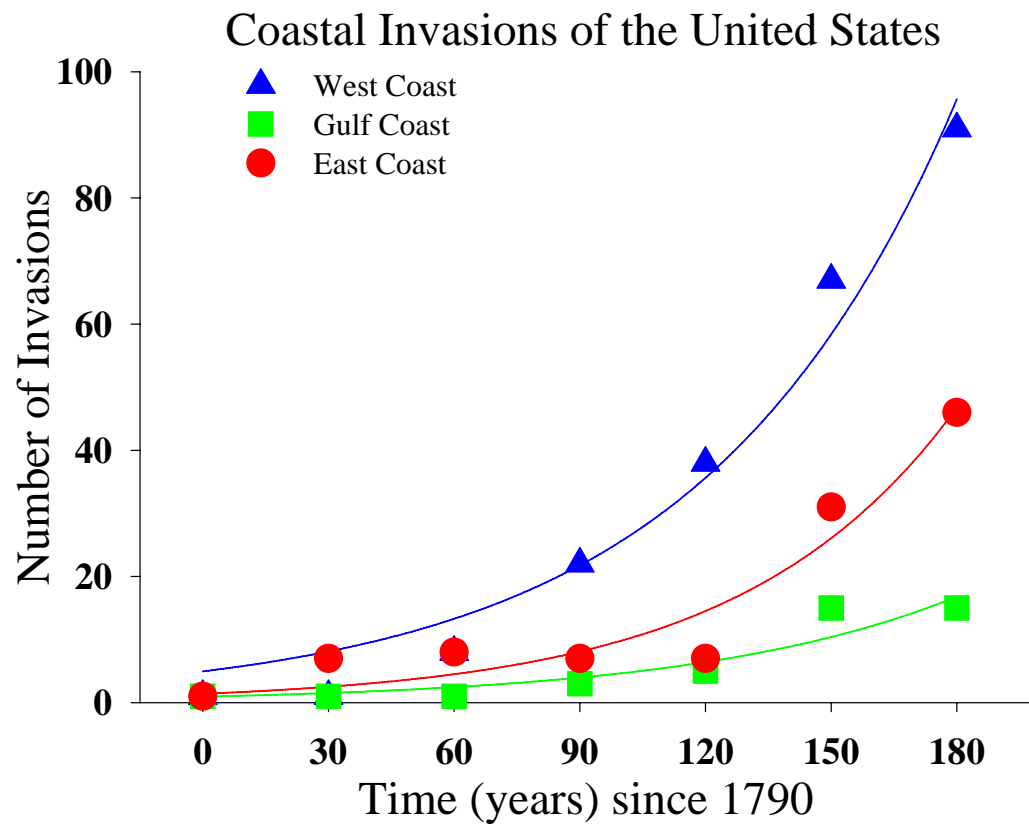


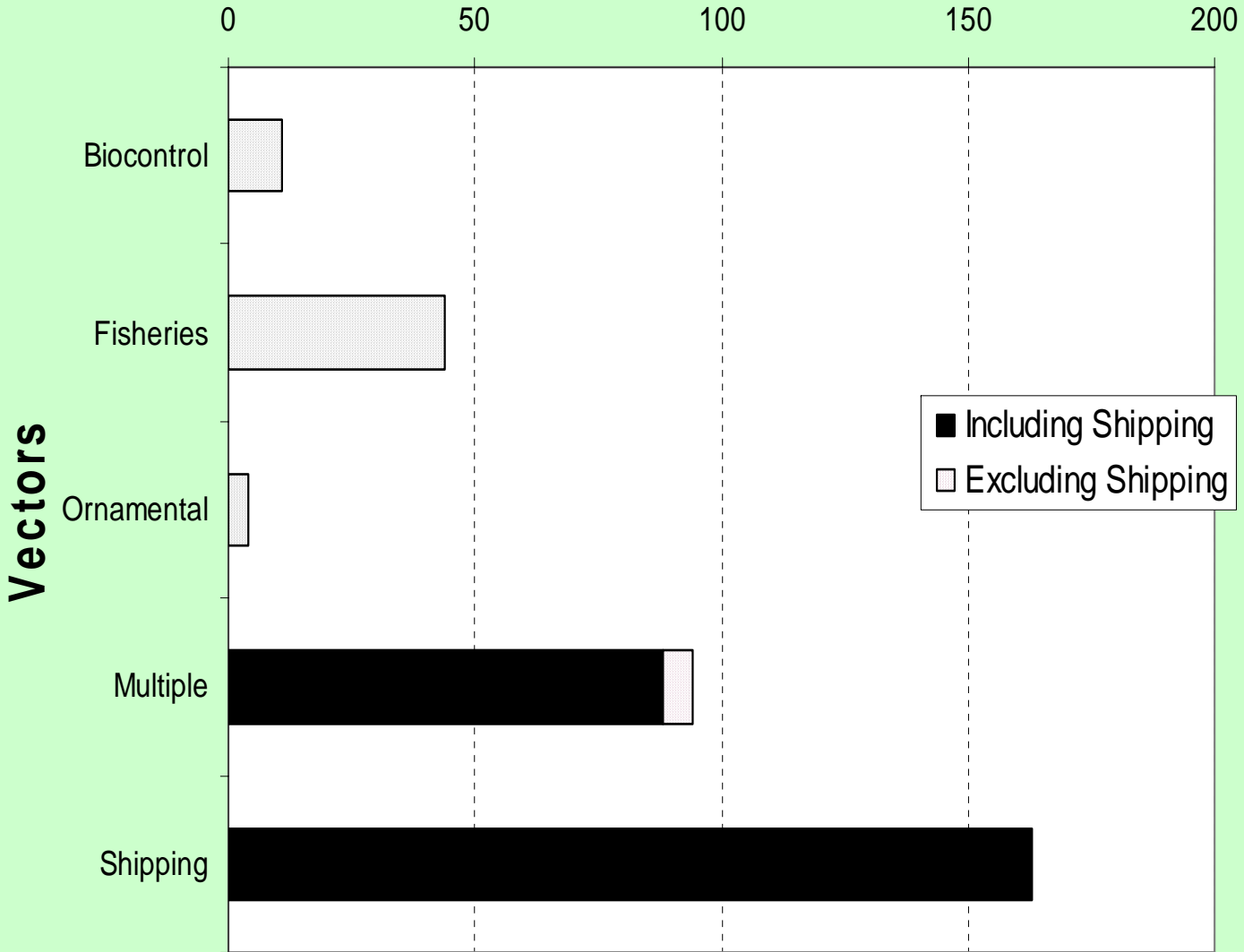


# Rate of new coastal invasions detected for each coast of North