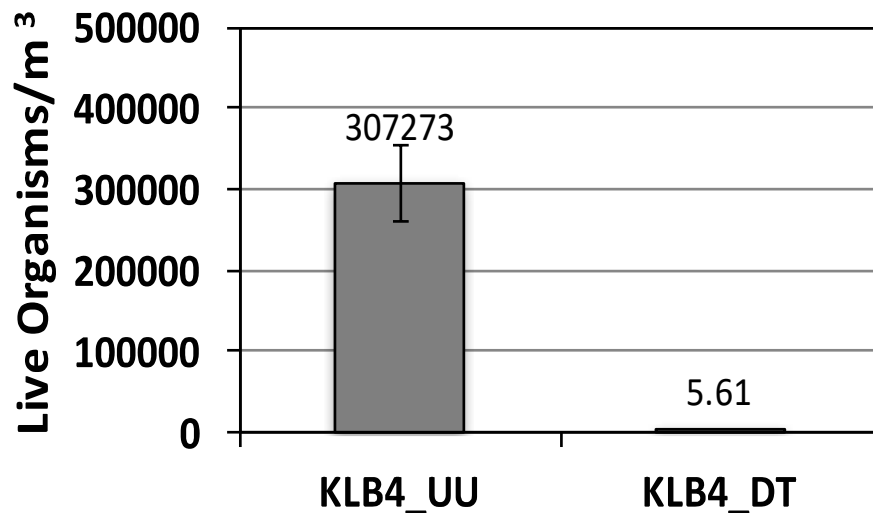
**Live Zooplankton (>50  $\mu\text{m}$ )**



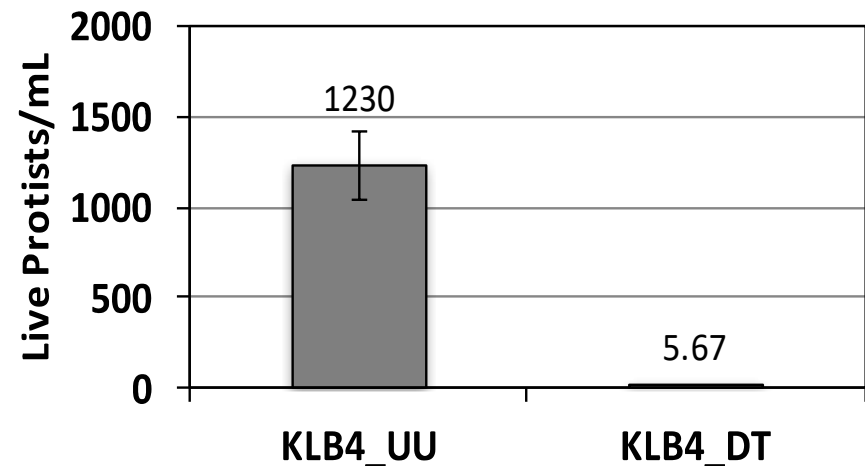
**Live Protists, Epi Microscopy (10-50  $\mu\text{m}$ )  
Phytoplankton + Heterotrophs**



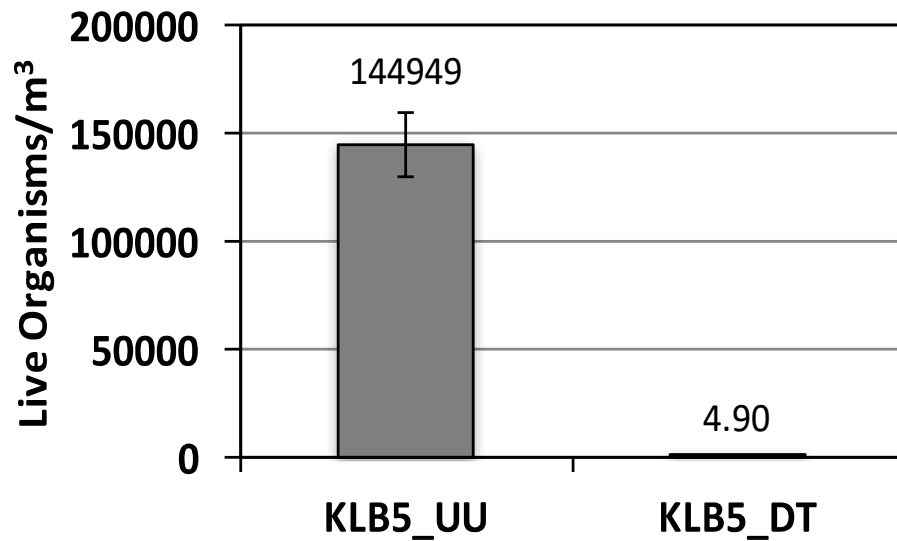
**Live Zooplankton (>50  $\mu\text{m}$ )**



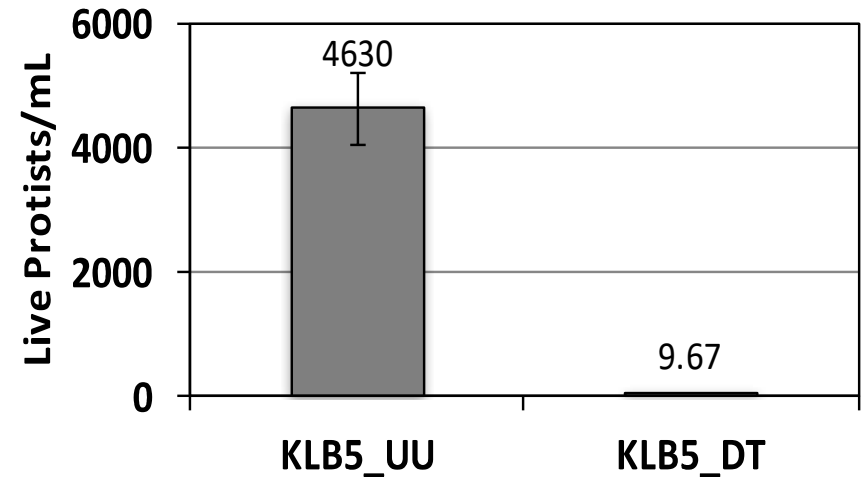
**Live Protists, Epi Microscopy (10-50  $\mu\text{m}$ )  
Phytoplankton + Heterotrophs**



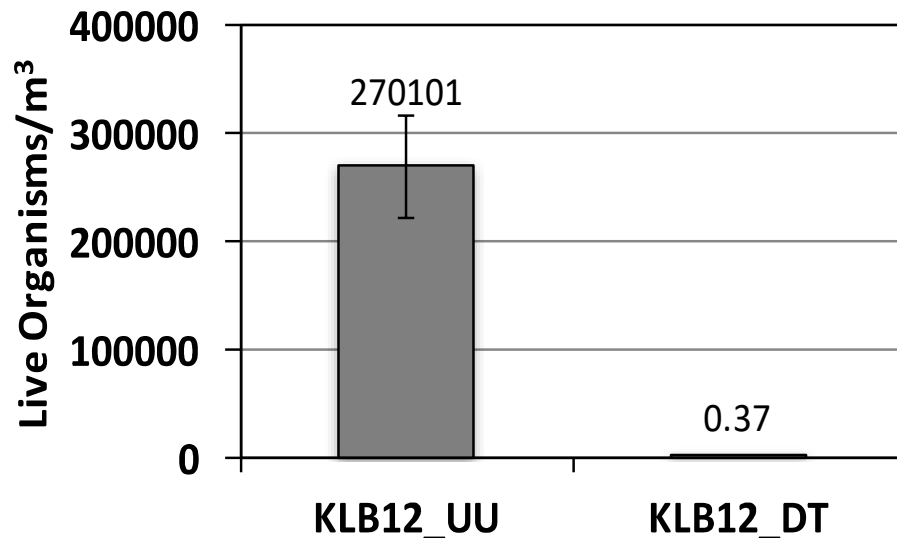
**Live Zooplankton (>50  $\mu\text{m}$ )**



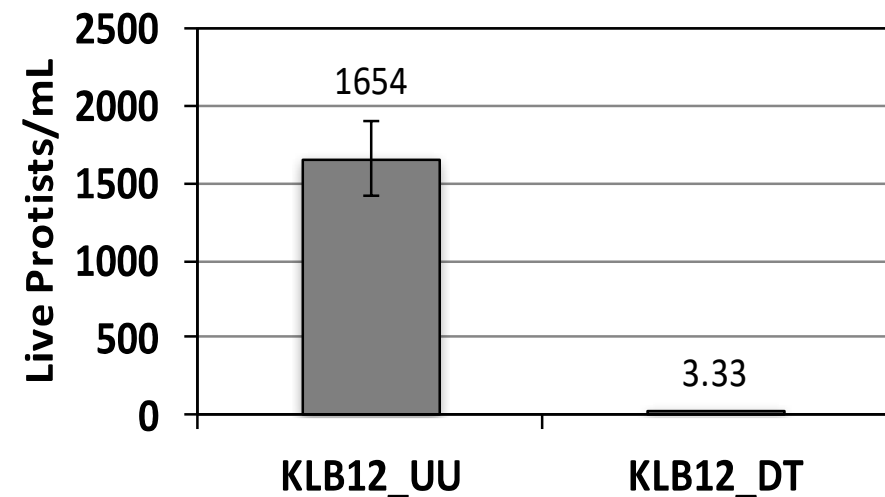
**Live Protists, Epi Microscopy (10-50  $\mu\text{m}$ )  
Phytoplankton + Heterotrophs**



**Live Zooplankton (>50  $\mu\text{m}$ )**

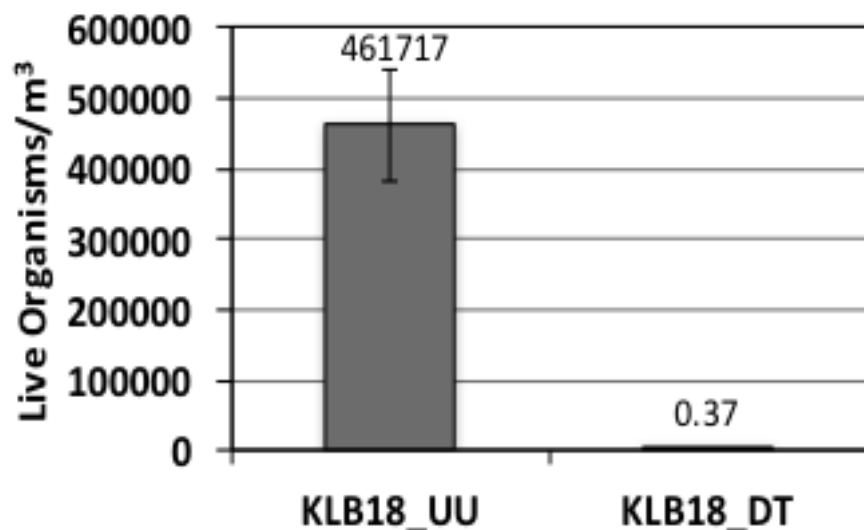


**Live Protists, Epi Microscopy (10-50  $\mu\text{m}$ )  
Phytoplankton + Heterotrophs**

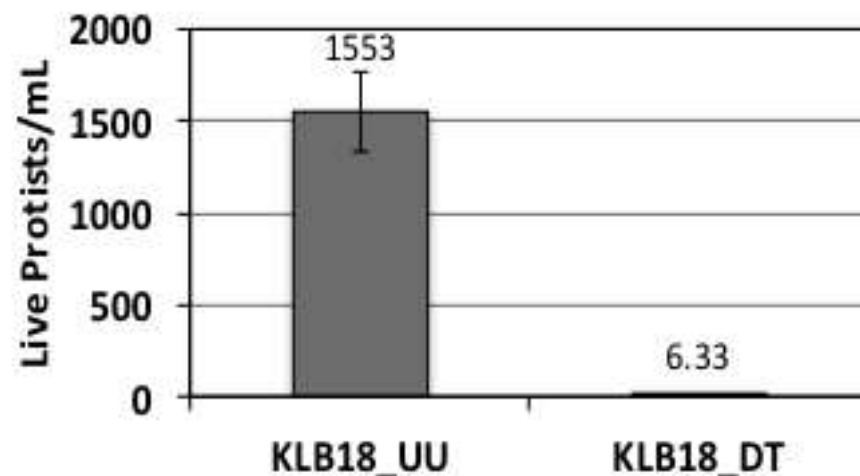




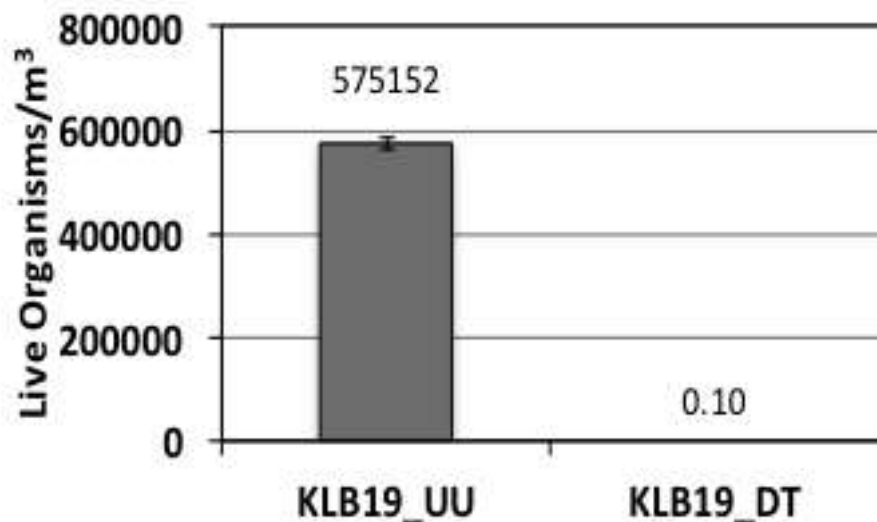
Live Zooplankton (>50  $\mu\text{m}$ )



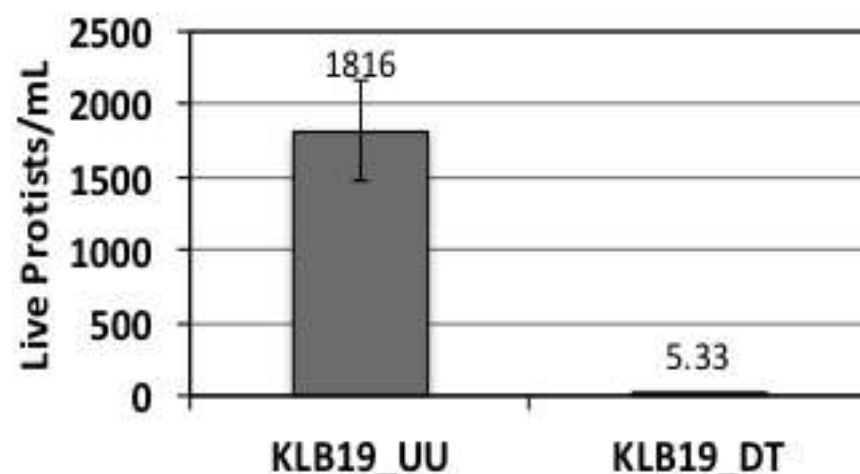
Live Protists, Epi Microscopy (10-50  $\mu\text{m}$ )  
Phytoplankton + Heterotrophs



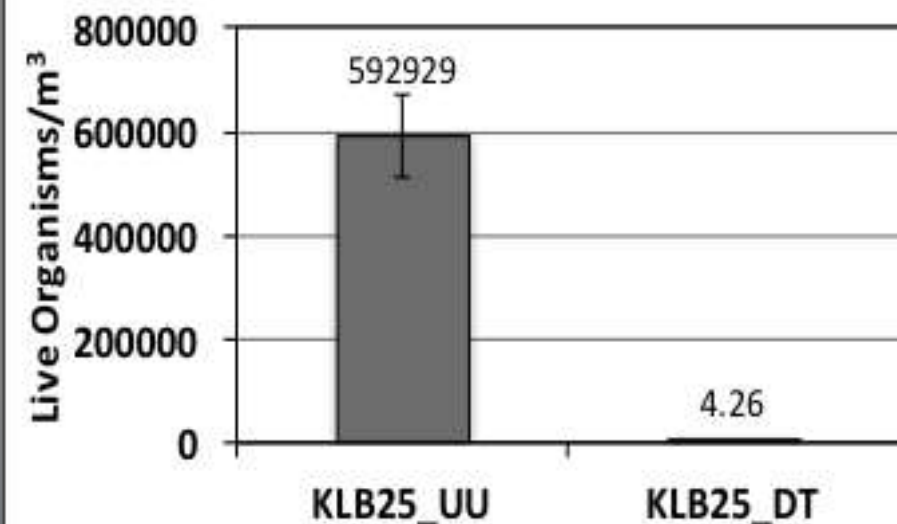
Live Zooplankton (>50  $\mu\text{m}$ )



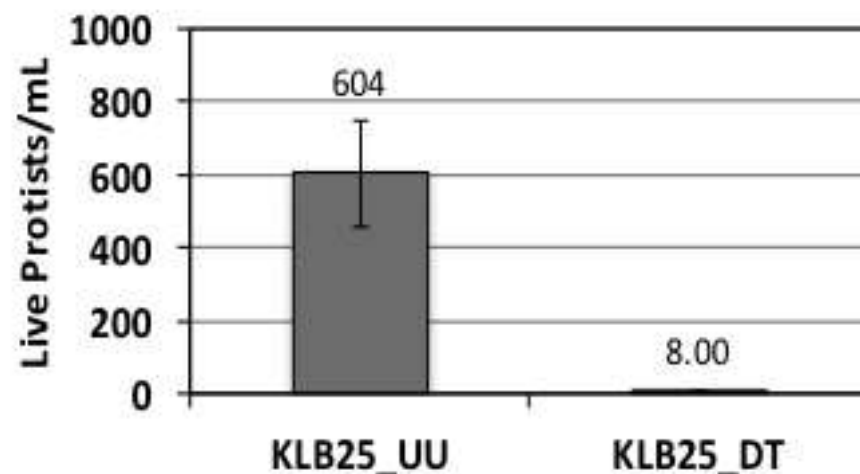
Live Protists, Epi Microscopy (10-50  $\mu\text{m}$ )  
Phytoplankton + Heterotrophs



