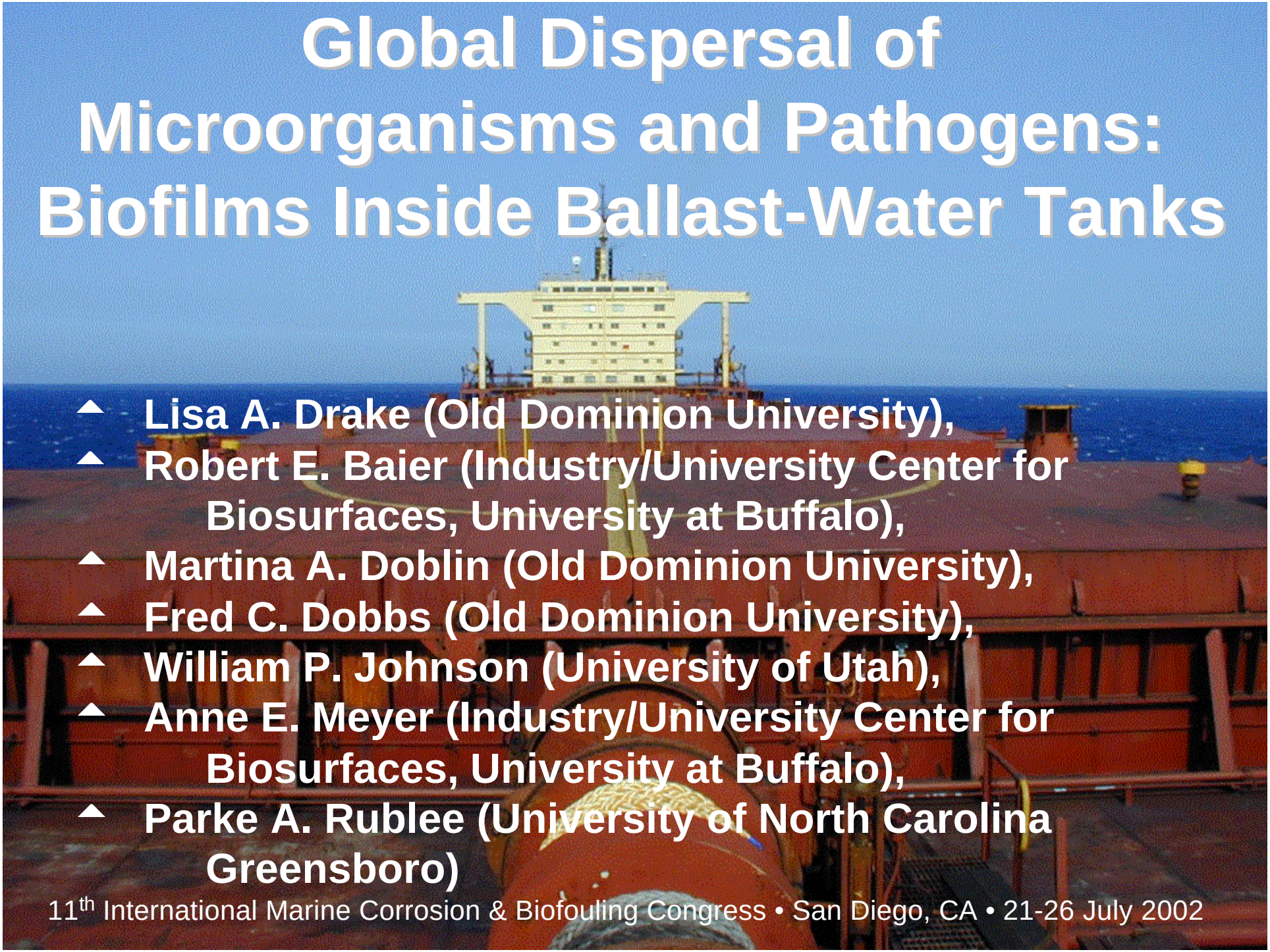
Global Dispersal of Microorganisms and Pathogens: Biofilms Inside Ballast-Water Tanks