America

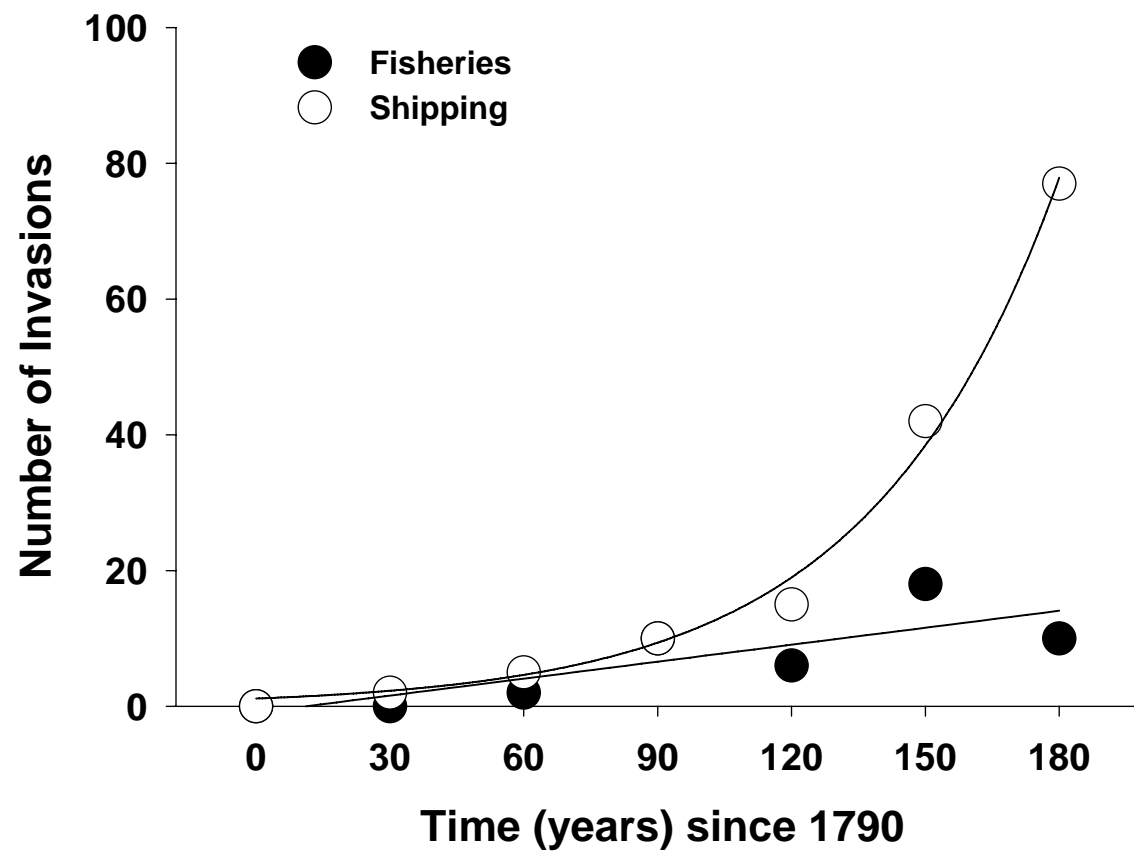


# Vectors for invertebrate and algal NIS introduced to the Coasts of North America (n=315)

Number of Species