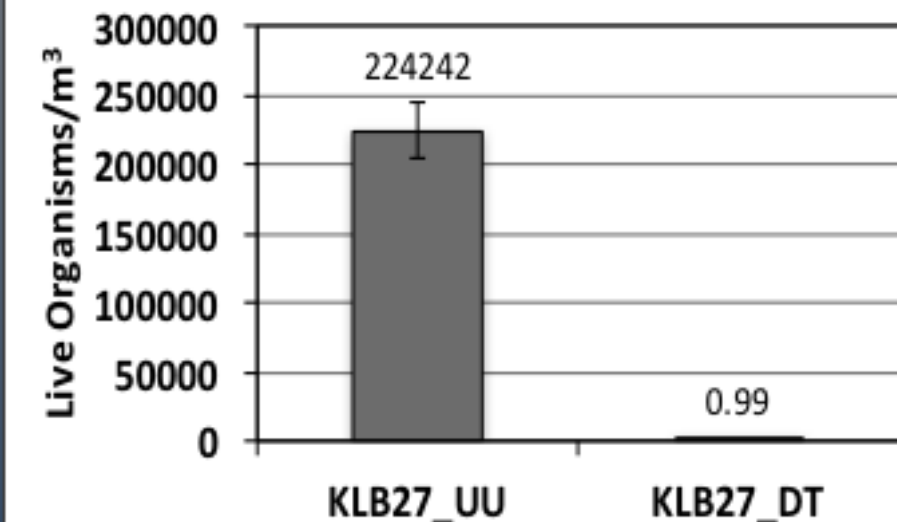
Live Zooplankton (>50  $\mu\text{m}$ )



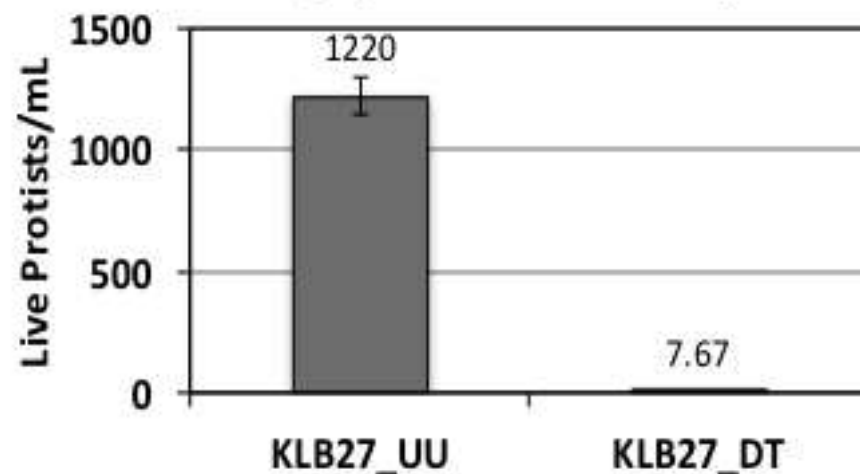
Live Protists, Epi Microscopy (10-50  $\mu\text{m}$ )  
Phytoplankton + Heterotrophs



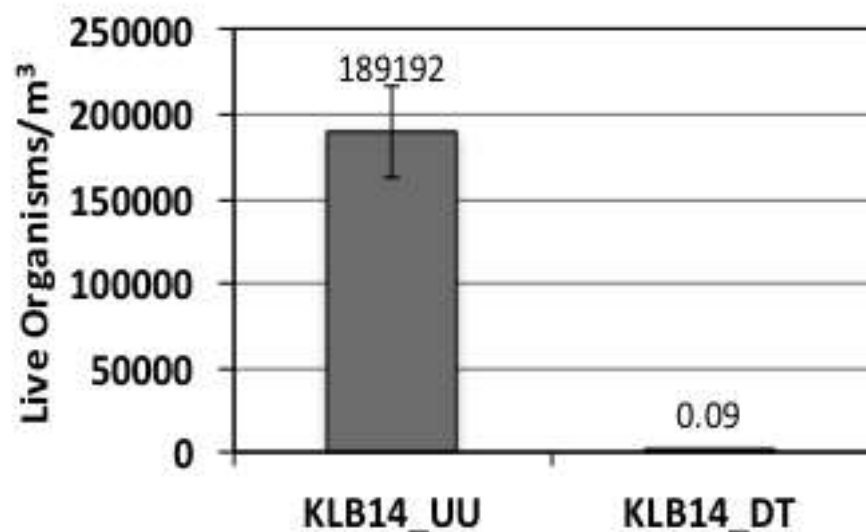
Live Zooplankton (>50  $\mu\text{m}$ )



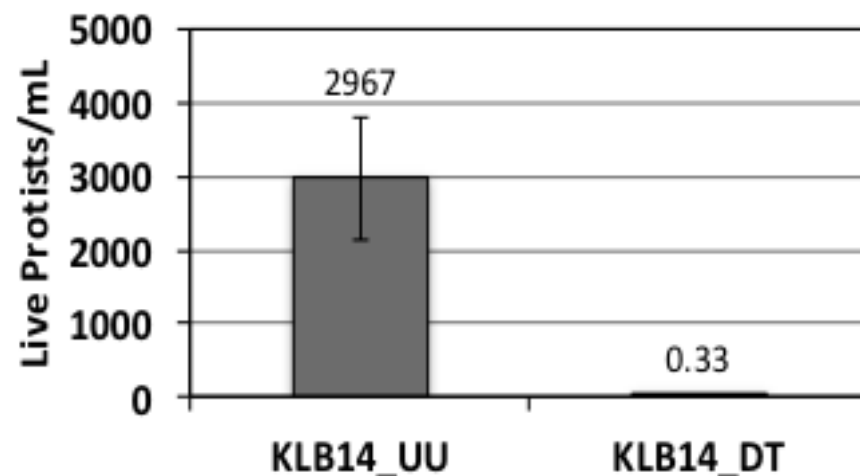
Live Protists, Epi Microscopy (10-50  $\mu\text{m}$ )  
Phytoplankton + Heterotrophs



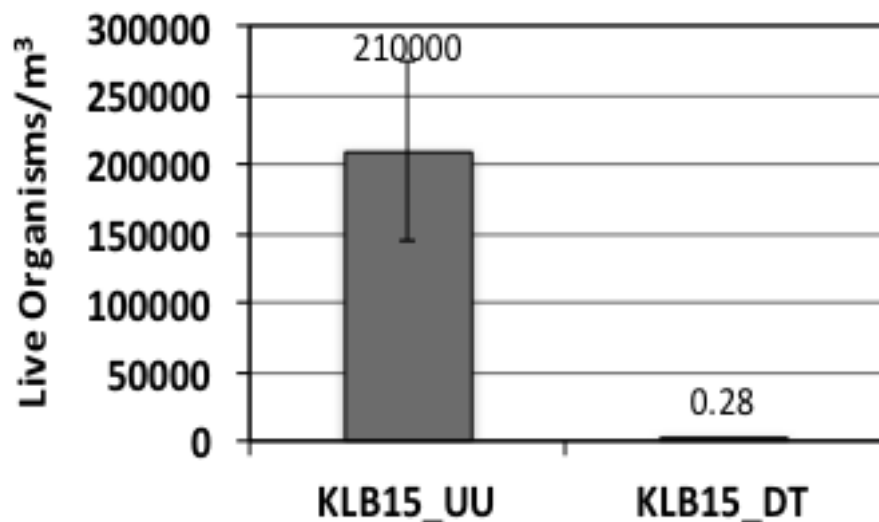
Live Zooplankton (>50  $\mu\text{m}$ )



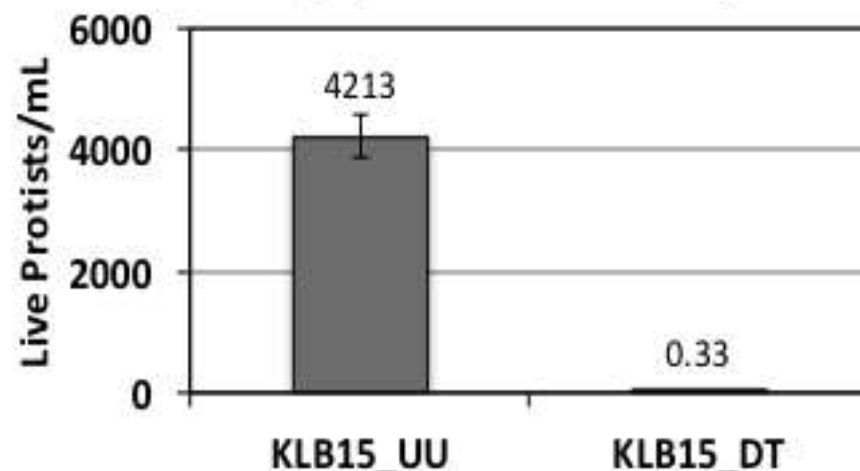
Live Protists, Epi Microscopy (10-50  $\mu\text{m}$ )  
Phytoplankton + Heterotrophs



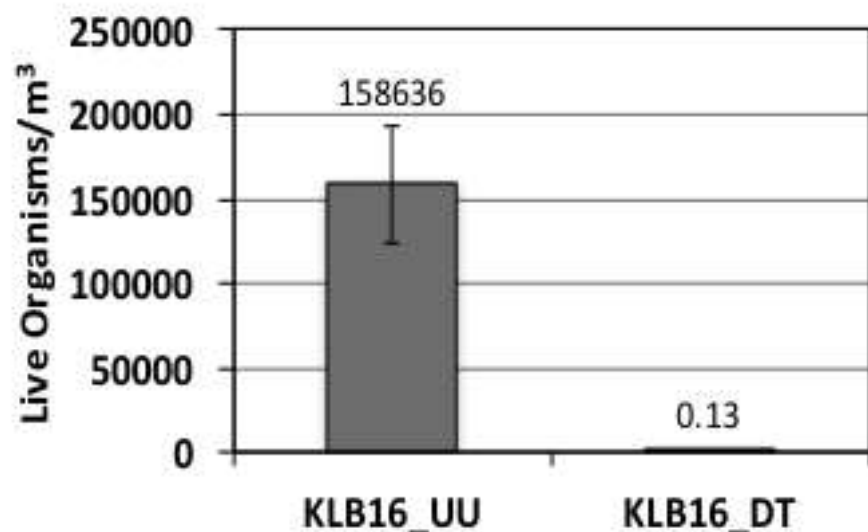
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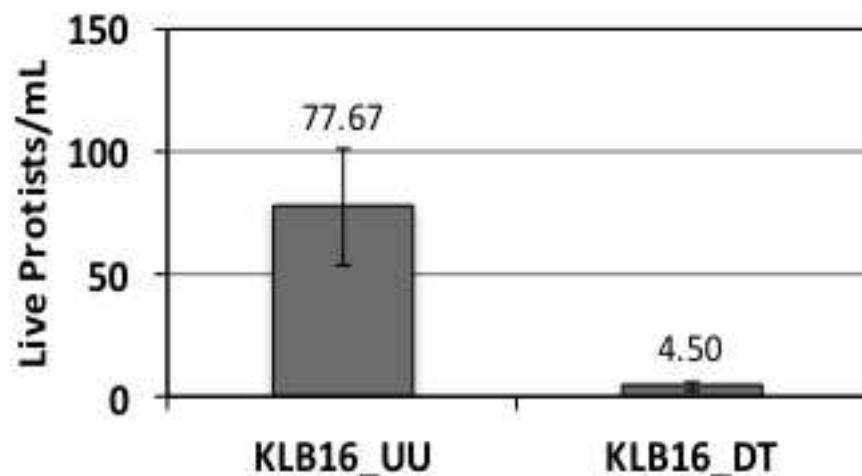
Live Protists, Epi Microscopy (10-50  $\mu\text{m}$ )  
Phytoplankton + Heterotrophs



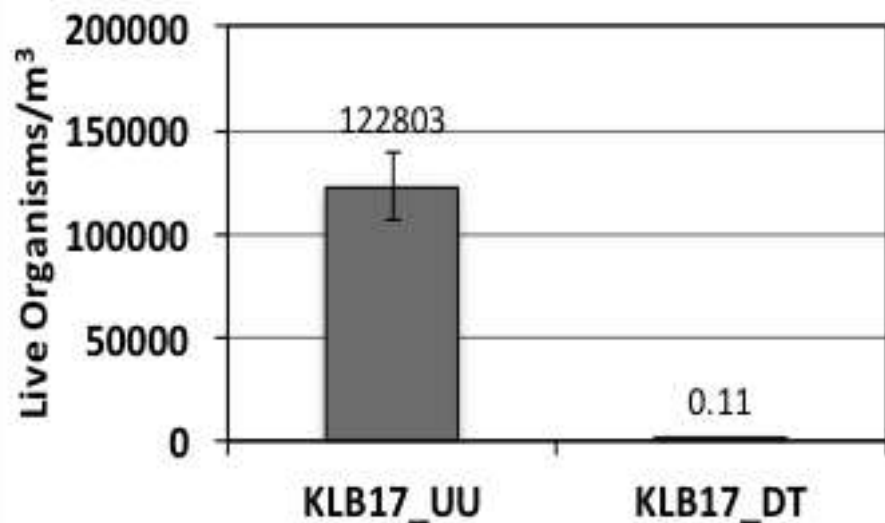
Live Zooplankton (>50  $\mu\text{m}$ )



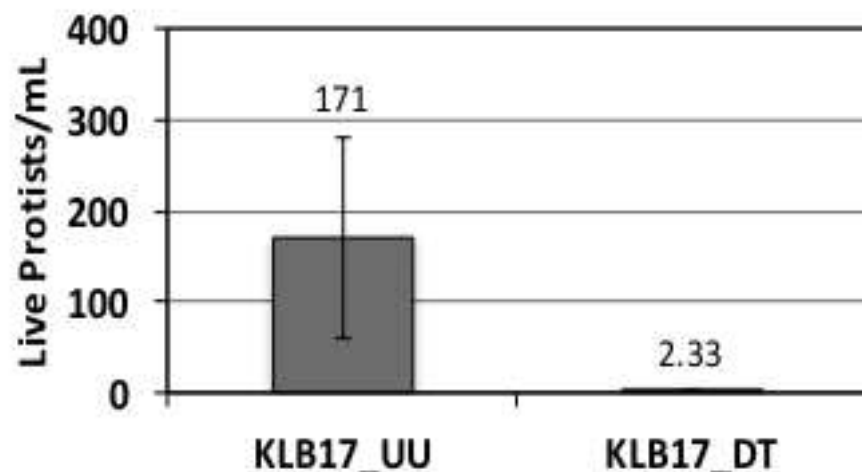
Live Protists, Epi Microscopy (10-50  $\mu\text{m}$ )  
Phytoplankton + Heterotrophs



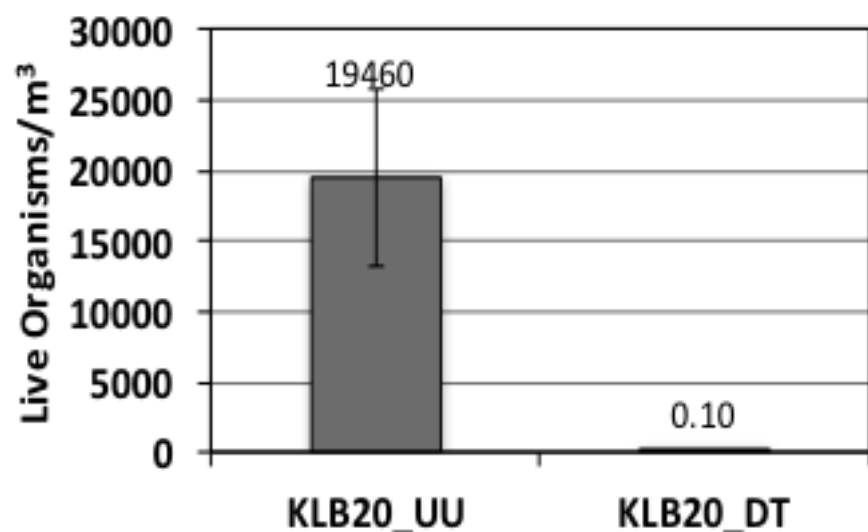
Live Zooplankton (>50  $\mu\text{m}$ )



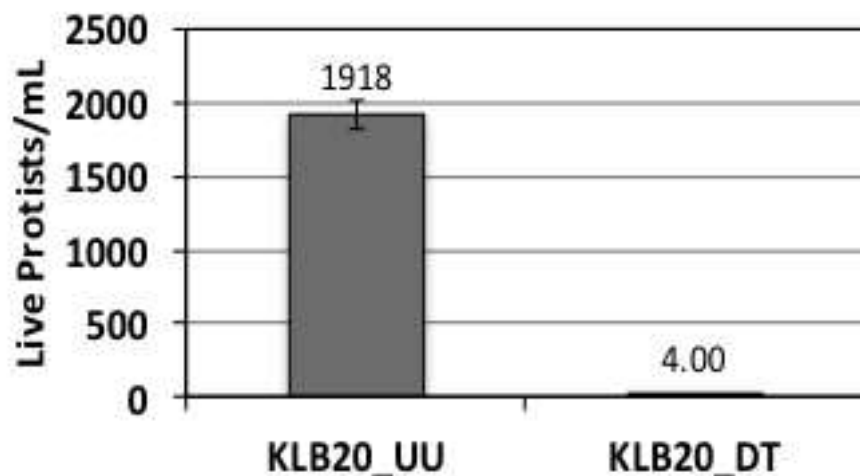
Live Protists, Epi Microscopy (10-50  $\mu\text{m}$ )  
Phytoplankton + Heterotrophs



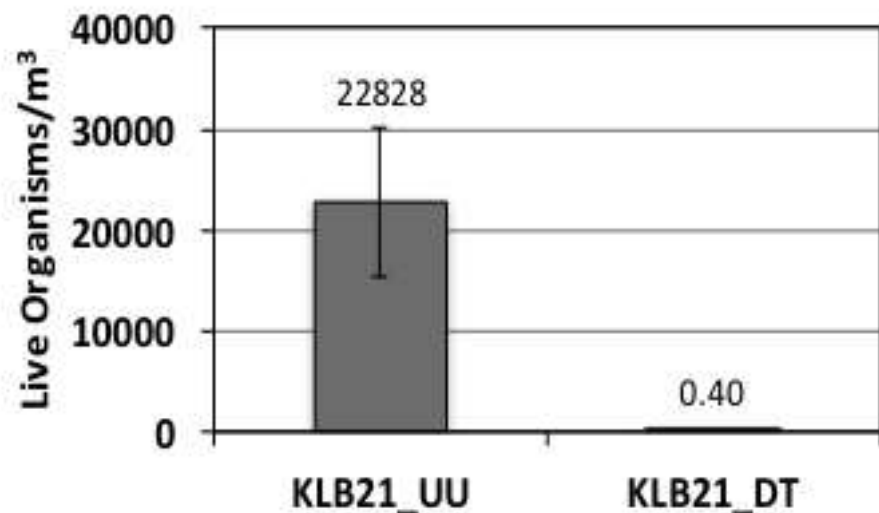
Live Zooplankton (>50  $\mu\text{m}$ )