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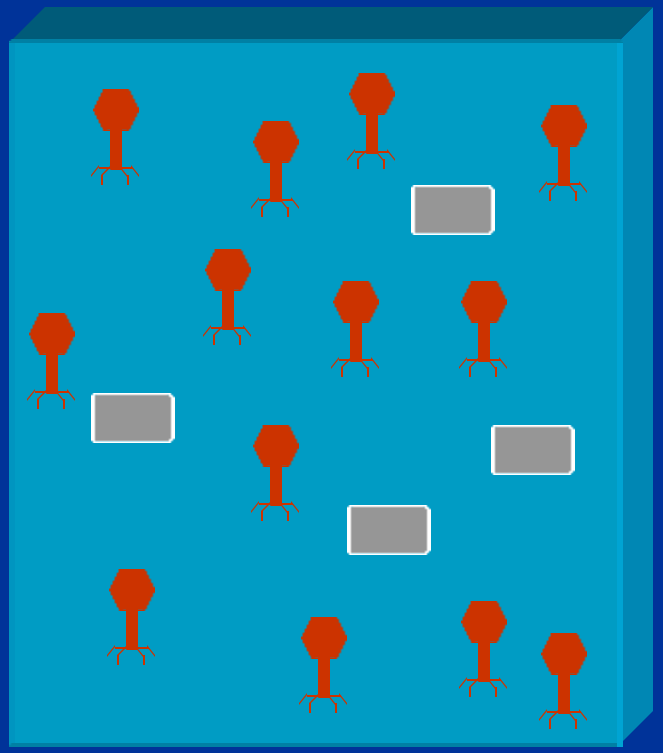
We know that microorganisms are very abundant in seawater:

Bacteria

VLPs

10^6 –10^{11} per liter



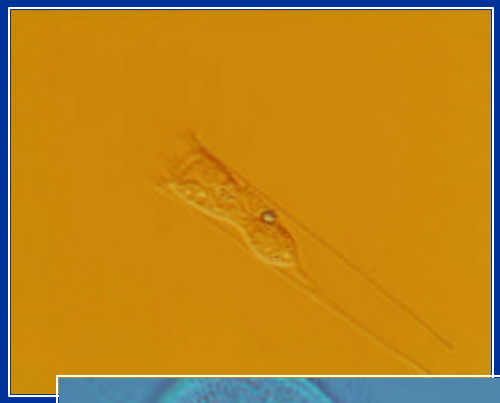
(most are not pathogenic forms)

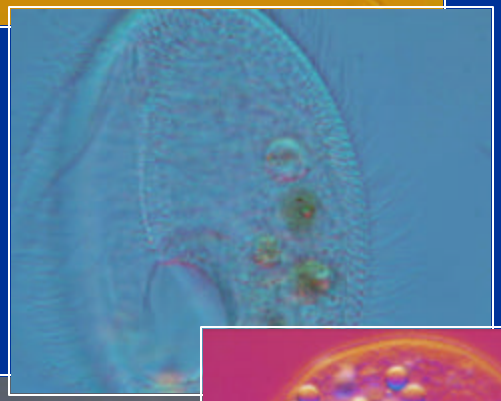
Therefore, the number of bacteria and viruses transported globally is staggering.