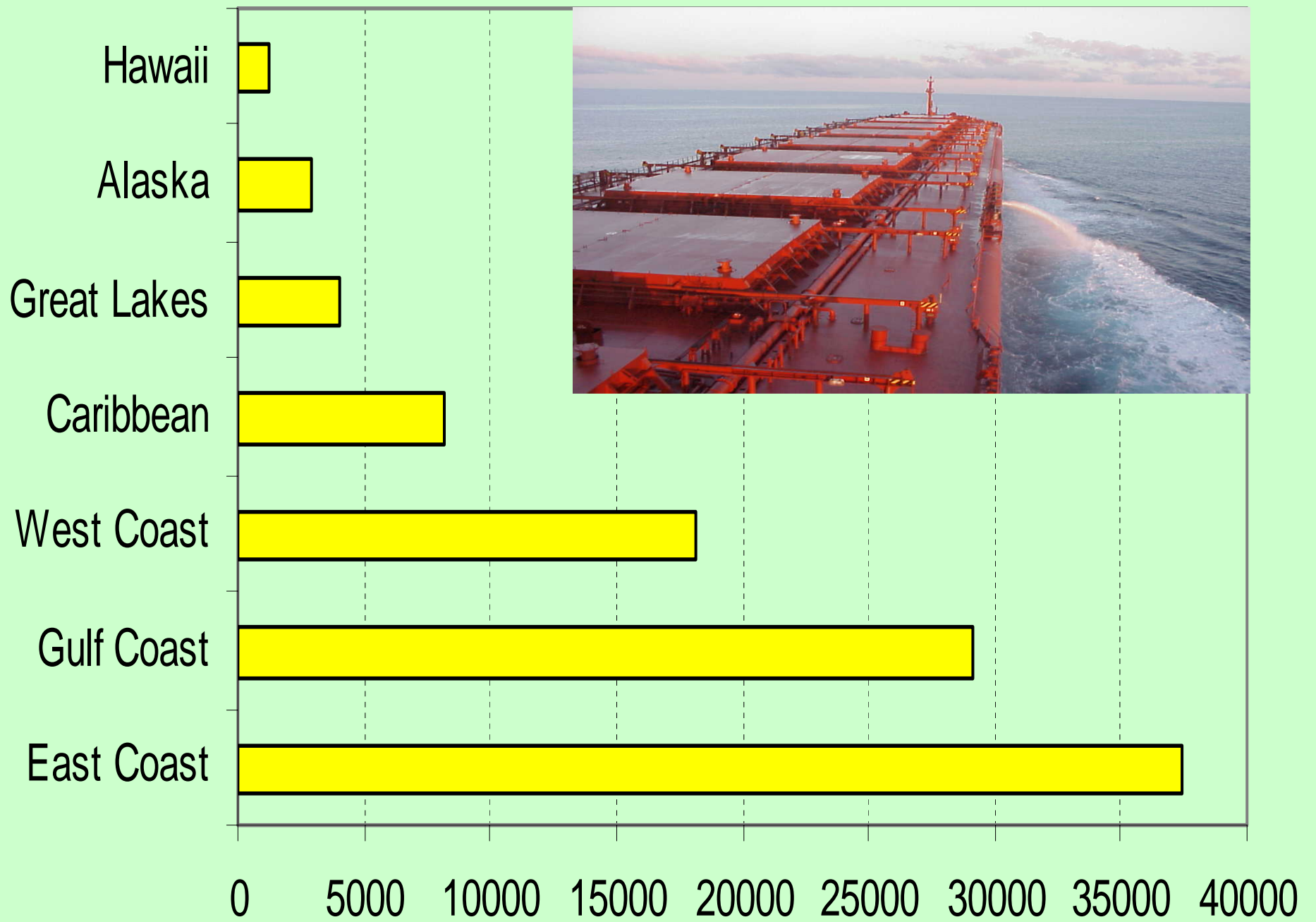
# Rate of new coastal invasions detected in North America attributed to each vector, per 30 yr interval