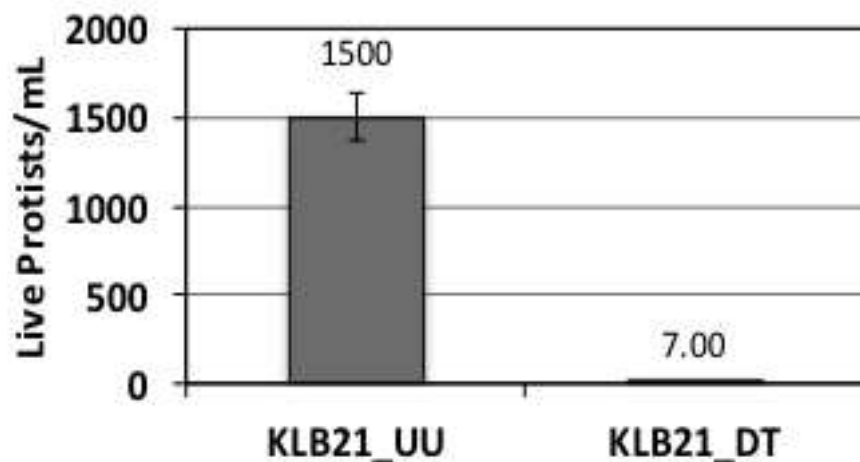
Live Protists, Epi Microscopy (10-50  $\mu\text{m}$ )  
Phytoplankton + Heterotrophs



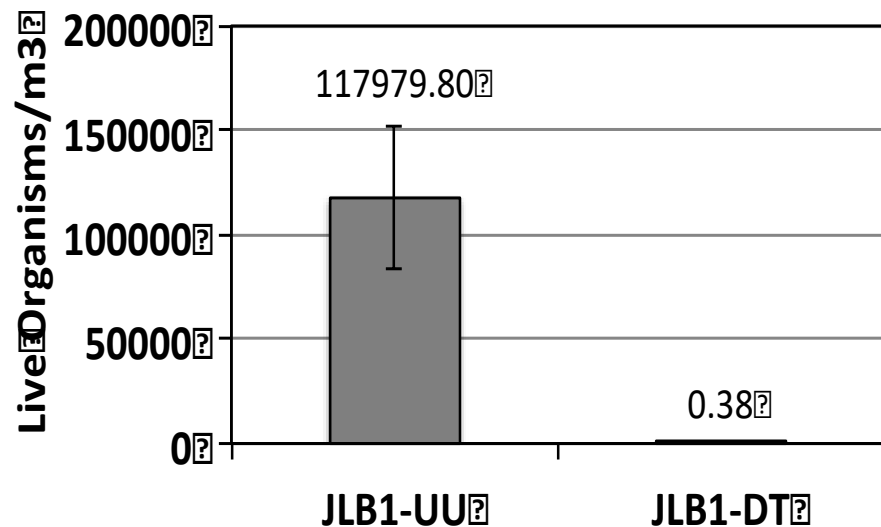
Live Zooplankton (>50  $\mu\text{m}$ )



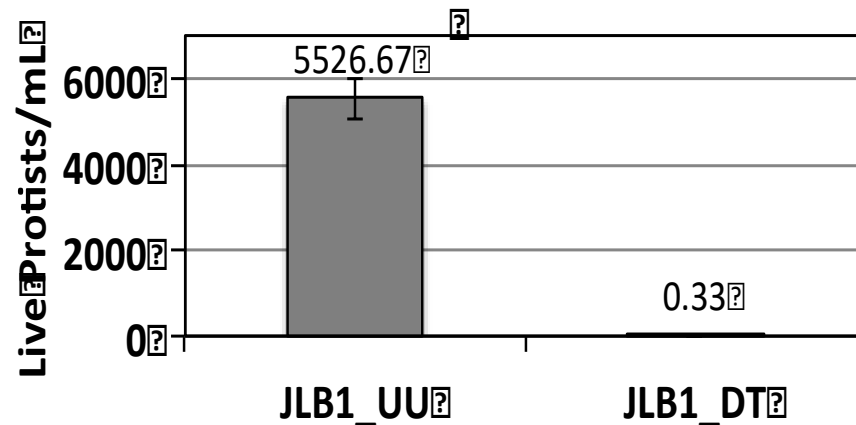
Live Protists, Epi Microscopy (10-50  $\mu\text{m}$ )  
Phytoplankton + Heterotrophs



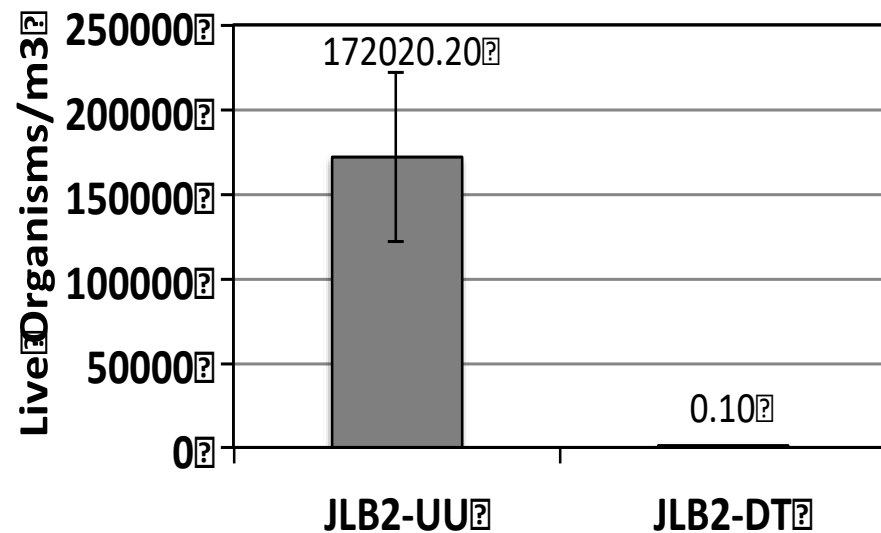
Live Zooplankton (>50um)



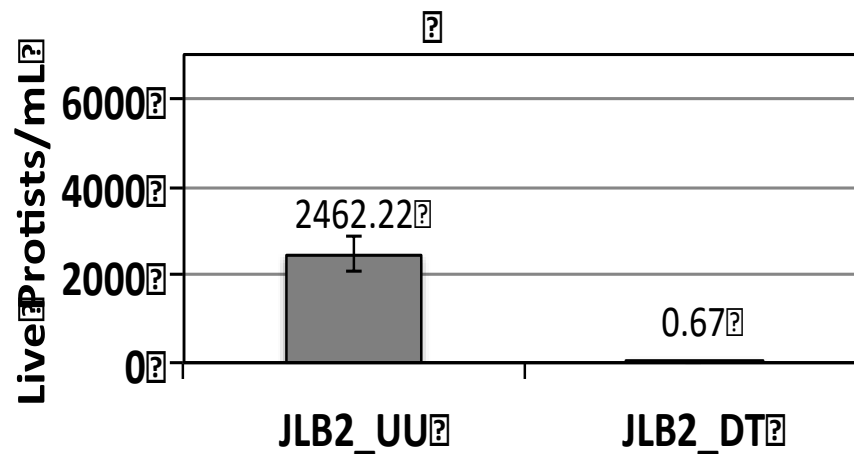
Live Protists, Epi Microscopy (10-50um)  
Phytoplankton+Heterotrophs



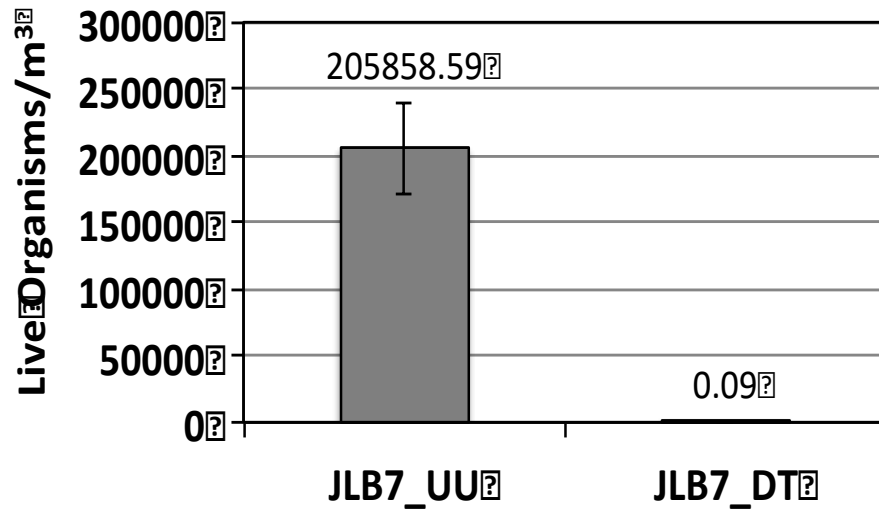
Live Zooplankton (>50um)



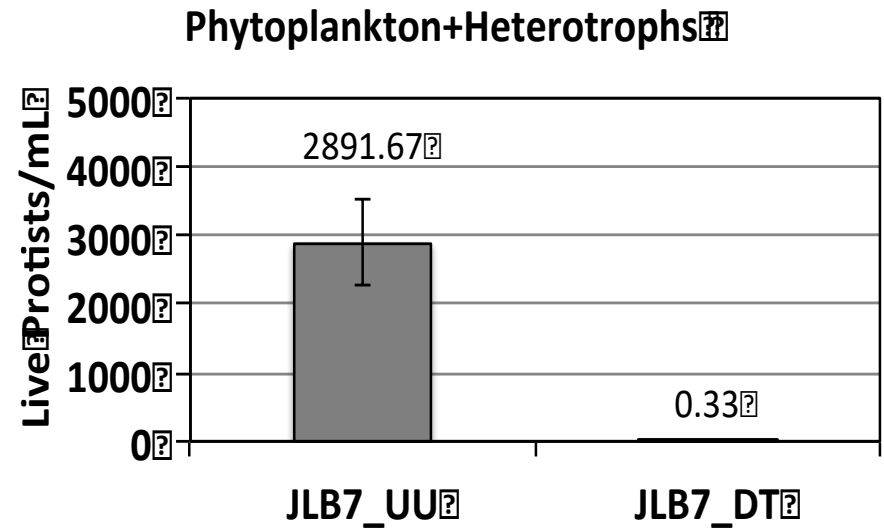
Live Protists, Epi Microscopy (10-50um)  
Phytoplankton+Heterotrophs



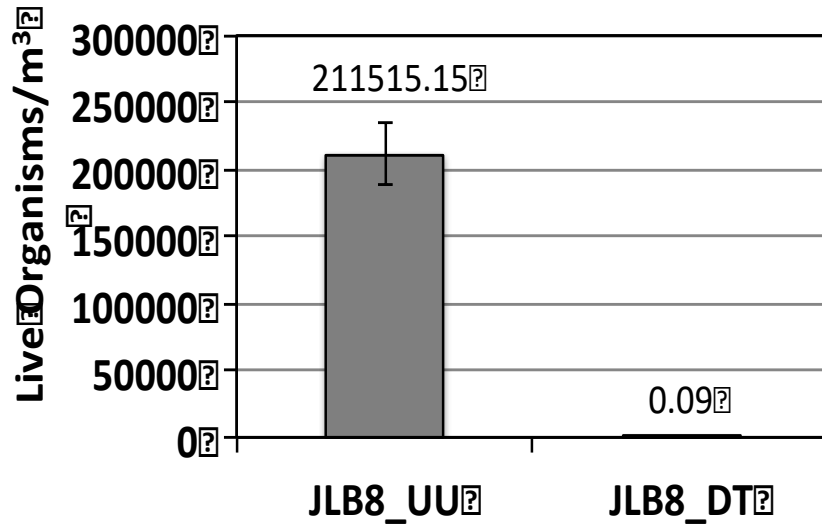
Live Zooplankton (>50um)



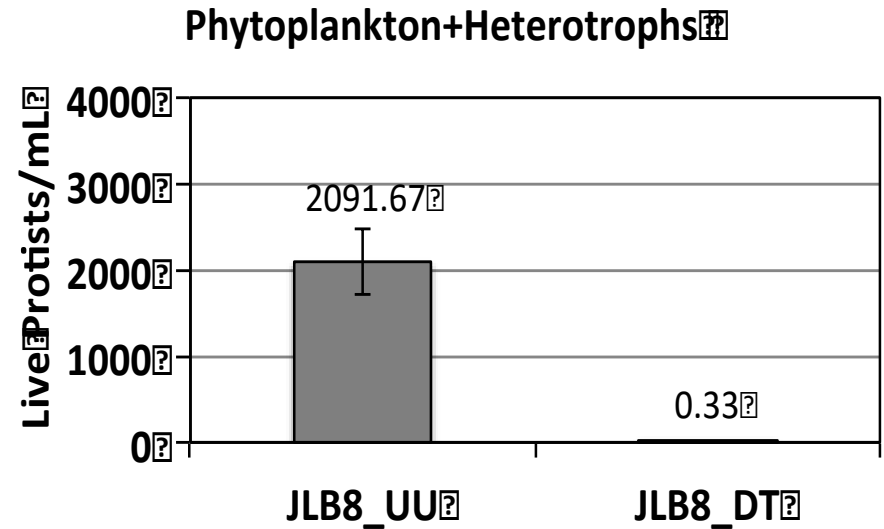
Live Protists, Epi Microscopy (10-50um)



Live Zooplankton (>50um)

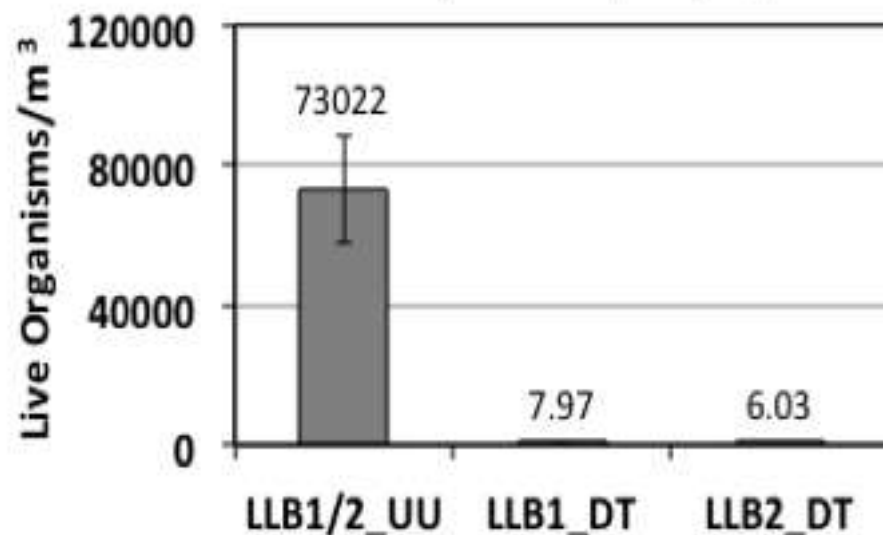


Live Protists, Epi Microscopy (10-50um)

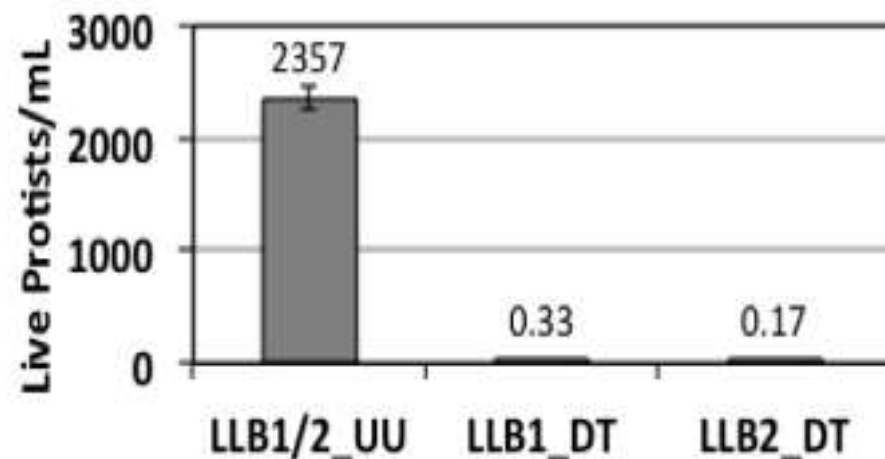




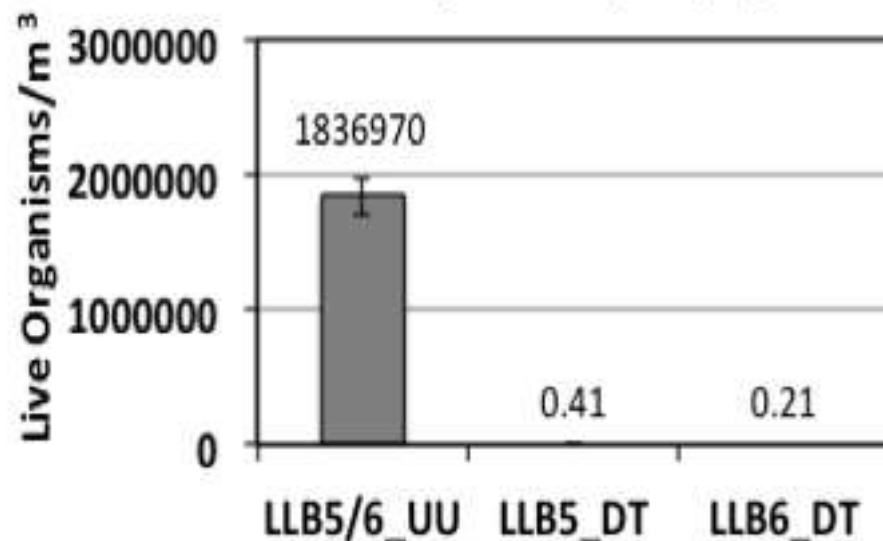
Live Zooplankton (>50  $\mu\text{m}$ )