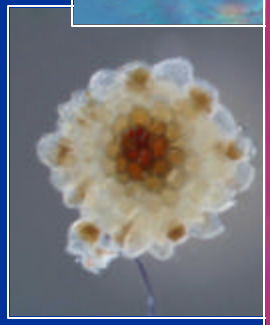
Protozoa

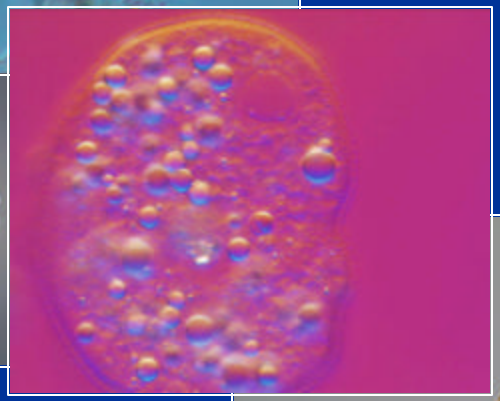
Dinoflagellates

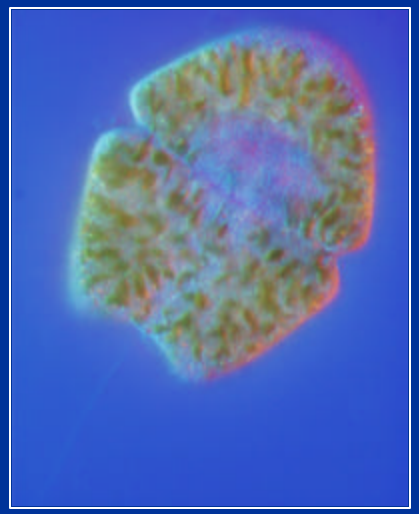
Other Phytoplankton

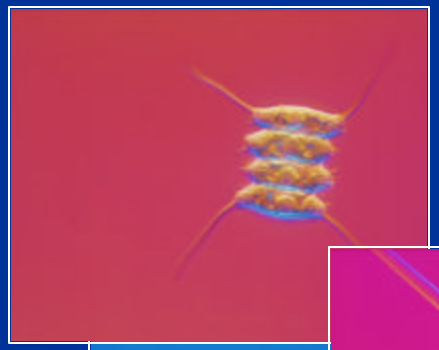


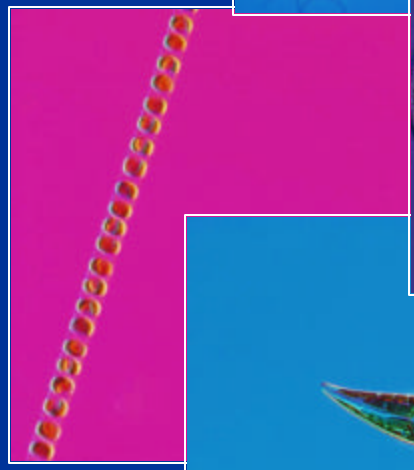


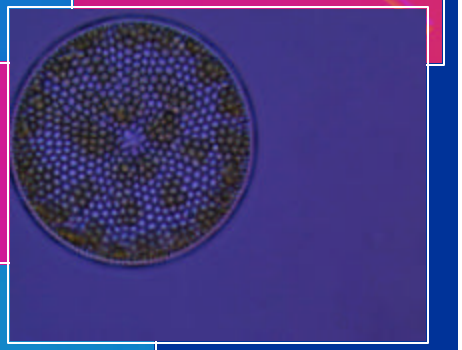