# TRADE IS PRIMARY DRIVER OF INVASIONS

- More Shipments
- Larger Shipments
- Faster Shipments
- More Source Regions
- More Recipient Regions





# Ship Arrivals from Overseas

## Ballast Water Discharge:

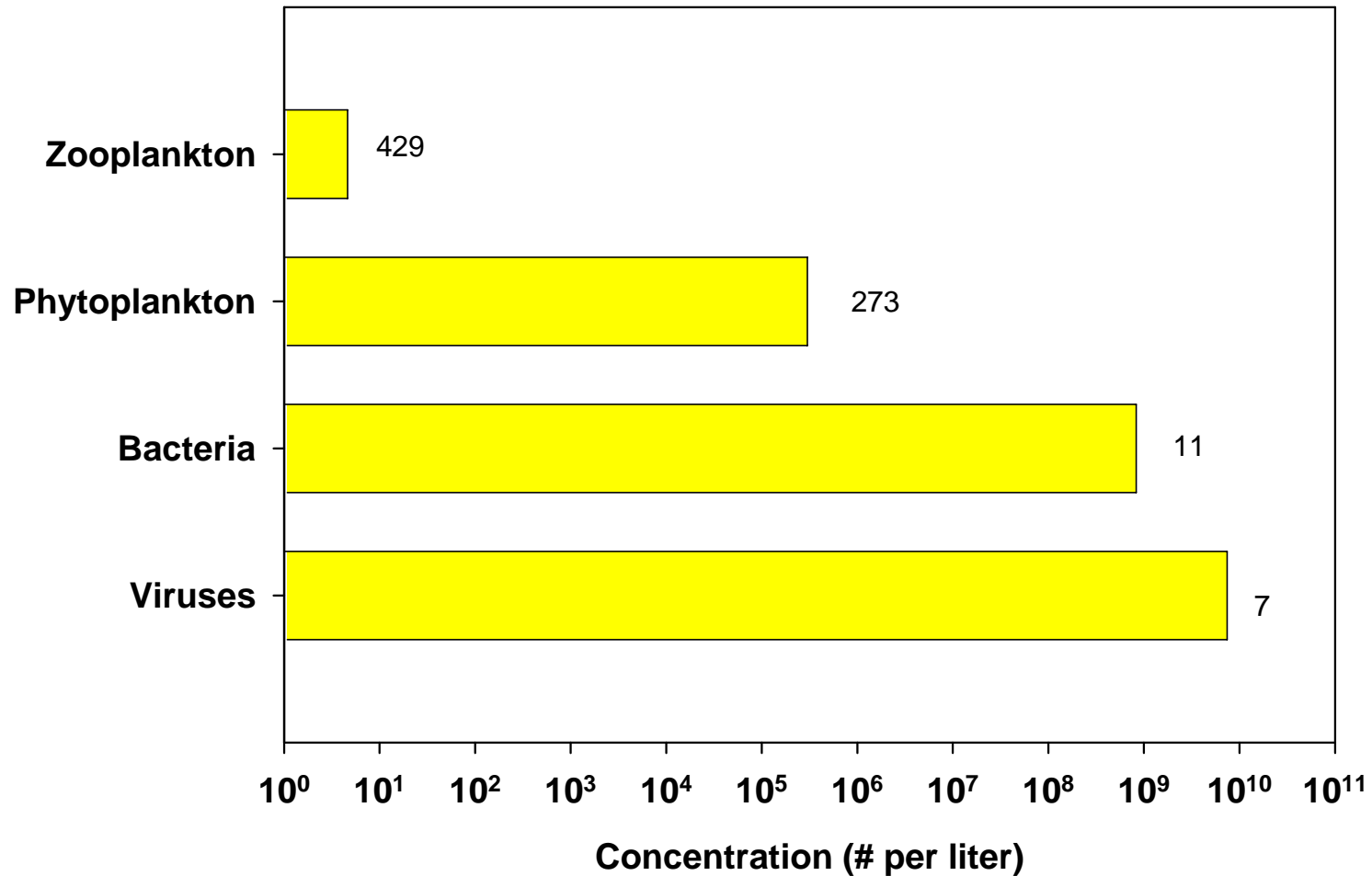
- ~100 Million Metric Tons / YR