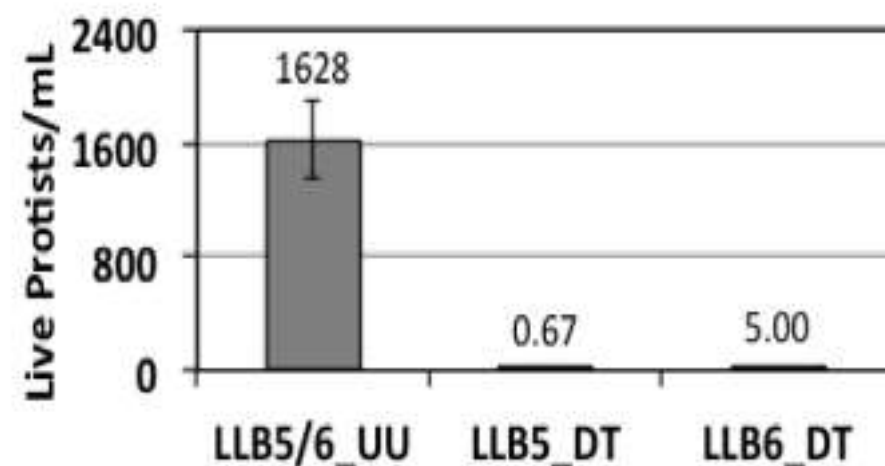
Live Protists, Epi Microscopy (10-50 $\mu\text{m}$ )  
Phytoplankton+Heterotrophs



Live Zooplankton (>50  $\mu\text{m}$ )

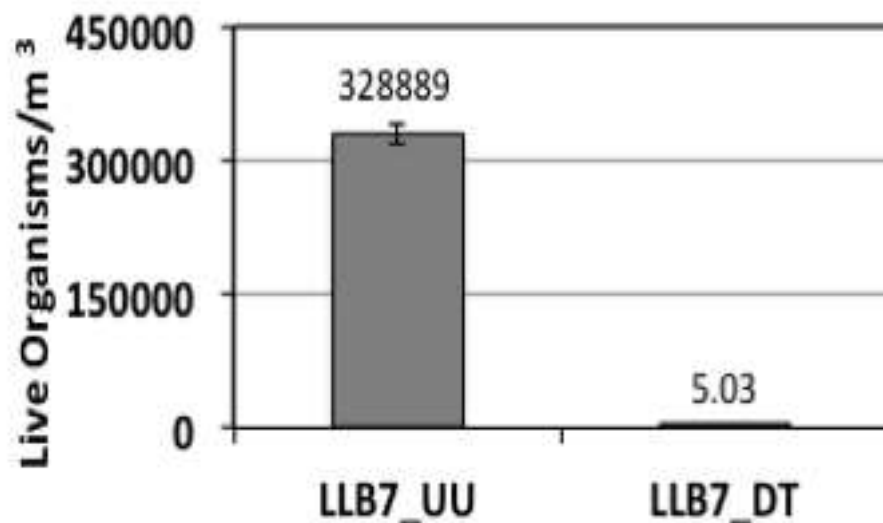


Live Protists, Epi Microscopy (10-50 $\mu\text{m}$ )  
Phytoplankton+Heterotrophs

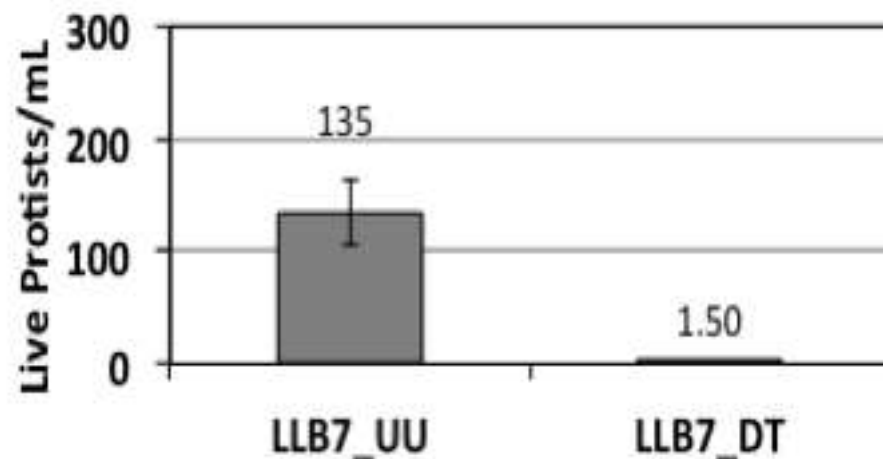




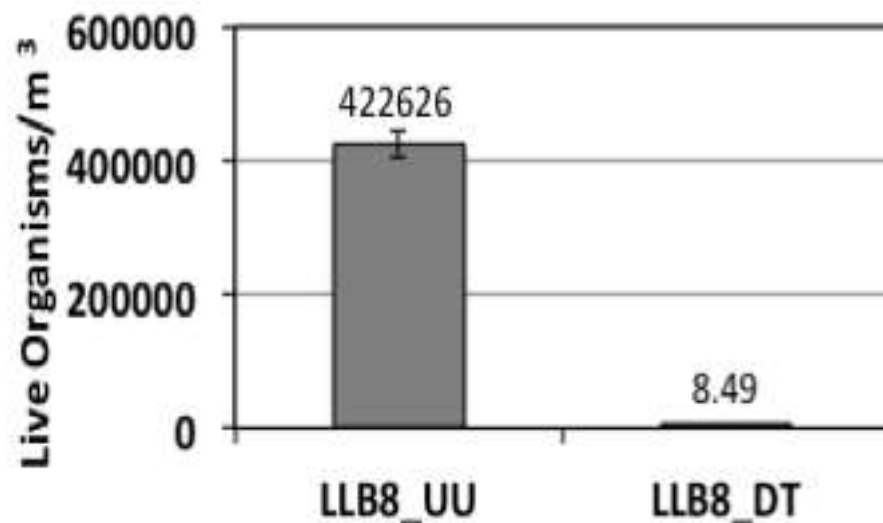
Live Zooplankton (>50  $\mu\text{m}$ )



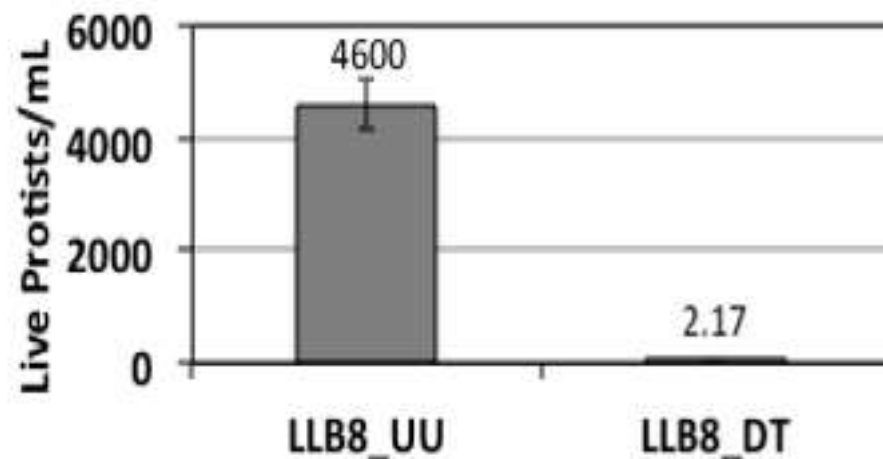
Live Protists, Epi Microscopy (10-50 $\mu\text{m}$ )  
Phytoplankton+Heterotrophs



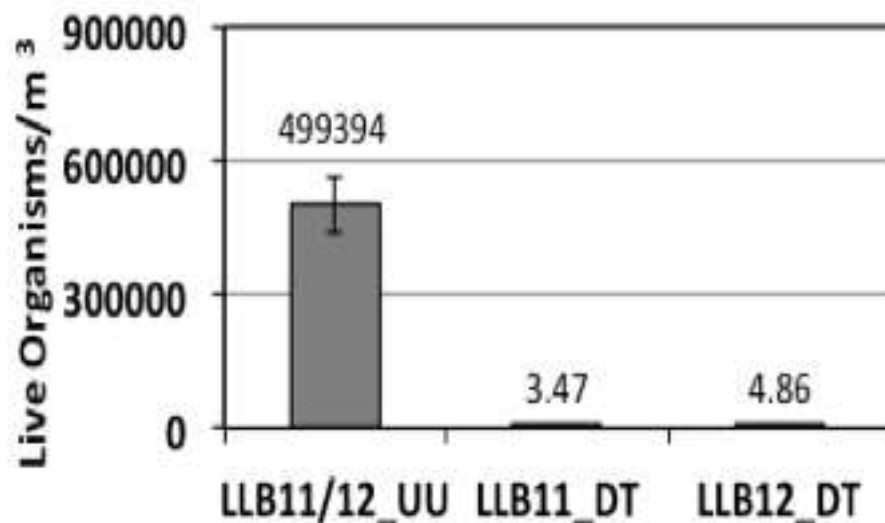
Live Zooplankton (>50  $\mu\text{m}$ )



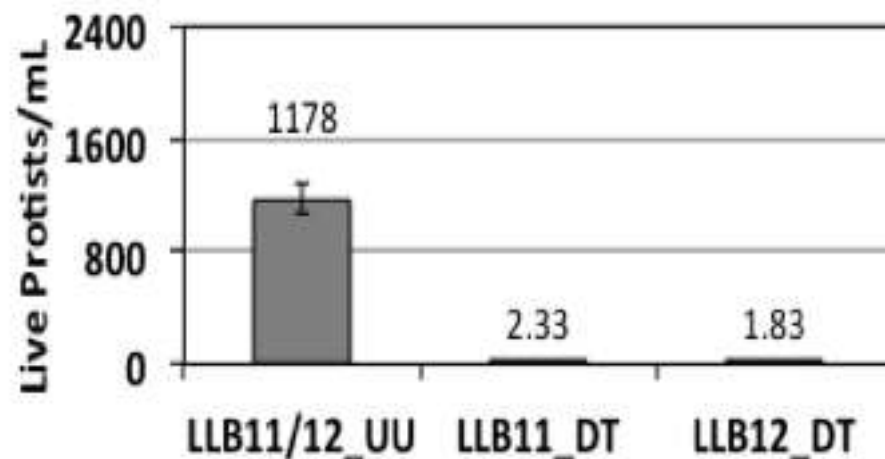
Live Protists, Epi Microscopy (10-50 $\mu\text{m}$ )  
Phytoplankton+Heterotrophs



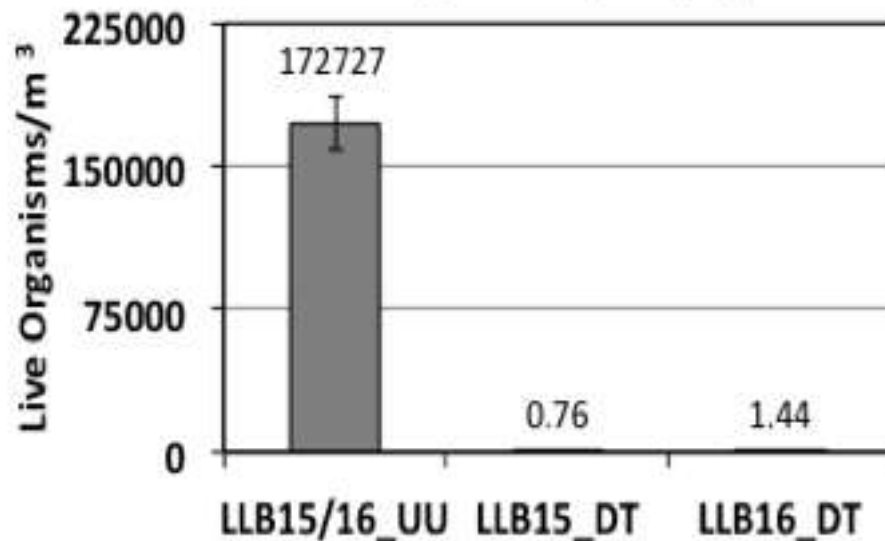
Live Zooplankton (>50  $\mu\text{m}$ )



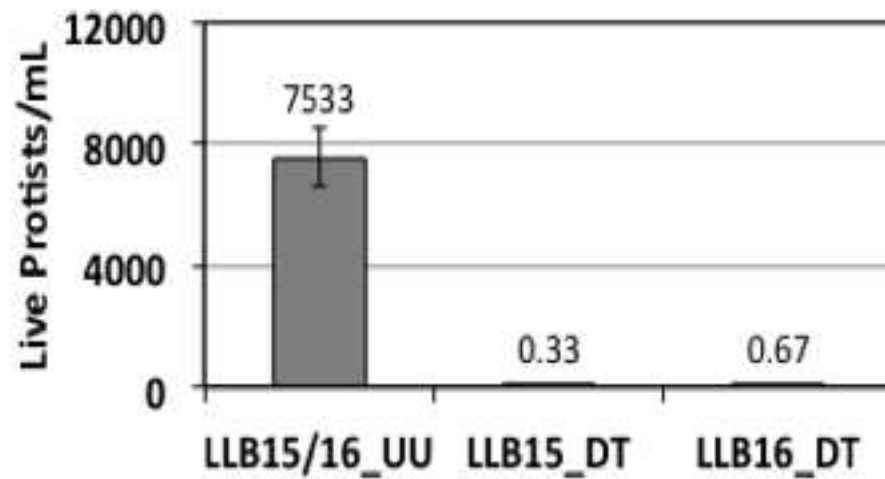
Live Protists, Epi Microscopy (10-50 $\mu\text{m}$ )  
Phytoplankton+Heterotrophs



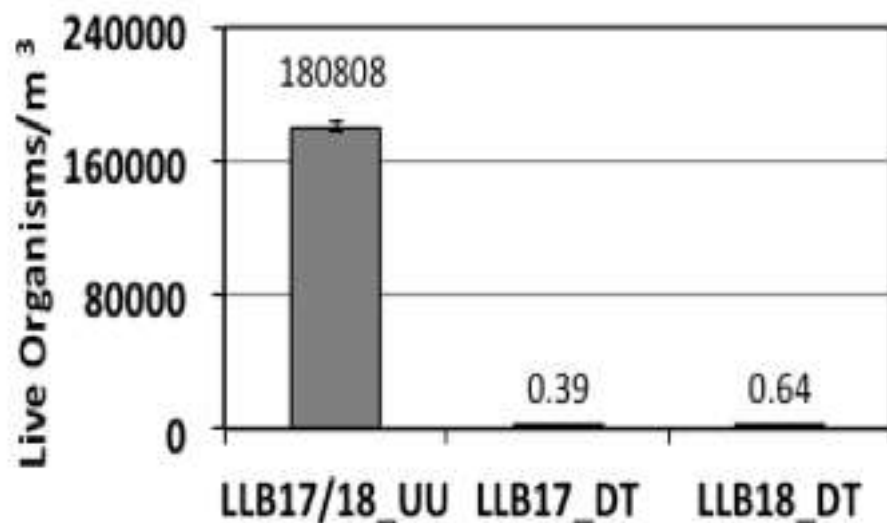
Live Zooplankton (>50  $\mu\text{m}$ )



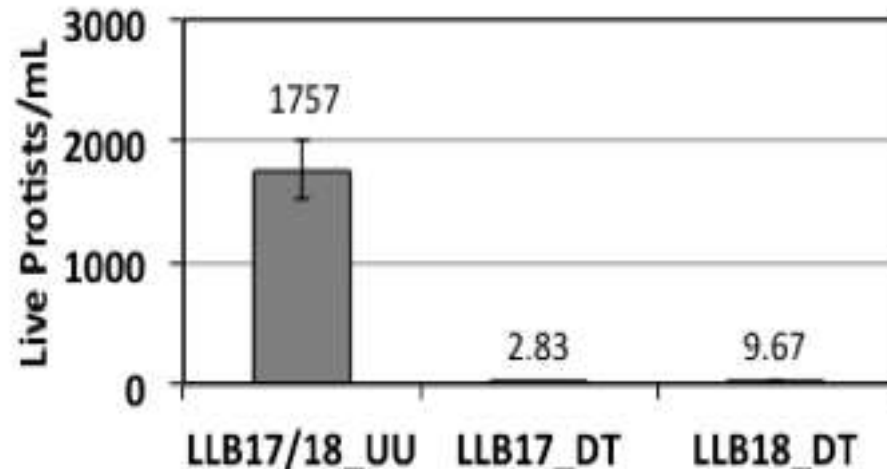
Live Protists, Epi Microscopy (10-50 $\mu\text{m}$ )  
Phytoplankton+Heterotrophs



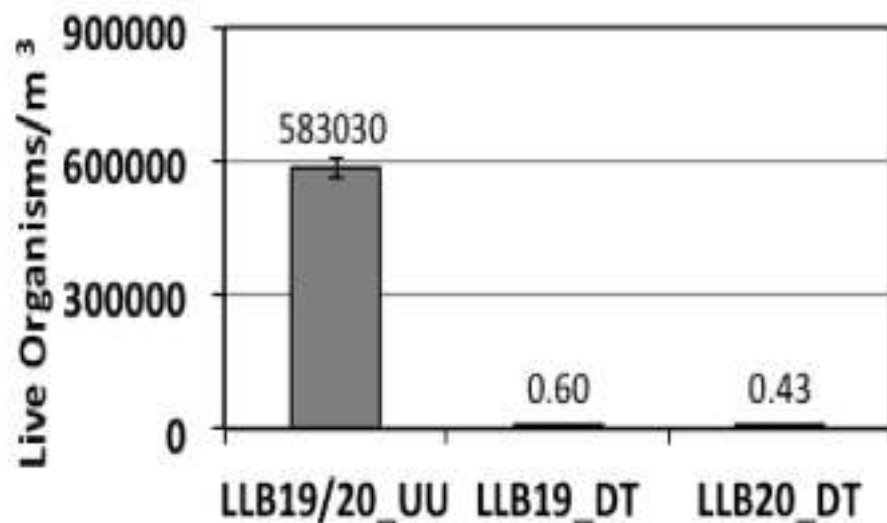
Live Zooplankton (>50  $\mu\text{m}$ )