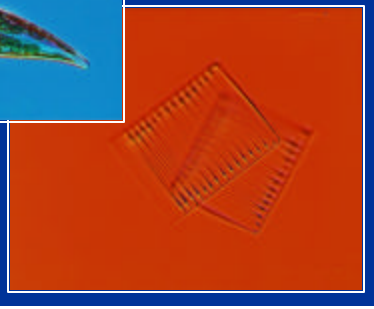












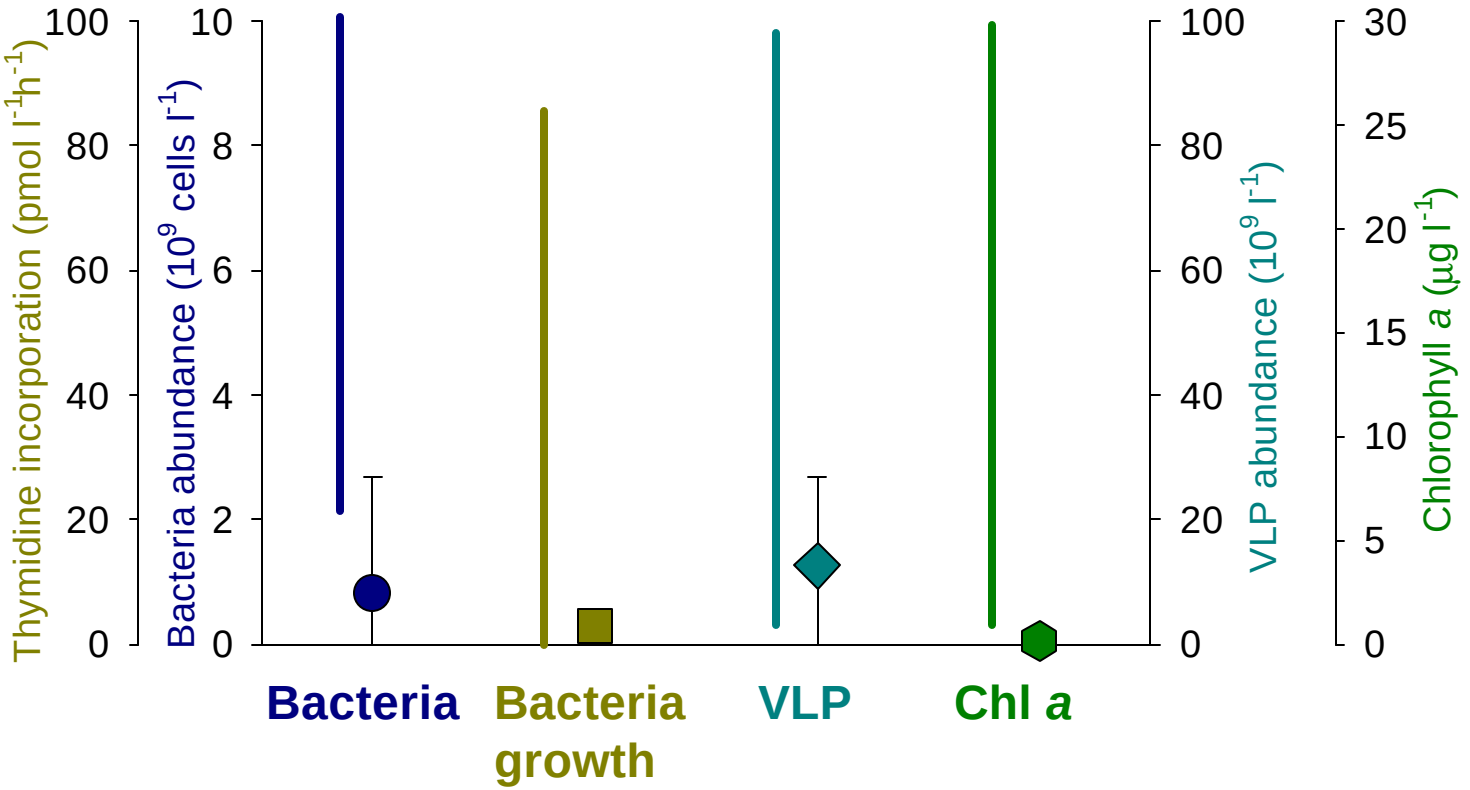
Potential pathogens

- *Vibrio cholerae*
  - Gulf of Mexico (McCarthy et al. 1992)
  - Chesapeake Bay (Ruiz et al. 2000)
- *Pfiesteria piscicida* (Rublee, unpublished)
- HAB species (Hallegraeff and others)
- *Cryptosporidium* sp. (Graczyk, unpublished)