## Hull Surface Area:

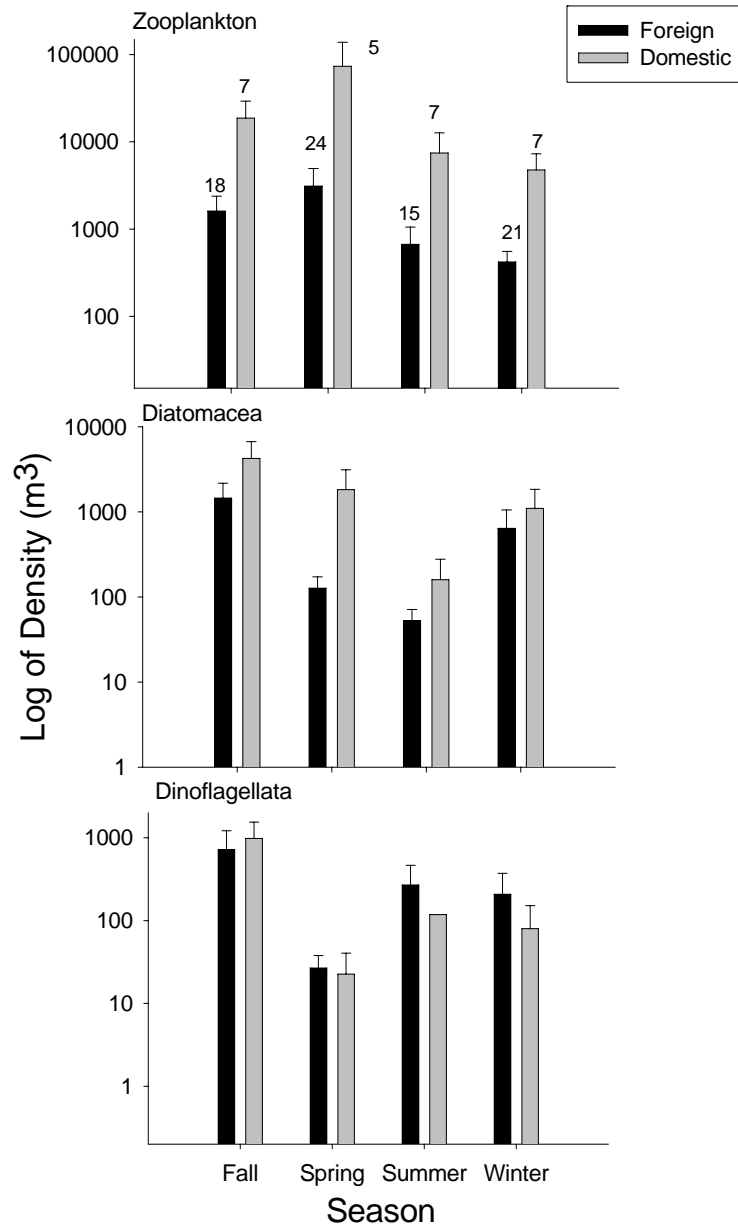
- ~ 335 Million M<sup>2</sup> / YR

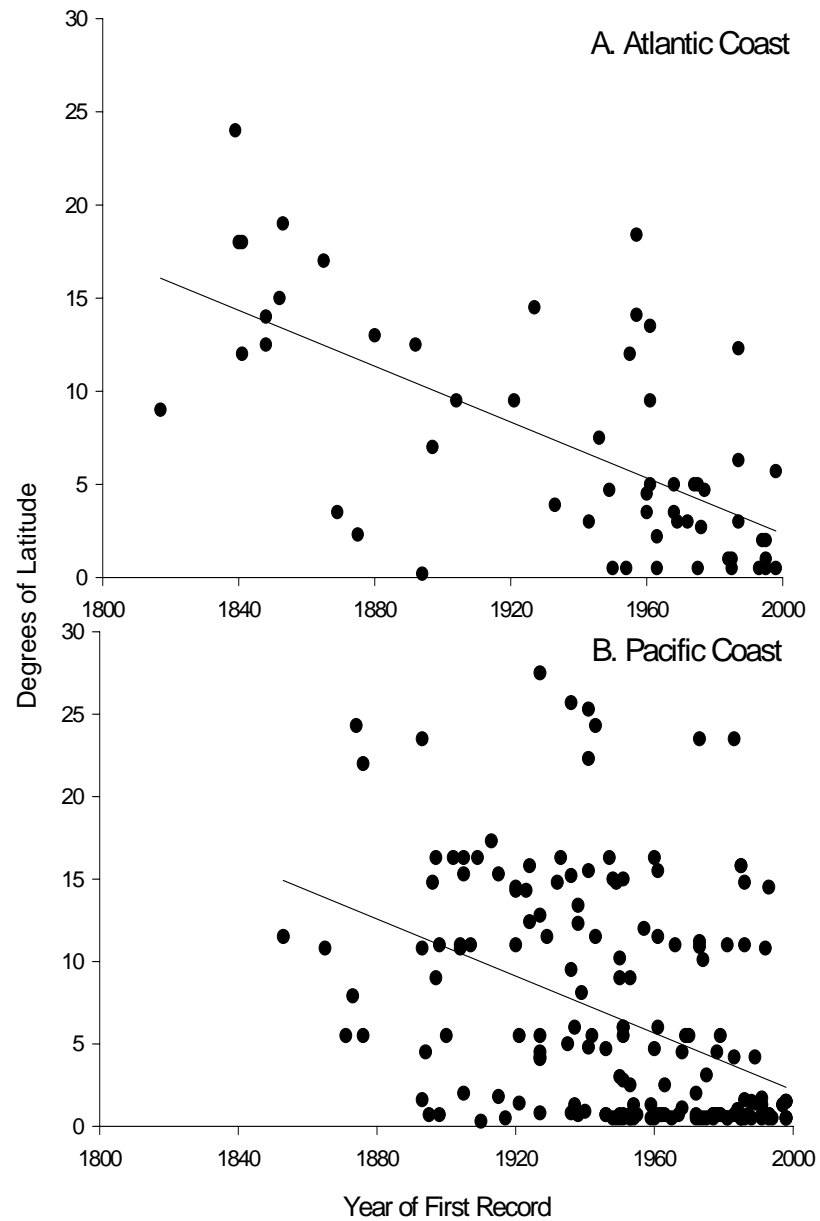