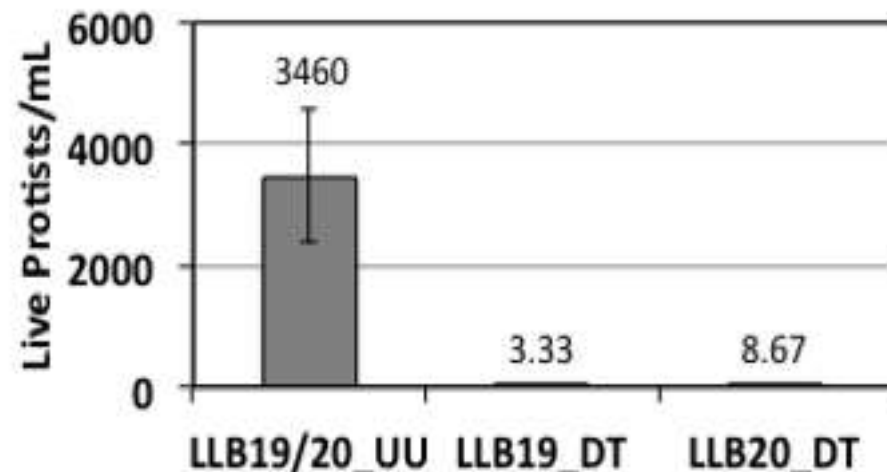
Live Protists, Epi Microscopy (10-50 $\mu\text{m}$ )  
Phytoplankton+Heterotrophs



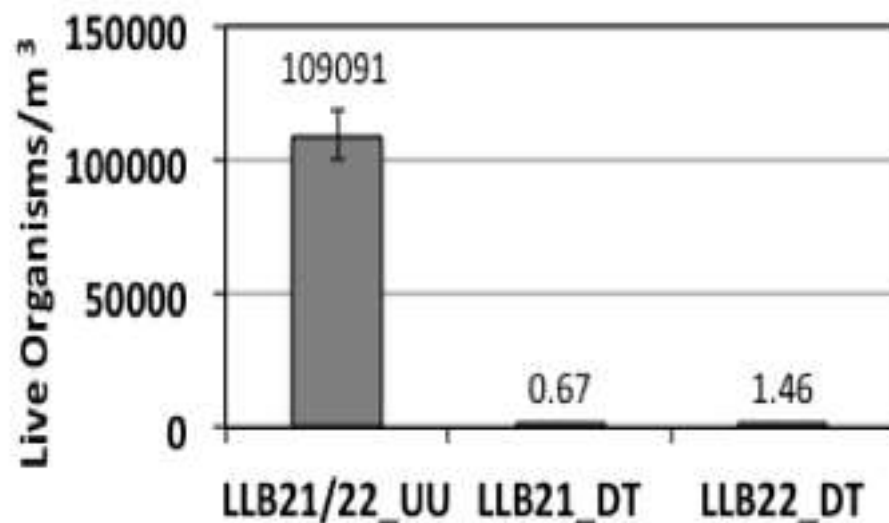
Live Zooplankton (>50  $\mu\text{m}$ )



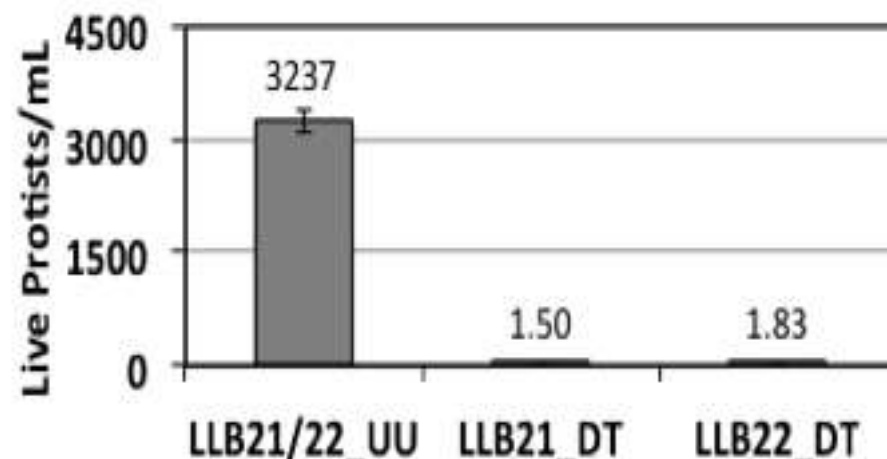
Live Protists, Epi Microscopy (10-50 $\mu\text{m}$ )  
Phytoplankton+Heterotrophs



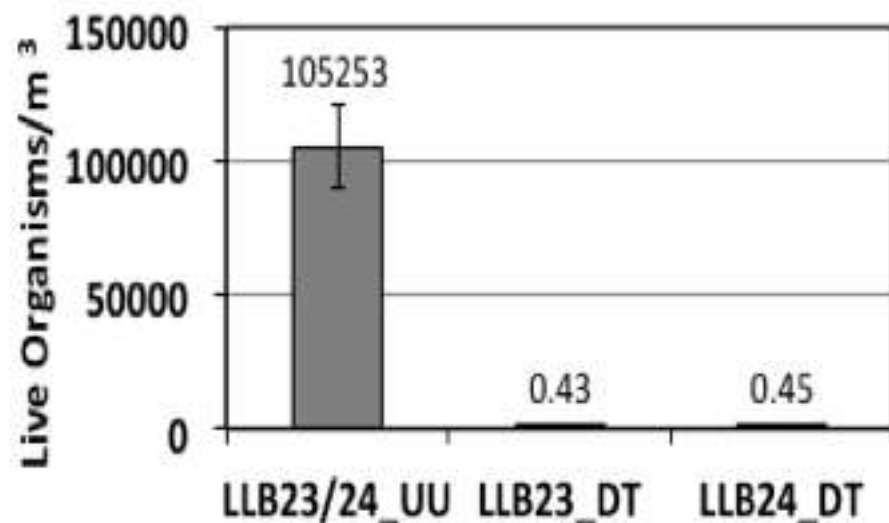
Live Zooplankton (>50  $\mu\text{m}$ )



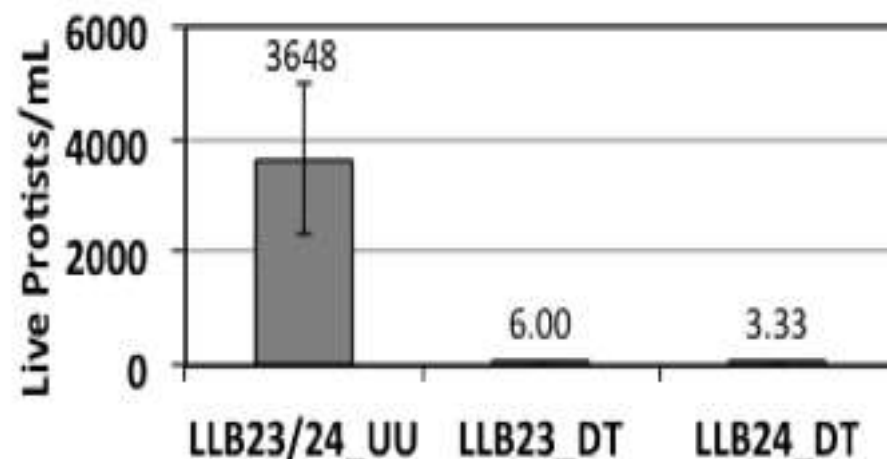
Live Protists, Epi Microscopy (10-50 $\mu\text{m}$ )  
Phytoplankton+Heterotrophs



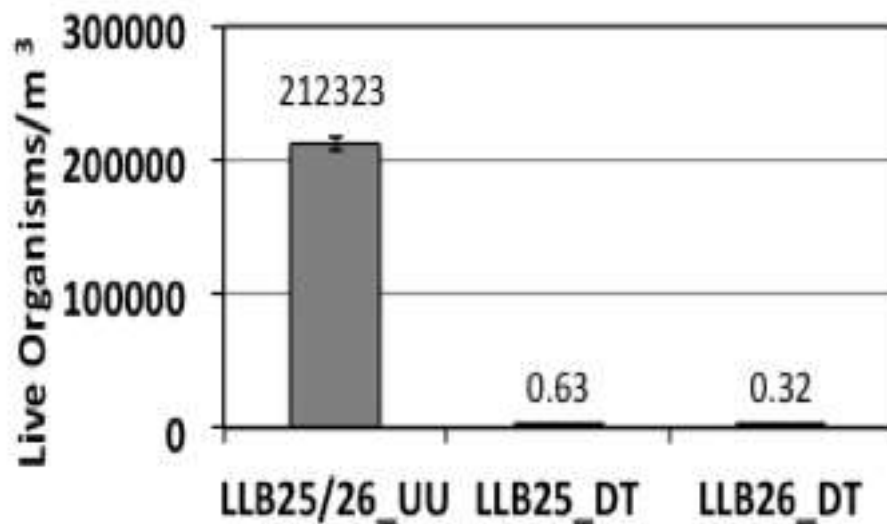
Live Zooplankton (>50  $\mu\text{m}$ )



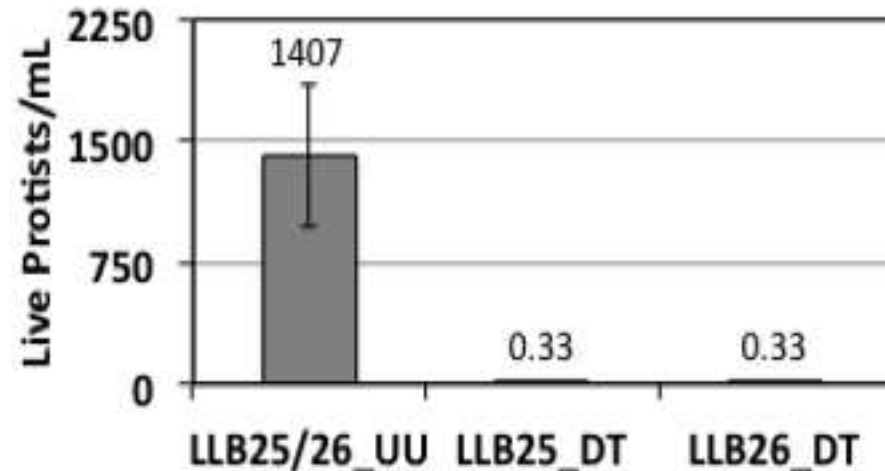
Live Protists, Epi Microscopy (10-50 $\mu\text{m}$ )  
Phytoplankton+Heterotrophs



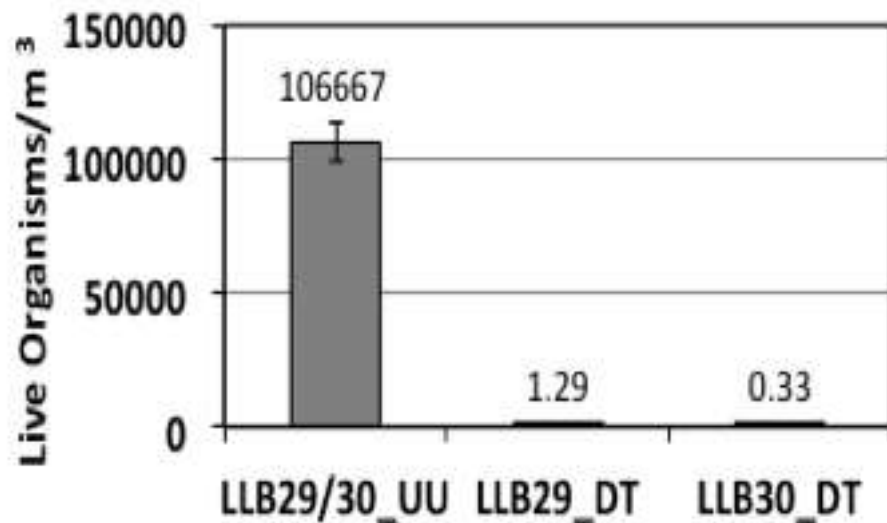
Live Zooplankton (>50  $\mu\text{m}$ )



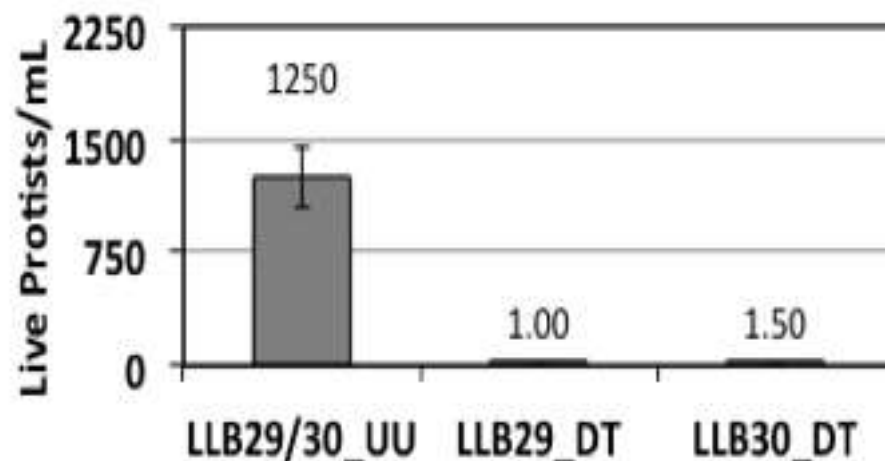
Live Protists, Epi Microscopy (10-50 $\mu\text{m}$ )  
Phytoplankton+Heterotrophs



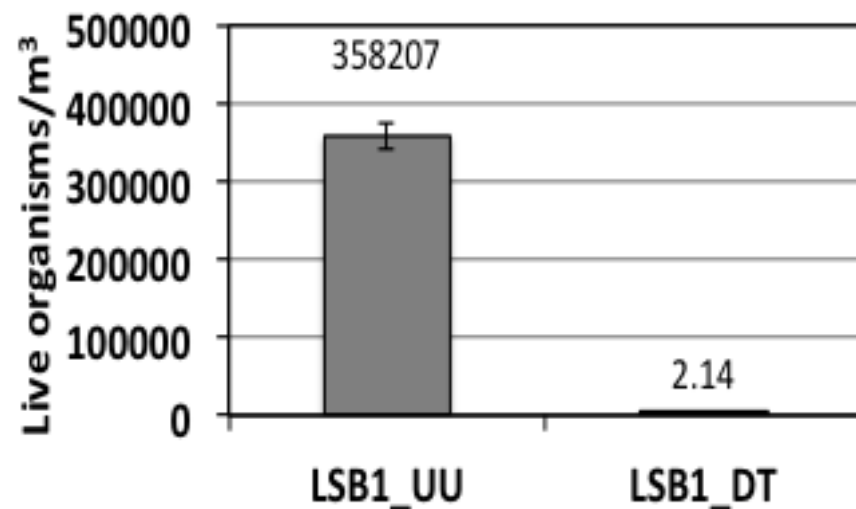
Live Zooplankton (>50  $\mu\text{m}$ )



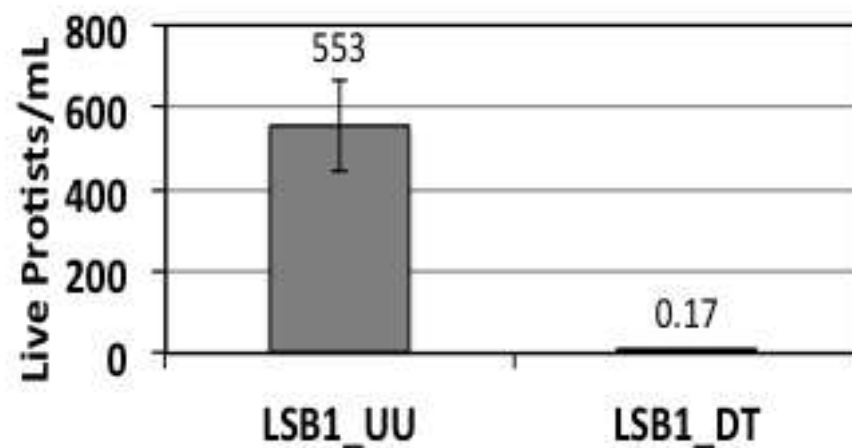
Live Protists, Epi Microscopy (10-50 $\mu\text{m}$ )  
Phytoplankton+Heterotrophs



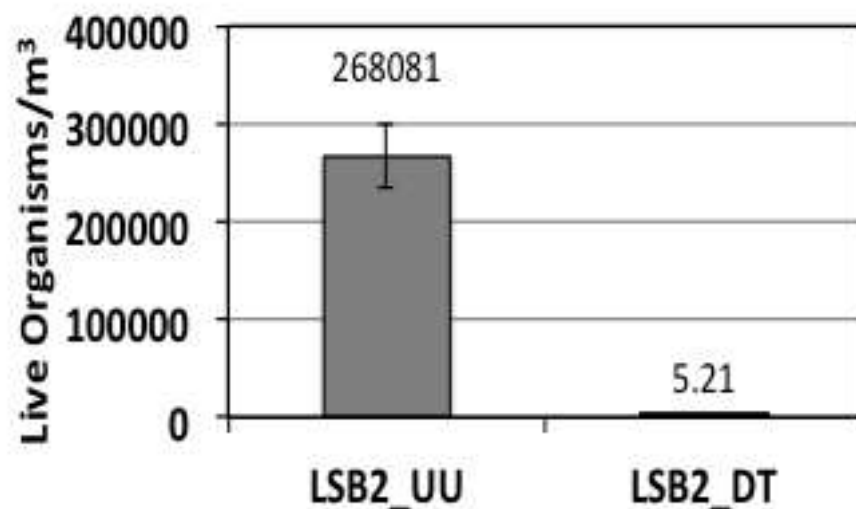
Live Zooplankton (>50  $\mu\text{m}$ )



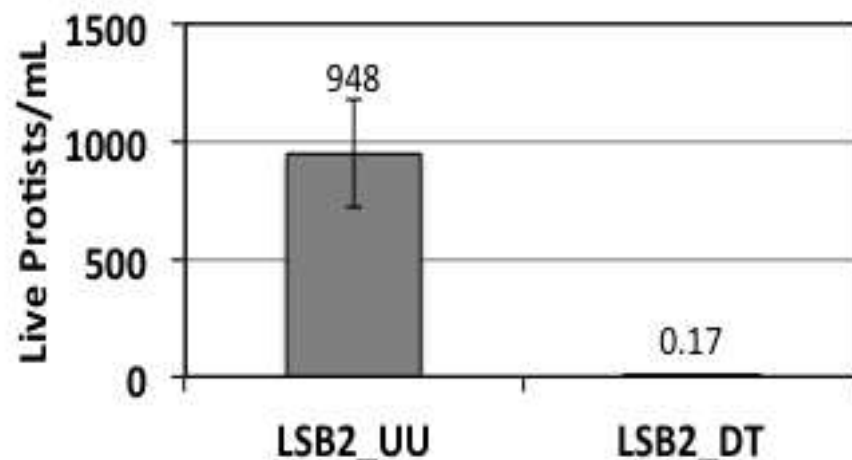
Live Protists, Epi Microscopy (10-50 $\mu\text{m}$ )  
Phytoplankton+Heterotrophs