Many microorganisms possess survival strategies to withstand harsh conditions

- cysts
- spores

Microbial values in ballast water vs. Chesapeake Bay

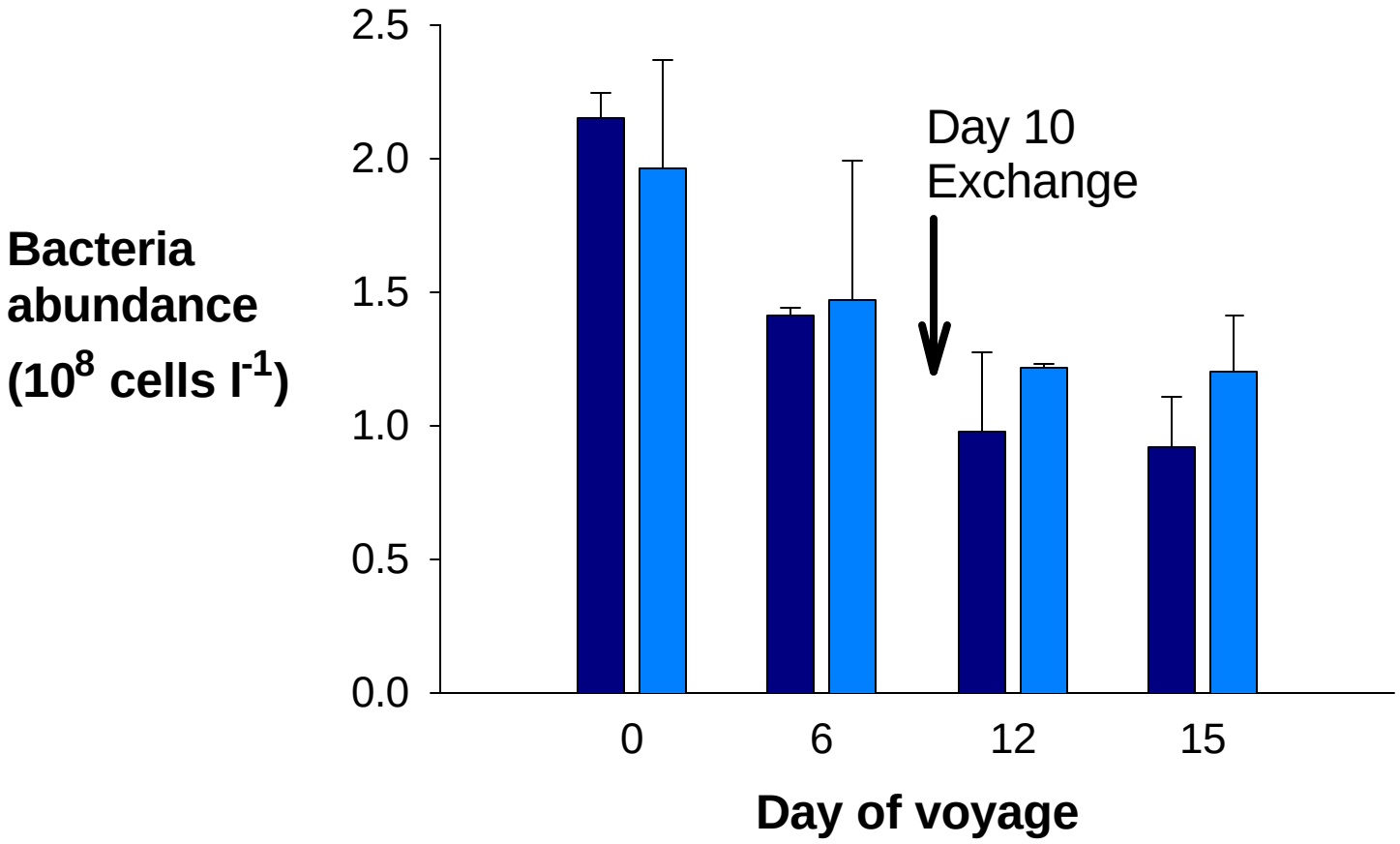


Lines = range of given microbial metric in Chesapeake Bay

Symbols = ballast-water grand means (n = 20 - 51)
error bars are 1 SD

Bacteria - Choi et al. 1999
Bacteria growth - Choi et al. 1998
VLPs - Wommack et al. 1992, Drake et al. 1998
Chlorophyll *a* - Choi et al. 1998