Live Zooplankton (>50 $\mu\text{m}$ )

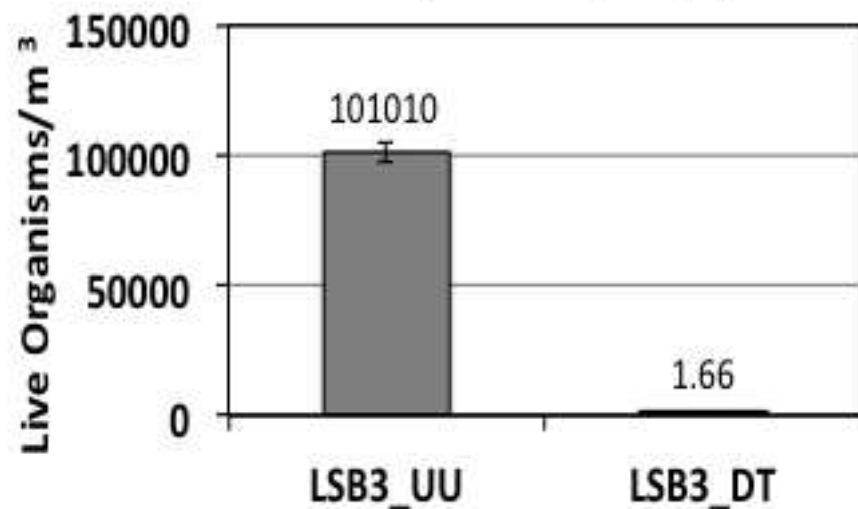


Live Protists, Epi Microscopy (10-50 $\mu\text{m}$ )  
Phytoplankton+Heterotrophs

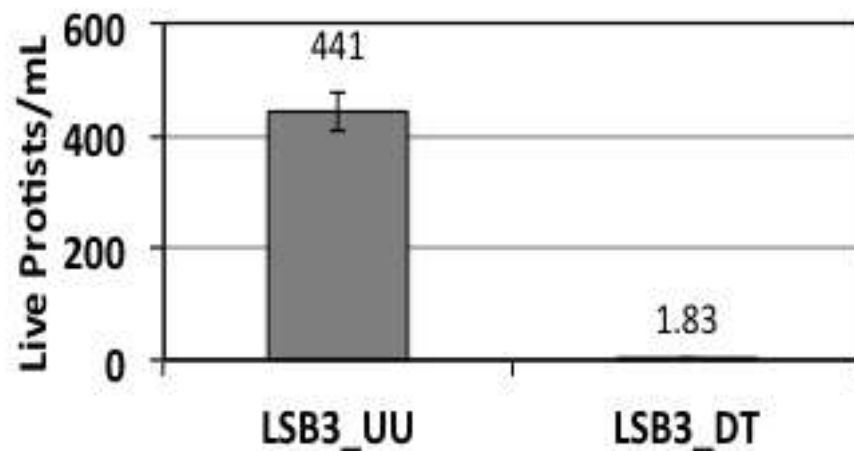




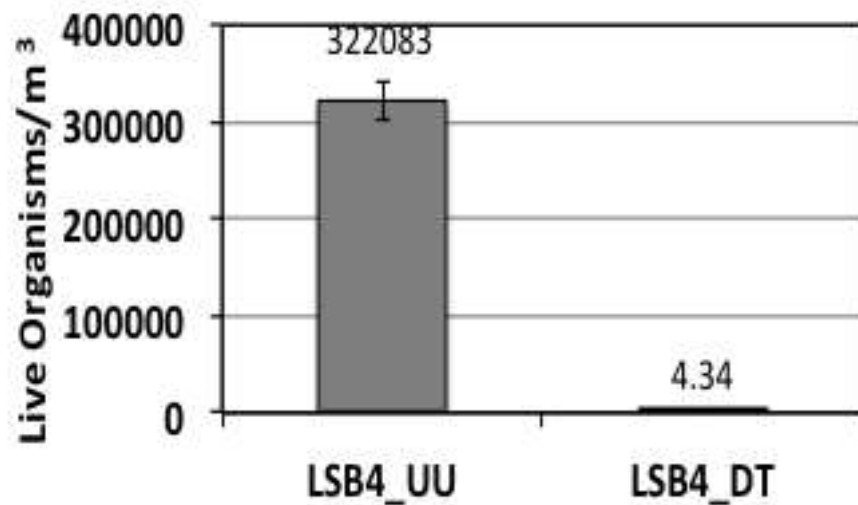
Live Zooplankton (>50  $\mu\text{m}$ )



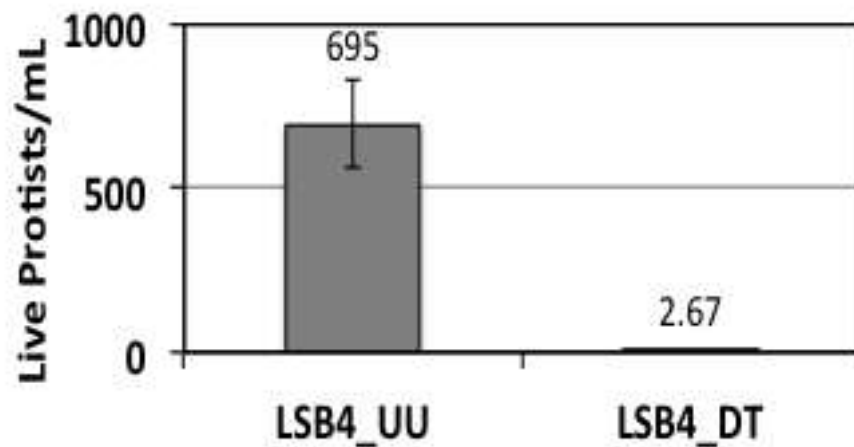
Live Protists, Epi Microscopy (10-50 $\mu\text{m}$ )  
Phytoplankton+Heterotrophs



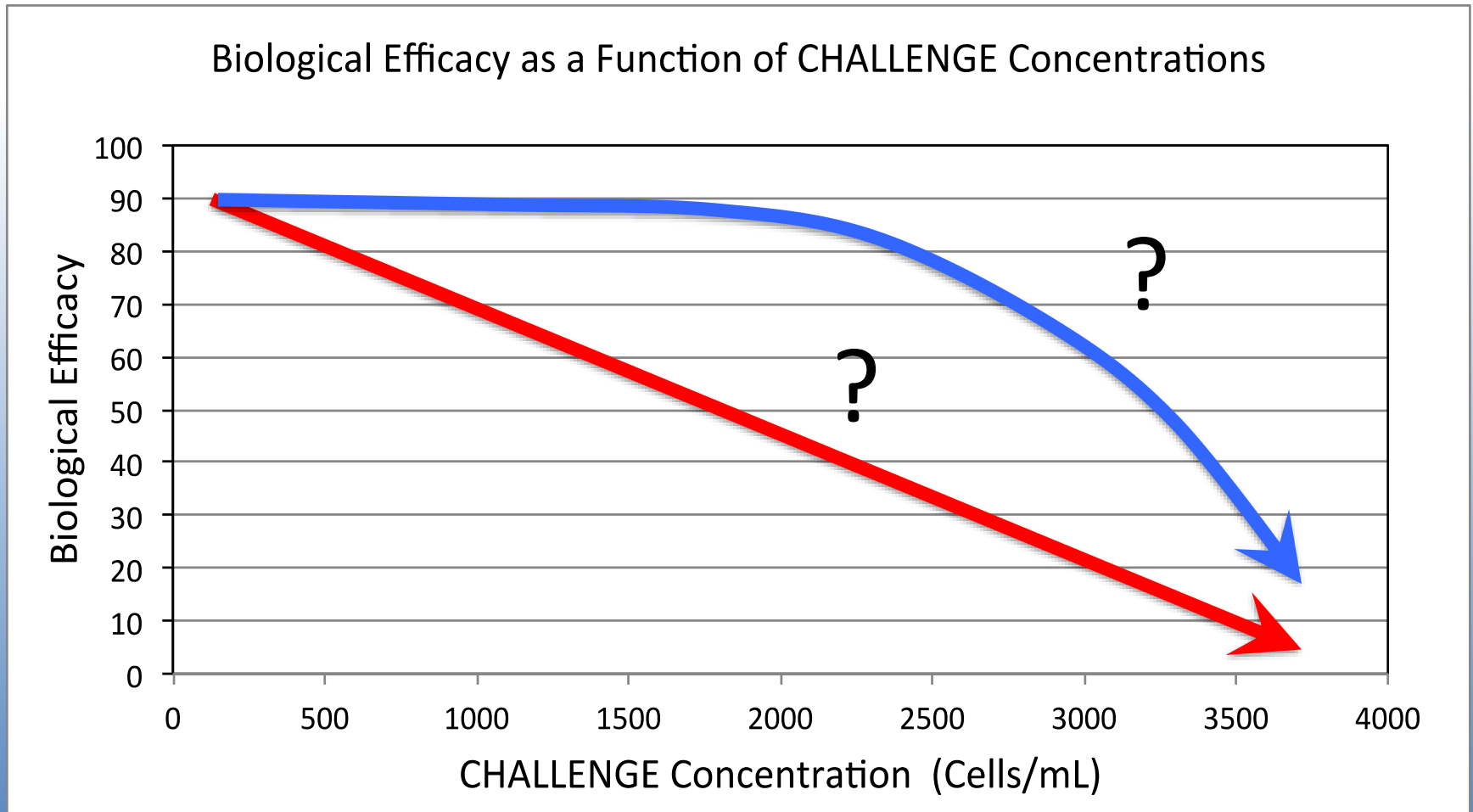
Live Zooplankton (>50  $\mu\text{m}$ )



Live Protists, Epi Microscopy (10-50 $\mu\text{m}$ )  
Phytoplankton+Heterotrophs

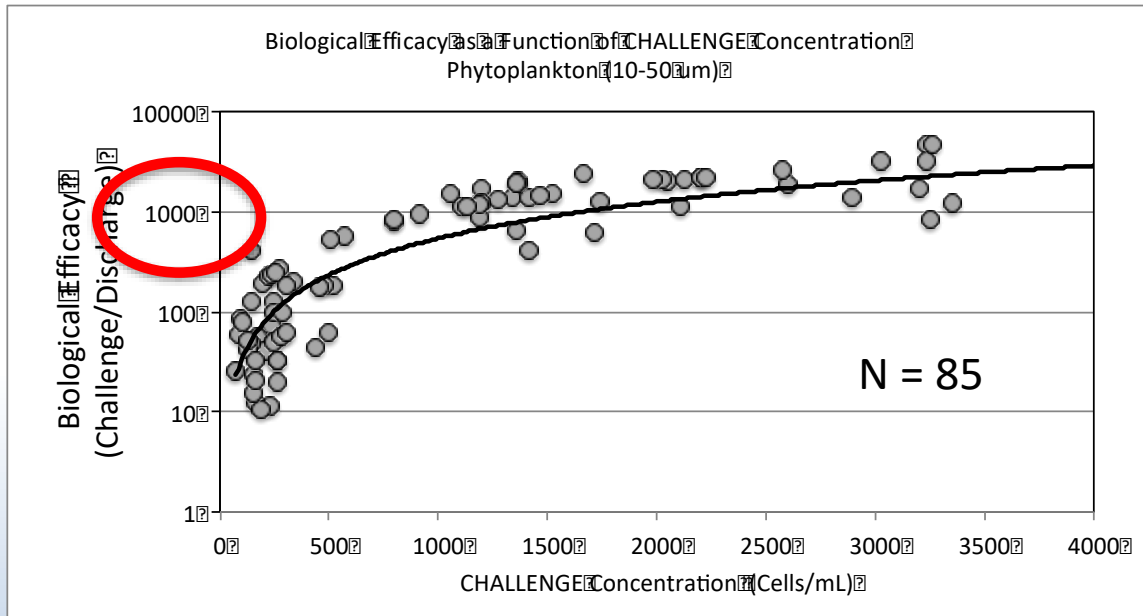


# “CHALLENGE” in Ballast Water Treatment Testing: Conceptions and Misconceptions

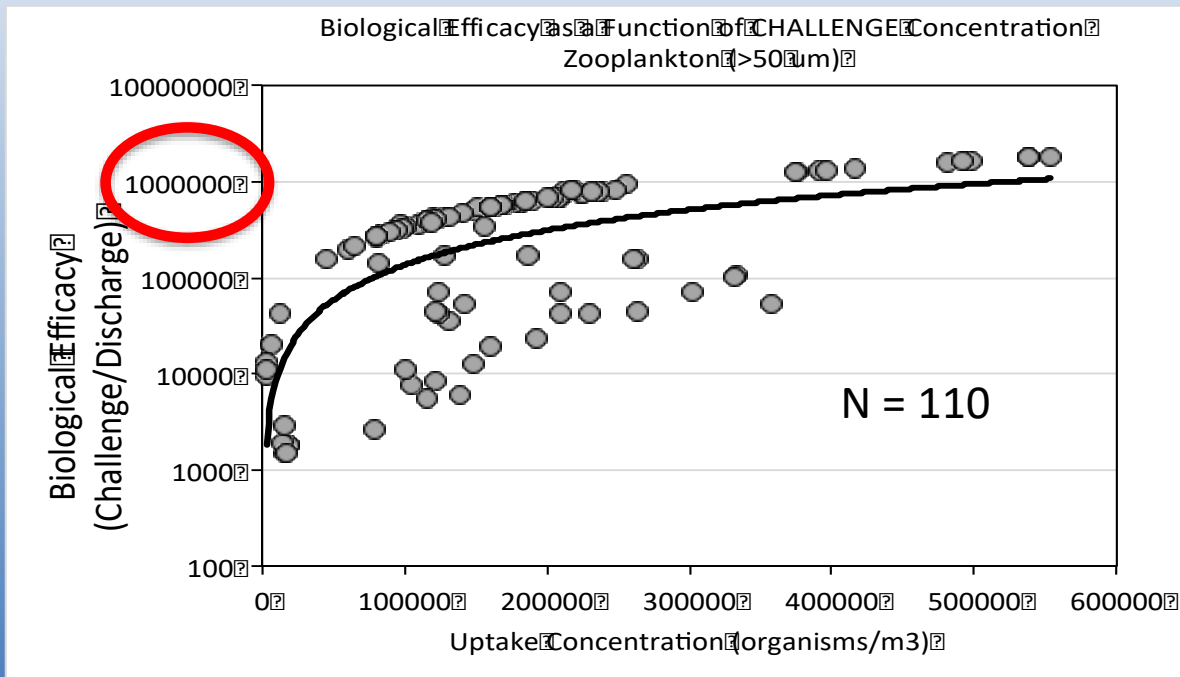




# Biological efficacy does not obey the CHALLENGE Concept in Ballast Water Testing



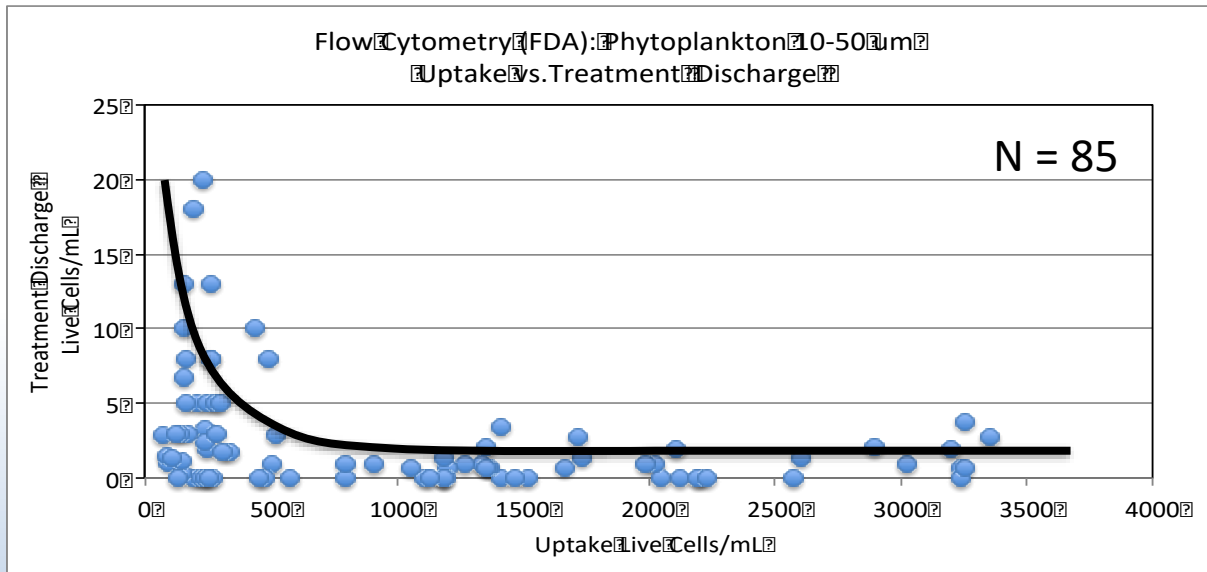
10-50  $\mu\text{m}$   
Live Phytoplankton (FDA)



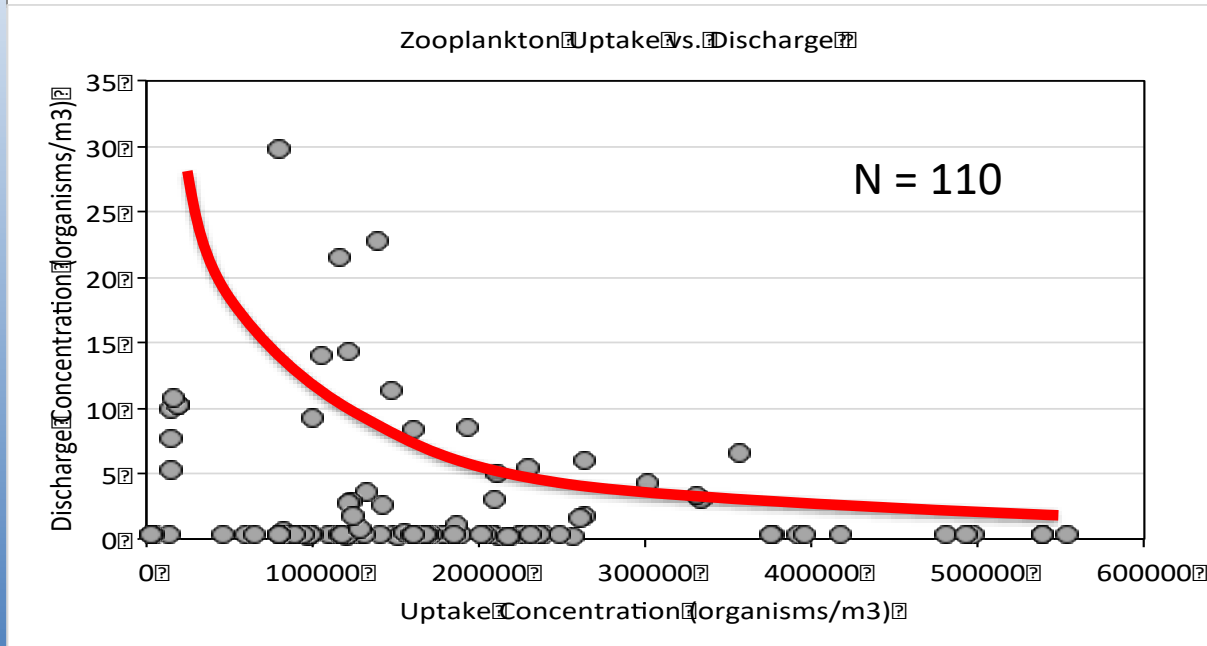
>50  $\mu\text{m}$   
Live Zooplankton

CHALLENGE: Higher uptake concentrations yield a more 'Challenging' test

## ?? A Misconception ??

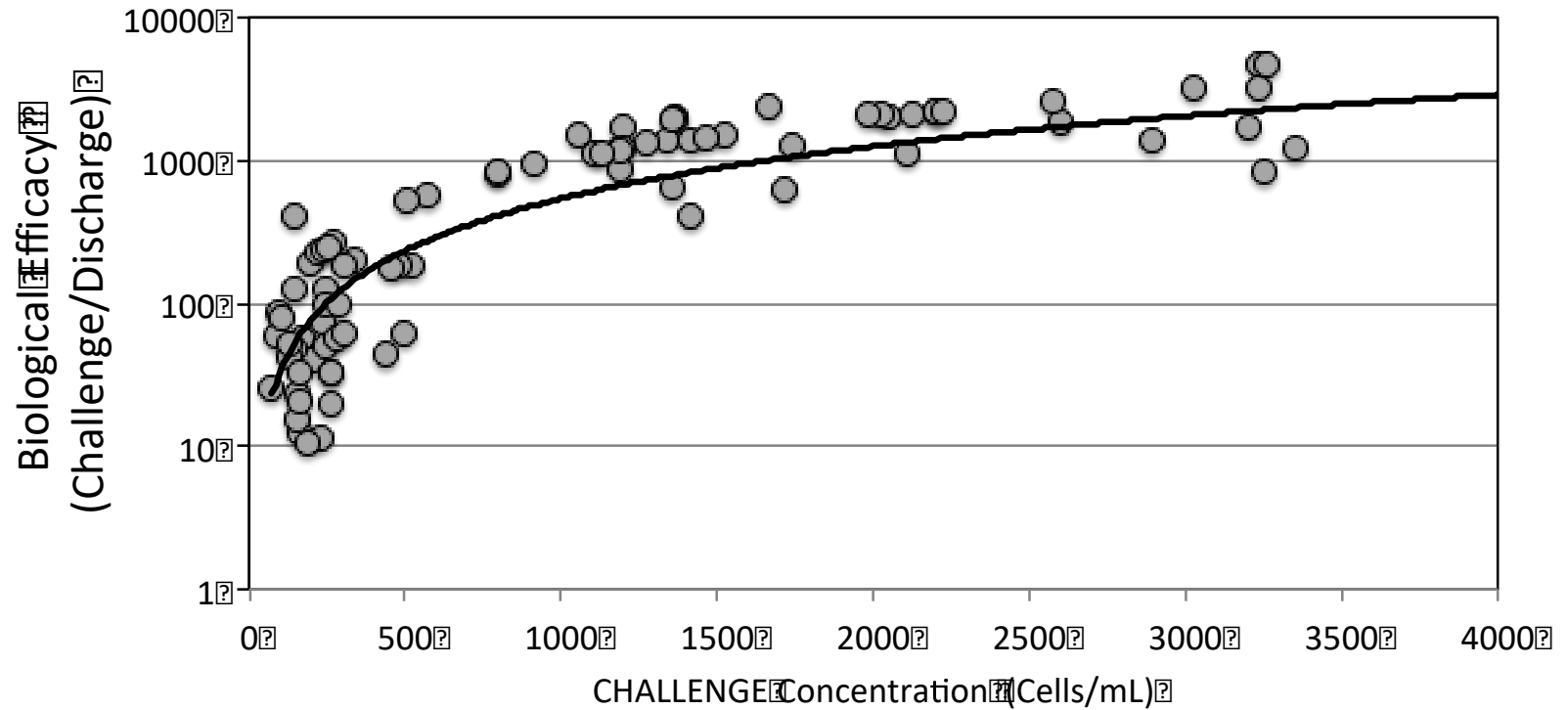


10-50  $\mu\text{m}$   
Live Phytoplankton (FDA)

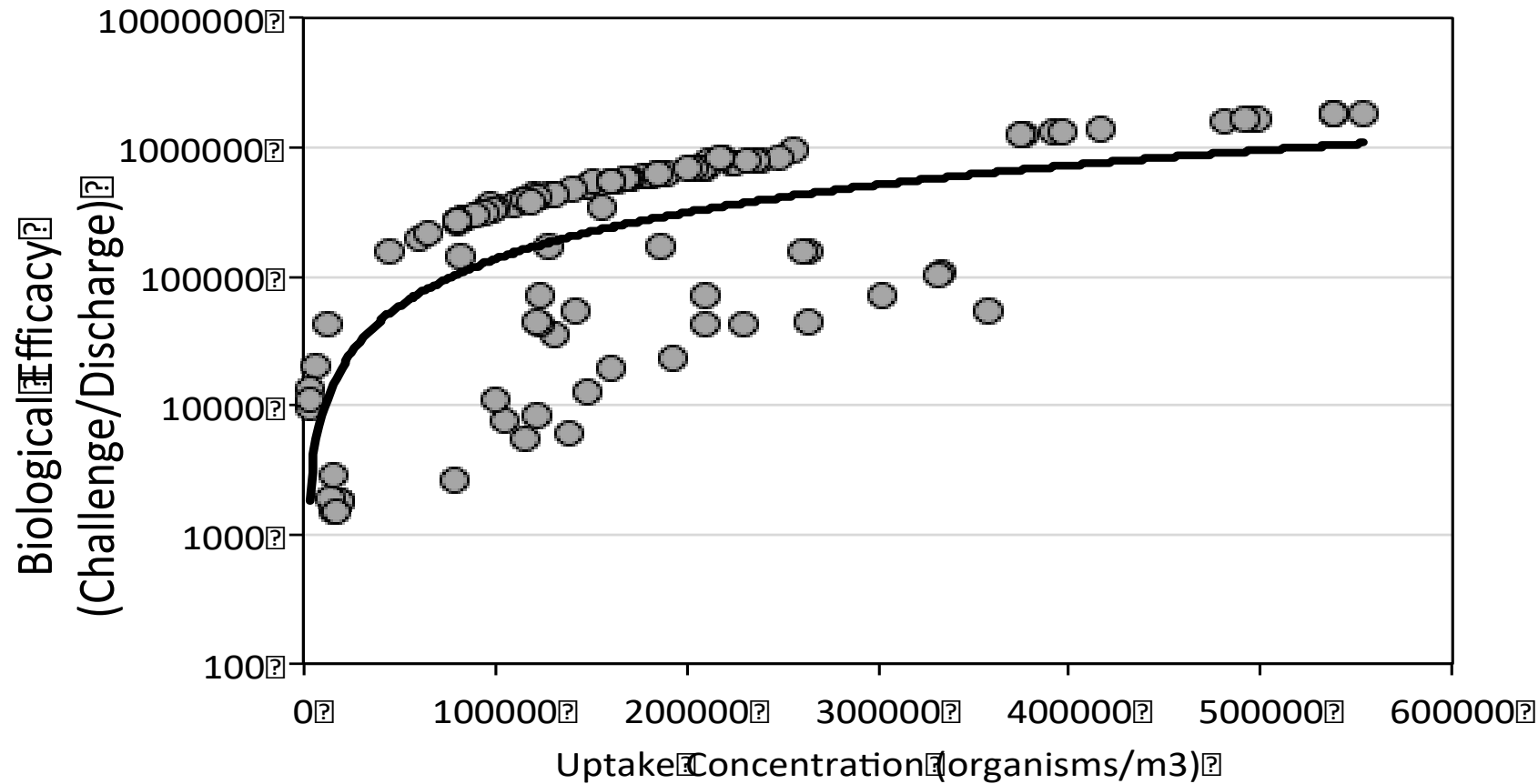


>50  $\mu\text{m}$   
Live Zooplankton

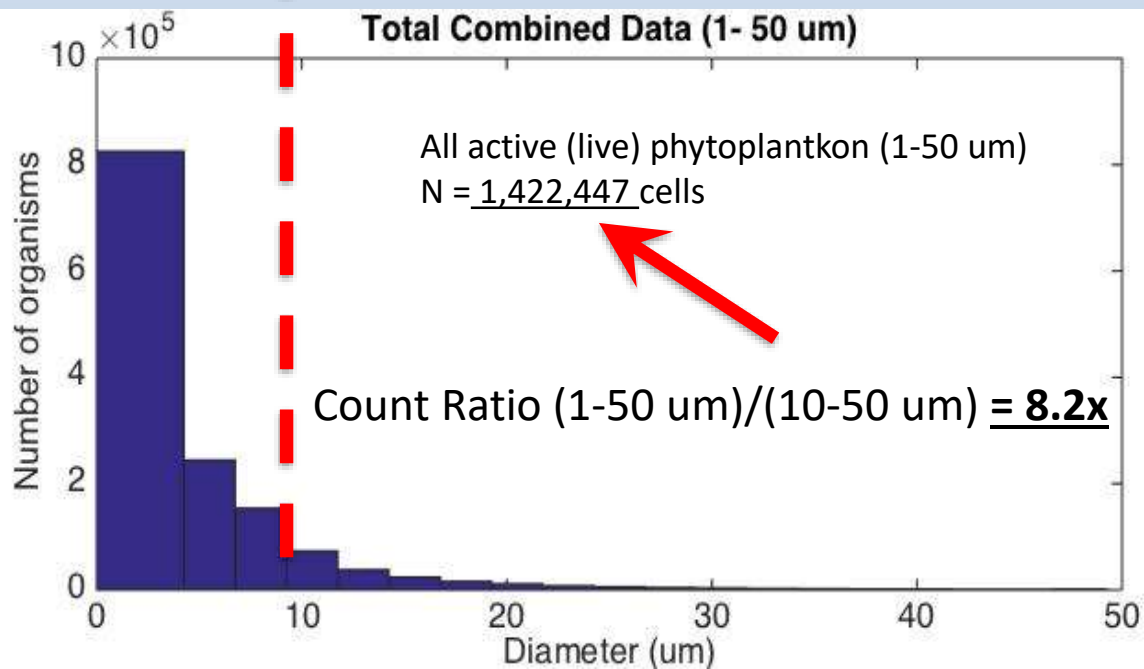
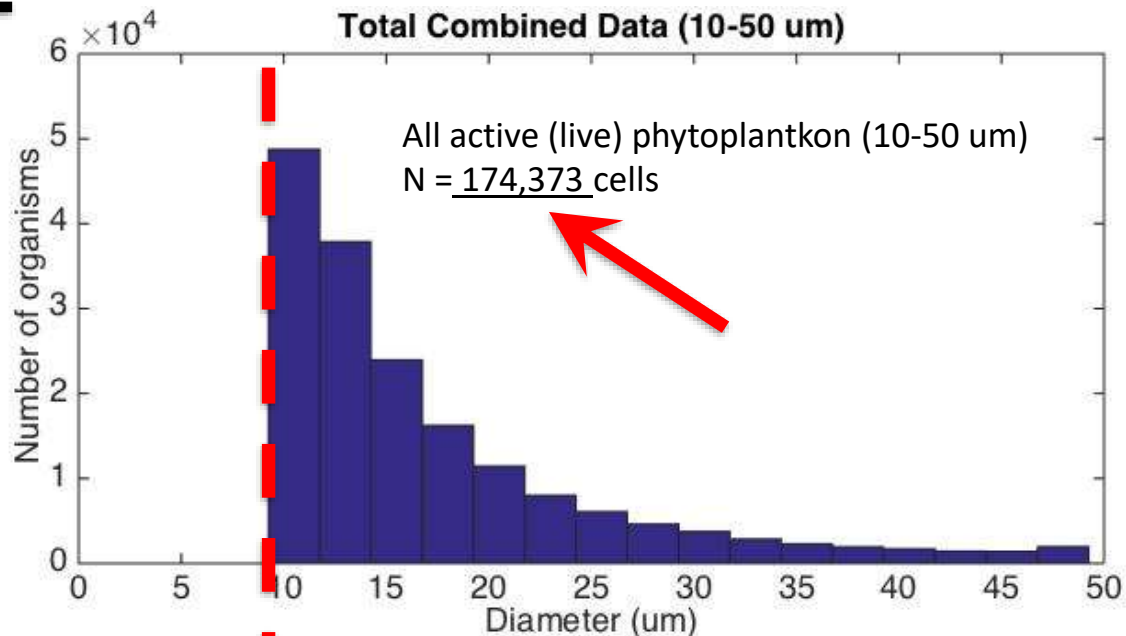
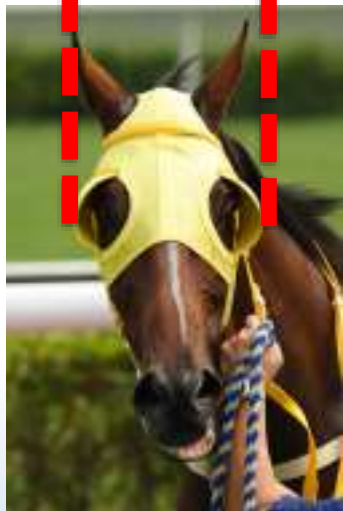
Biological Efficacy as a Function of CHALLENGE Concentration  
Phytoplankton (10-50  $\mu$ m)



Biological Efficacy as a Function of CHALLENGE Concentration  
 Zooplankton (>50  $\mu$ m)



→ 10-50  $\mu\text{m}$  ←



# QUESTION:

## HOW ARE WE DOING IN BALLAST WATER TREATMENT?

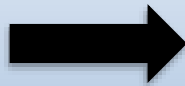
- Let's see how ballast treatment success compares with other applications in pollution and public health

## Environmental Successes:

### 1. Visible reductions in Los Angeles smog



Then...



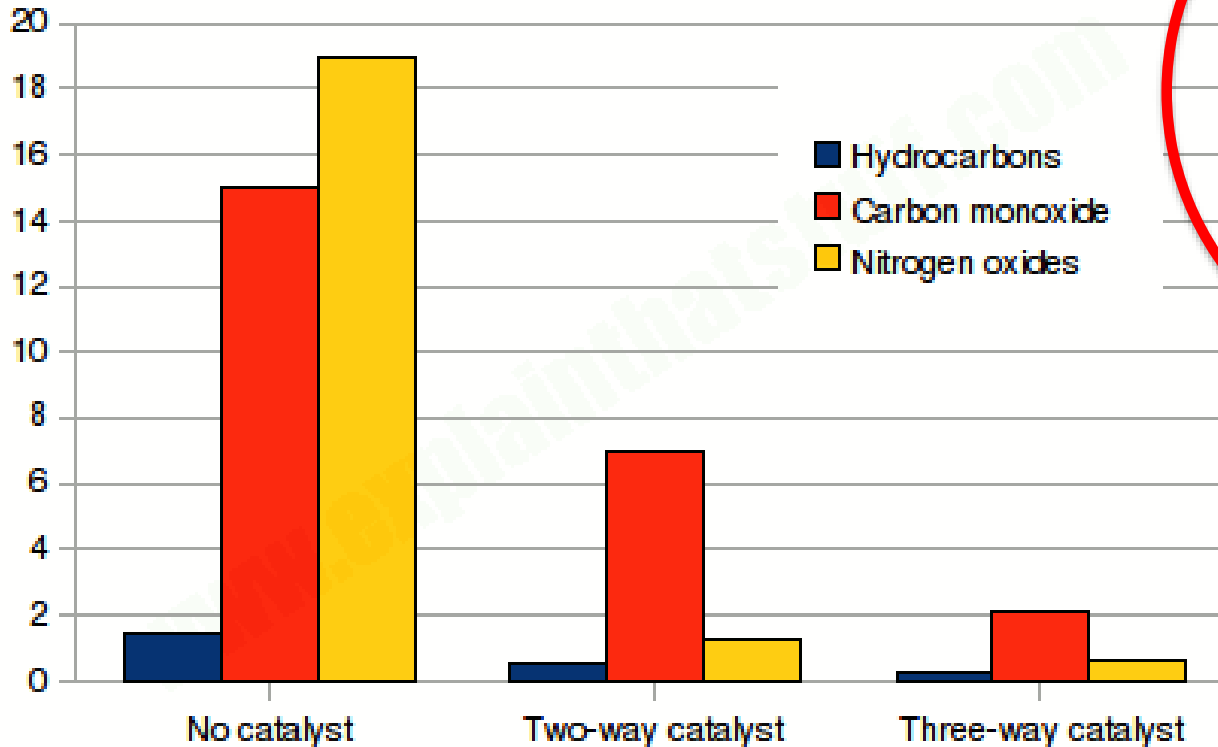
Now



## Environmental Successes:

### 1. Visible reductions in Los Angeles smog... How? Regulatory emissions control

***Effectiveness of catalytic converters***



Roughly...