Motor Bulk Carrier *Hadera*
Hadera, Israel to Baltimore, USA
July - August 1999



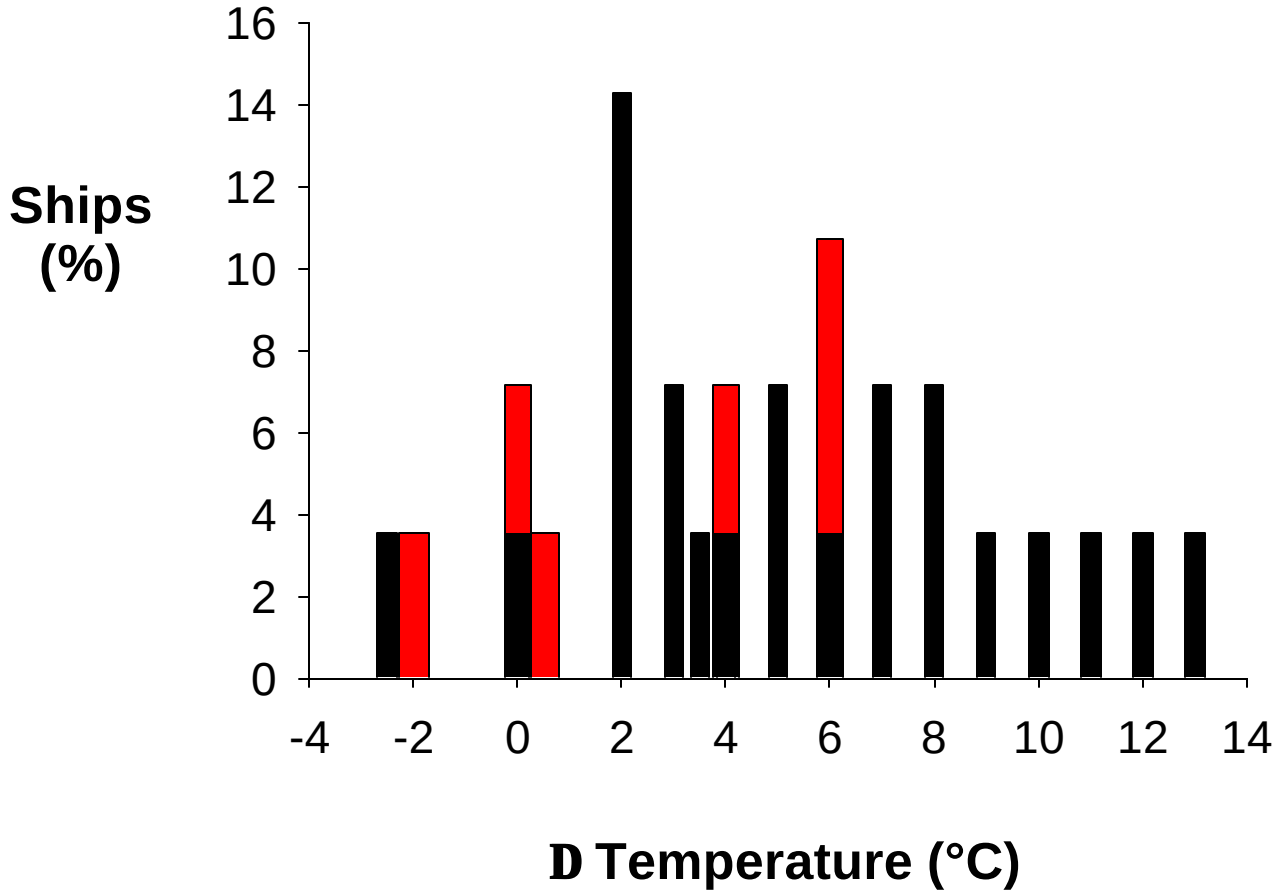
Dark blue bars are from Control Holds; light blue from Exchange Holds
n = 2, with 5-6 subsamples per replicate
Error bars represent one standard deviation

→ No evidence of the “incubator hypothesis”

- Instead, the “decay hypothesis” seems applicable

Nonetheless, profound numbers of microorganisms are transported globally

D Temperature
($T_{ballast\ water}$ - $T_{Chesapeake\ Bay}$)



Exchanged ballast water
Unexchanged ballast water
n = 29 ships

A broad estimate of microorganismal growth

IF:

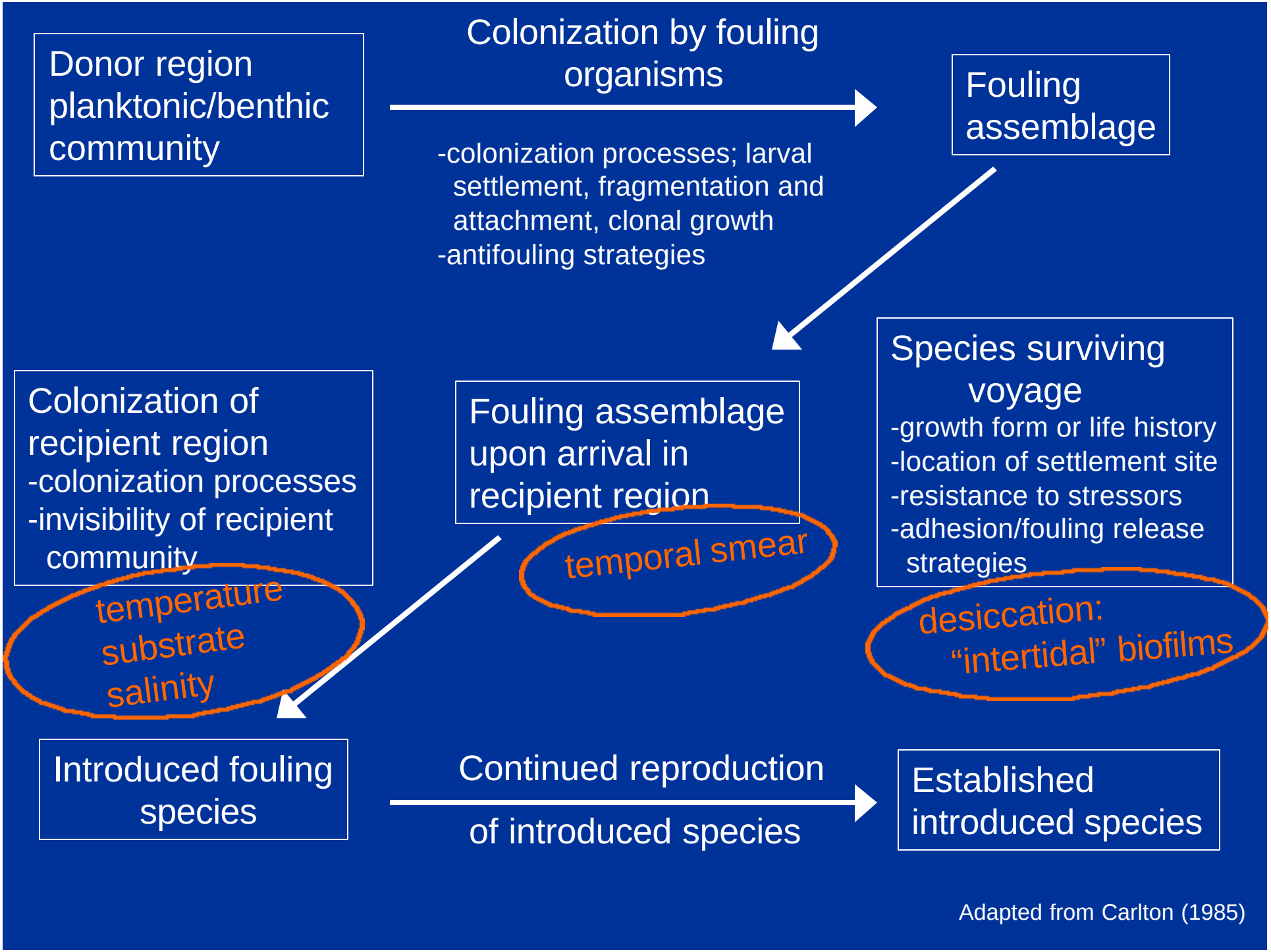
- most microorganisms have a 10°C temperature range for ***optimum growth*** (Brock et al. 1994),
- microorganisms inhabit ballast water at the midpoint of their optimum temperature

THEN:

- microorganisms will grow best when discharged into water ± 5°C of the ballast water.
- from the data, we conclude that ***about half*** of ships arriving to Chesapeake Bay contain microorganisms that will encounter optimum temperatures at the time of delivery.

What about “interior hull fouling”, biofilms?

- Resistant to
  - Predation
  - Chemical treatment
- Biofilms can have greater bacteria abundance and activity than water samples (e.g., Haglund et al. 2002).