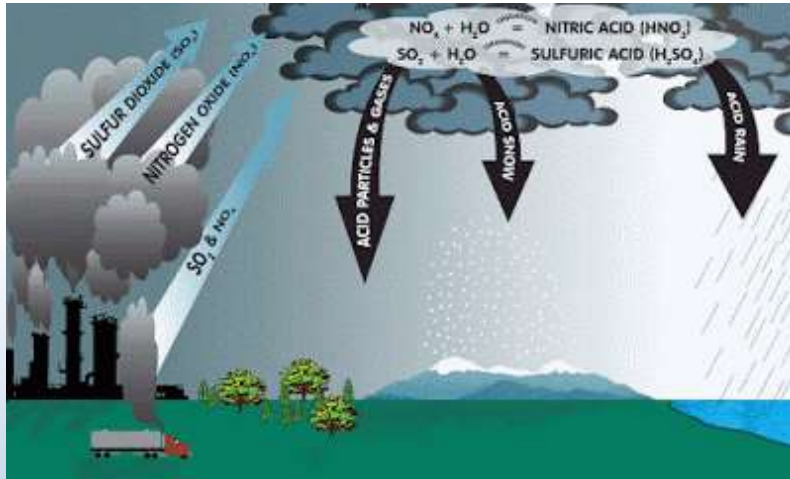
**10x** reduction in  
pollution emissions,  
even with modern  
3-way converters



# Environmental Successes:

## 2. Reduction in Acid Rain

Death to acid-intolerant forests



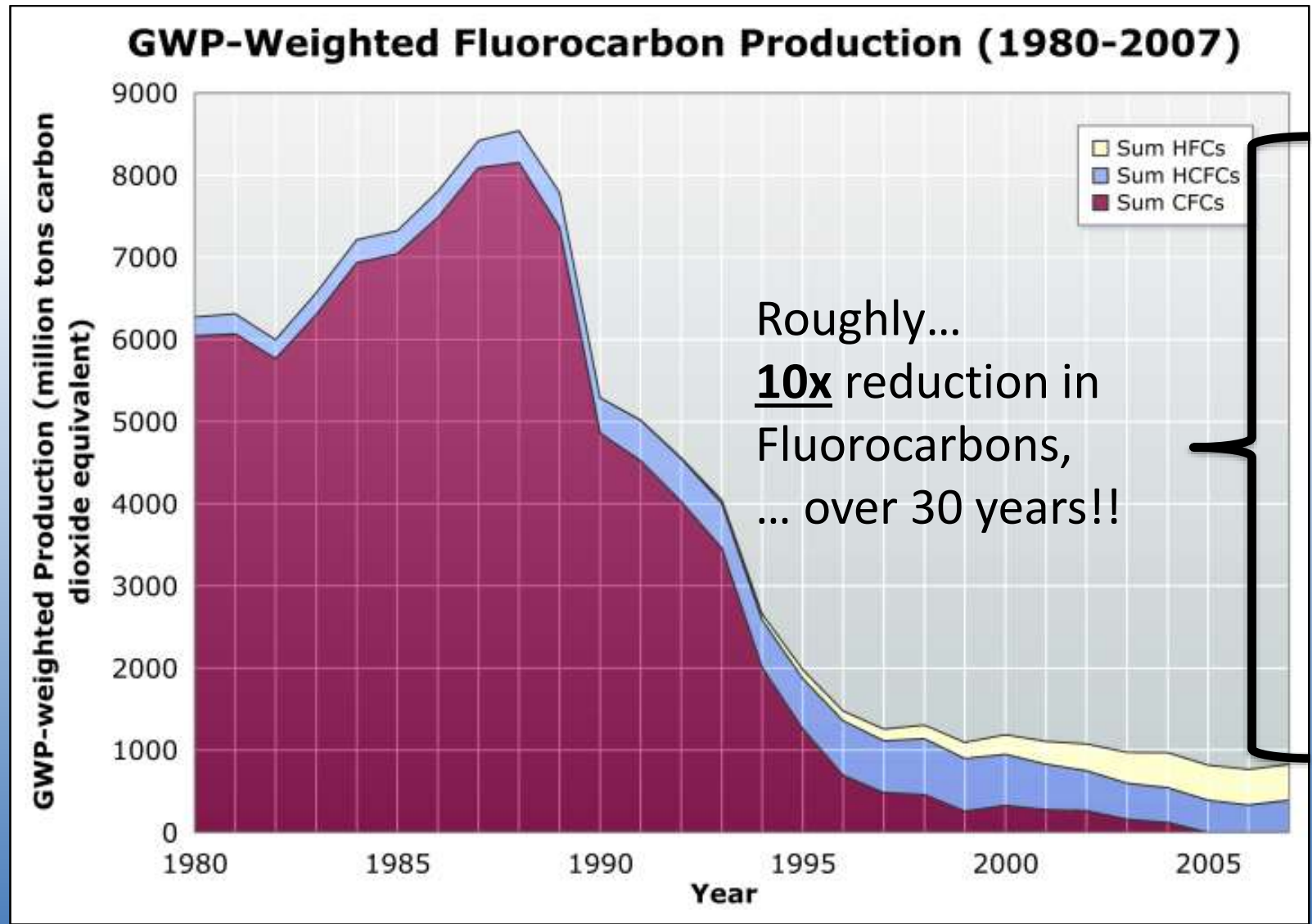
### The Clean Air Act 1970

Stack-gas scrubbers:  
Roughly...

**5x – 20x** reductions in  
SO<sub>2</sub> and NO<sub>x</sub>

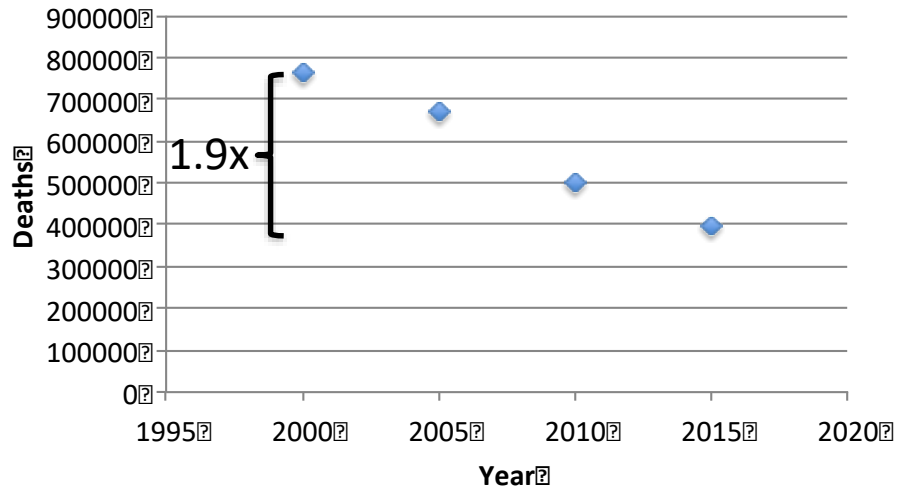
## Environmental Successes:

### 3. Reduction of the Antarctic Ozone 'Hole' The Montreal Agreement (1987)

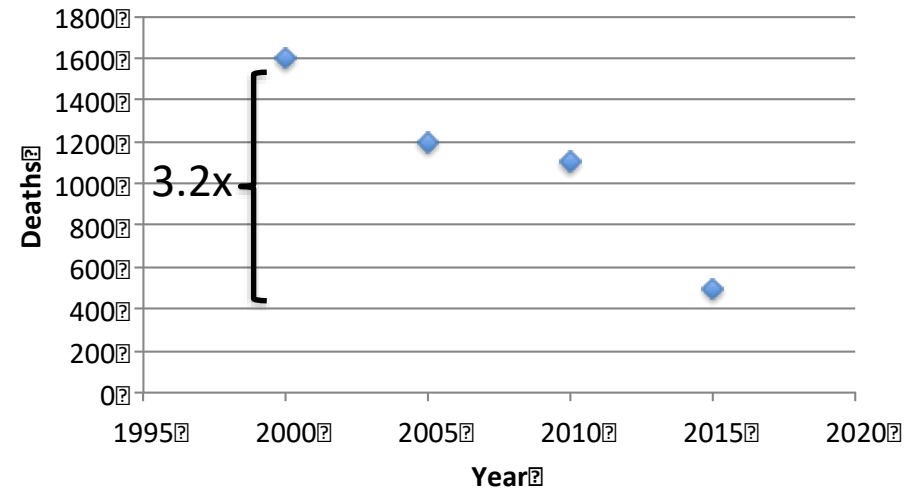


# How about 'efficacy' in disease control?

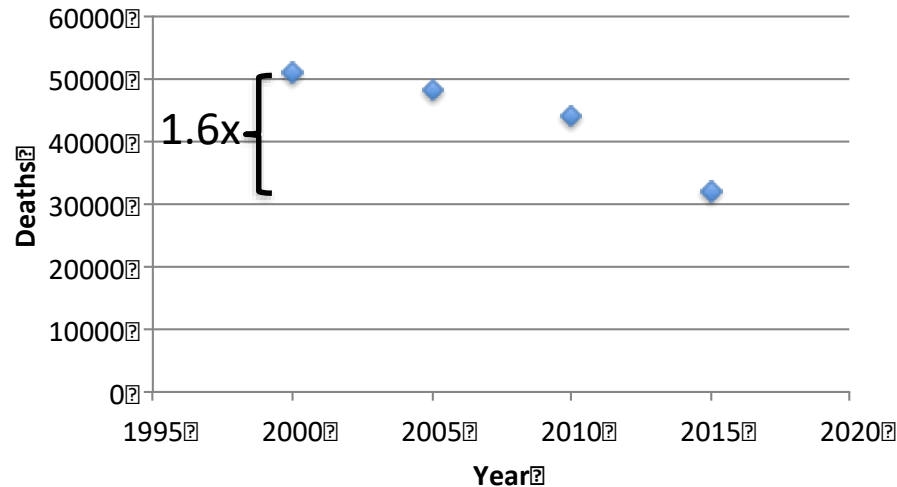
Malaria Deaths by Region (WHO: Africa)



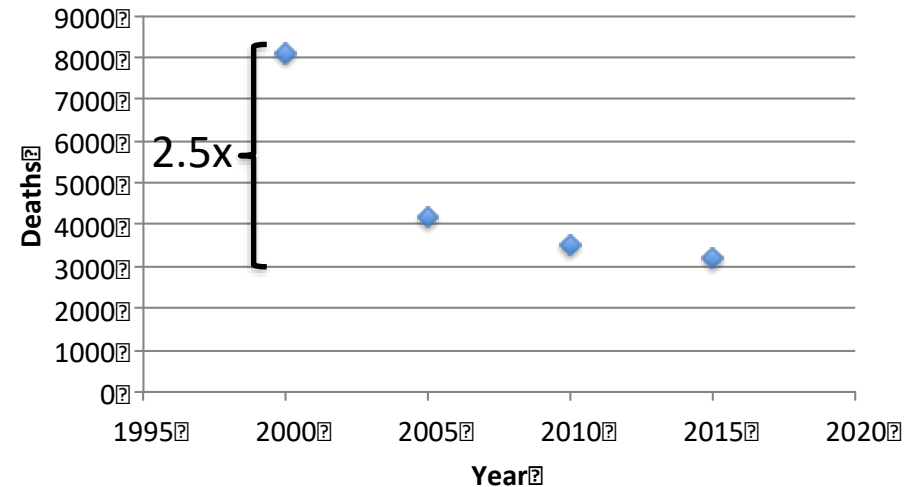
Malaria Deaths by Region (WHO: Americas)



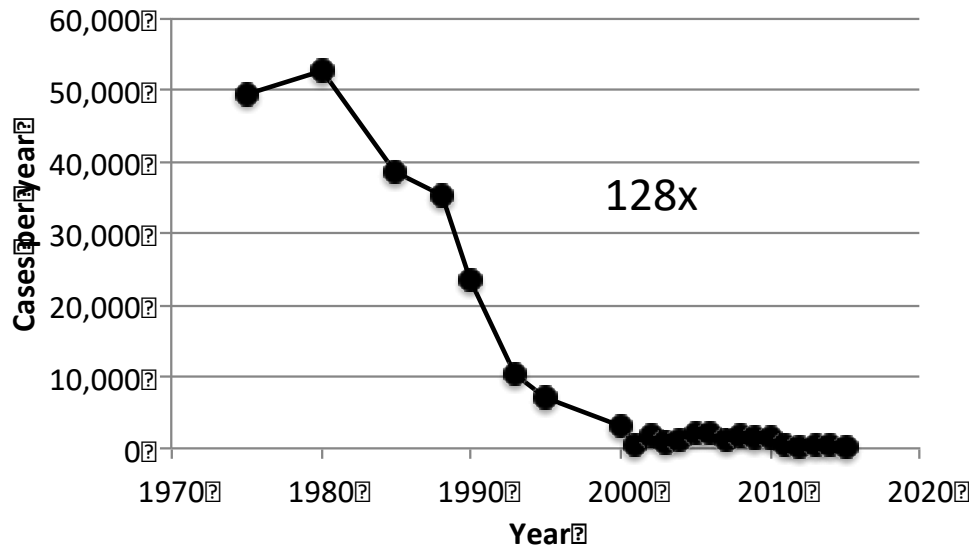
Malaria Deaths by Region (WHO: SE Asia)



Malaria Deaths by Region (WHO: West Pacific)



Polio



Recall the Challenge of Land-based Ballast Water Tests:

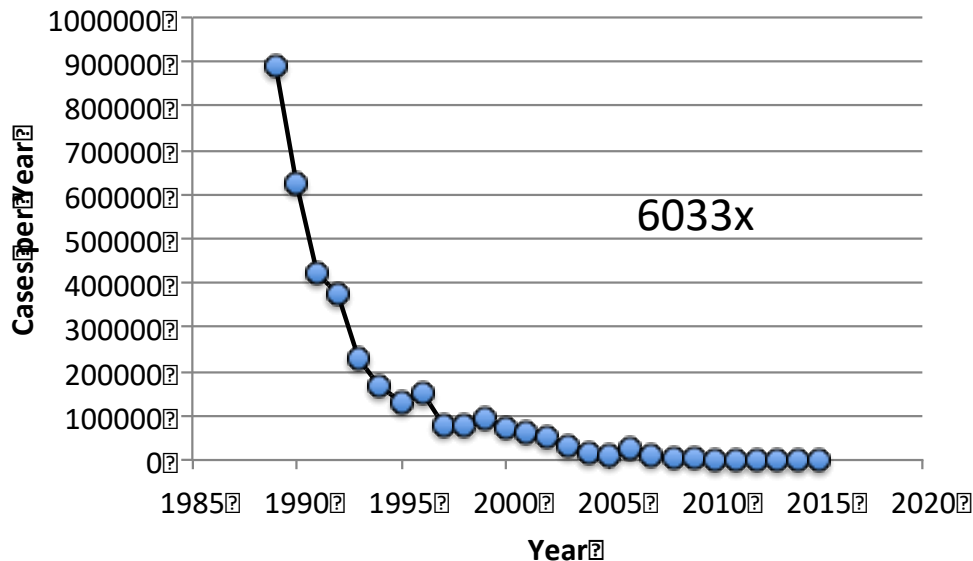
>50 um Challenge = 100,000/m<sup>3</sup>

Ballast Water Discharge Std. = 10/m<sup>3</sup>

A 10,000x reduction (in one day!)

A 0.01% contamination will cause a FAIL

Guinea Worm Cases per Year



# Successes in Disease Elimination/Eradiation:

## Vaccination programs against 'organismic invaders'

Progress to date against diseases for which vaccines already exist and deaths from diseases for which vaccines might be developed

	<b>Annual deaths (all ages) if no immunization</b>	<b>Prevented</b>	<b>Occurring</b>	<b>% prevented</b>
Smallpox	5.0 million	5.0 million	--	100
Diphtheria	260,000	223,000	37,000	86
Whooping cough	990,000	630,000	360,000	64
Measles	2.7 million	1.6 million	1.1 million	60
Neonatal tetanus	1.2 million	0.7 million	0.5 million	58
Hepatitis B	1.2 million	0.4 million	0.8 million	33
Tuberculosis	3.2 million	0.2 million	3.0 million	6
Polio (cases of lifelong paralysis)	640,000	550,000	90,000	86
Malaria/other parasitic infections	2.2 million	--	2.2 million	0
HIV/sexually transmitted diseases	1.3 million	--	1.3 million	0
Diarrhoea/enteric fevers*	3.0 million	--	3.0 million	0
Acute respiratory infections	3.7 million	--	3.7 million	0

Reduction:

7.0x

2.8x

2.5x

2.4x

1.5x

7.1x

Three of the greatest environmental successes in modern history...

1. Reduction in smog derived from automobiles
2. Reduction of acid rain
3. Shrinkage of the 'ozone hole'

... were accomplished with reductions in the respective putative pollutants that were **approximately 10x**.

**HOW ARE WE DOING IN BALLAST WATER TREATMENT?**

Fantastic...





## NUMBERS FROM ONE TO TEN

1. TWO
2. SEVEN
3. THREE
4. FOUR
5. ONE
6. EIGHT
7. FIVE
8. SIX
9. NINE
10. TEN





1. IMO and USCG BWDSs are not evaluated statistically in Type Approval Tests.
2. Calibration 'standards' for the 'live organism' metabolic condition are not available; true number of 'live' protists is never known, it is determined by chemical proxy.
3. A 'fraction-of-a-micron' edge exists near 50  $\mu\text{m}$ , where BWDSs elevate to an instant 1 million-fold increase in stringency; 10/mL to 10/ $\text{m}^3$ .
4. BWDSs for *E. coli* and *Enterococcus* are too high, the vast majority of tested water 'passes' with no need for treatment.
5. BWDSs for *Vibrio Cholerae* provide no efficacy information since none have been detected.
6. The BWDSs for  $\geq 50\mu\text{m}$  size class is too low: contamination from 'dead volumes' (0.01% contamination) drive results above the BWDS.
7. USCG BWDSs for the 10-50  $\mu\text{m}$  protist group is analyzed by a 'required' method that is plagued by false-positives (FDA/CMFDA).
8. BWDSs for the 10-50  $\mu\text{m}$  group vastly underestimate the true number of planktonic protists (by at least 10x) because most protists are  $<10 \mu\text{m}$ .
9. Challenge level for IMO shipbased HPC bacteria is too high; 10,000 CFU/mL.
10. Required five 'consecutive' passes allow statistically poorer systems to pass.



Thank you!