Donor region planktonic/benthic community
Colonization by fouling organisms
-colonization processes; larval settlement, fragmentation and attachment, clonal growth
-antifouling strategies
Fouling assemblage
Species surviving voyage
-growth form or life history
-location of settlement site
-resistance to stressors
-adhesion/fouling release strategies
desiccation: "intertidal" biofilms
Fouling assemblage upon arrival in recipient region
temporal smear
Colonization of recipient region
-colonization processes
-invisibility of recipient community
temperature
substrate
salinity
Introduced fouling species
Continued reproduction of introduced species
Established introduced species
Adapted from Carlton (1985)

Abundance of microorganisms and pathogens associated with biofilms inside ballast-water tanks…

1. Field sampling:

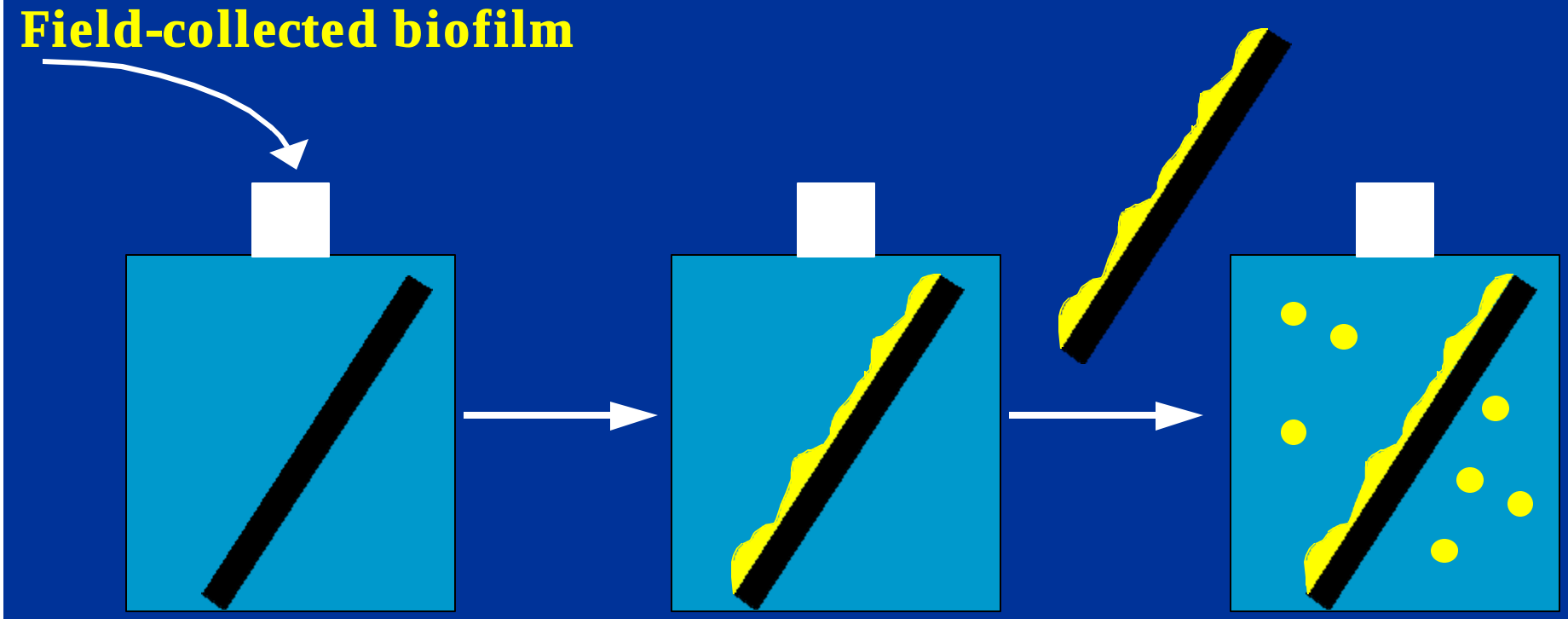
- Collect biofilm samples, analyze them for microbial constituents
  - Community metrics:
    total bacteria, virus-like particles, chlorophyll *a*
  - Specific pathogens:
    Vibrio cholerae, Pfiesteria spp., *Pseudomonas* spp., etc.

2. Field Experiments:

- Deploy field sampling devices (BOBs) during voyages
  - Measure microbial metrics in – biofilms on slides
    – water in tank

…and their capacity to act as ‘vertical seed banks’

3. Laboratory Experiments:



Future work

- Interaction between biofilm and sediments in ballast-water tanks
- Survival of specific microorganisms in new environments
- Genetic diversity
- Antibiotic resistance
- Transfer of ‘new’ strains of microorganisms

Acknowledgements

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