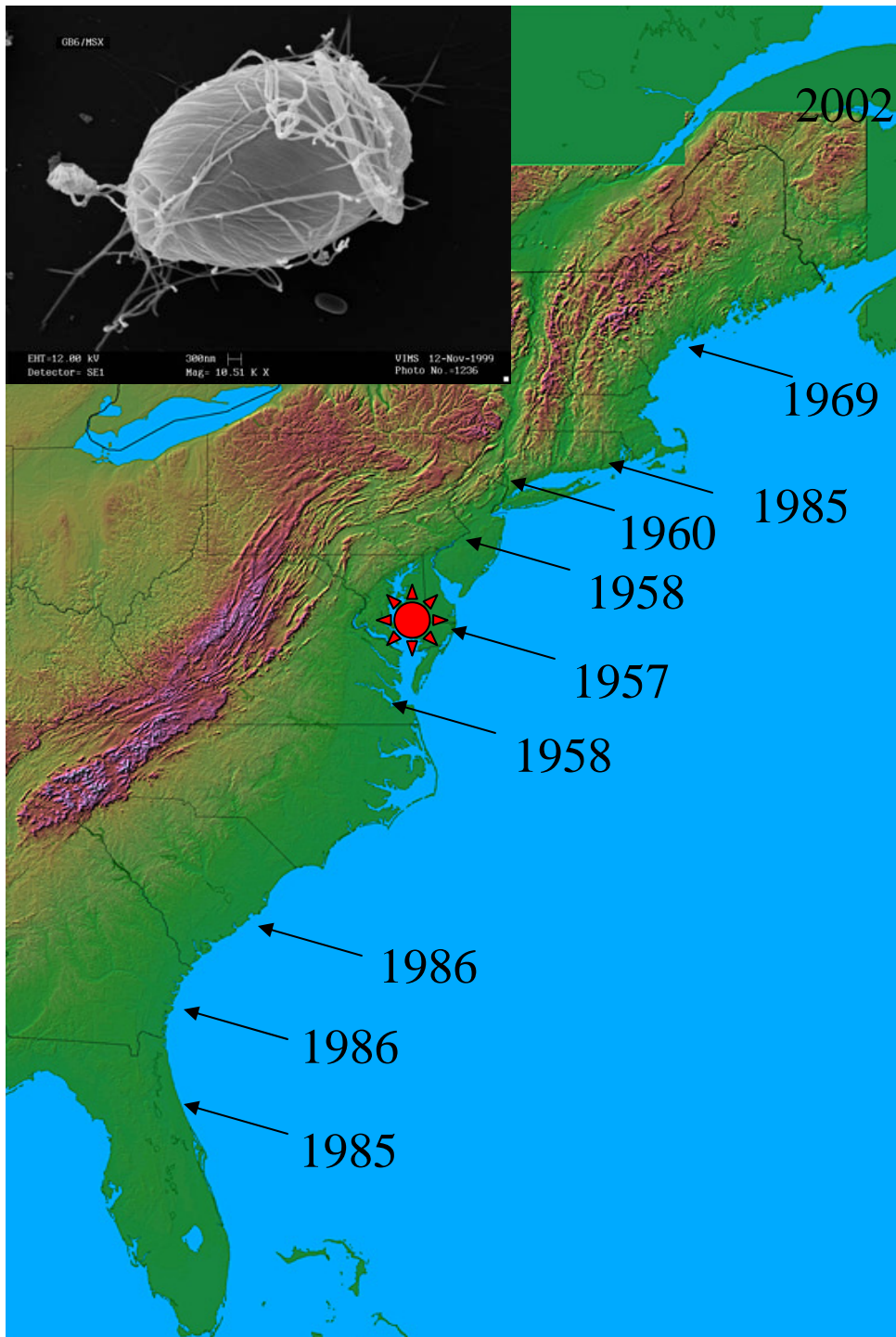


# Propagule Supply by Size



# Density in Foreign versus Domestic Vessels



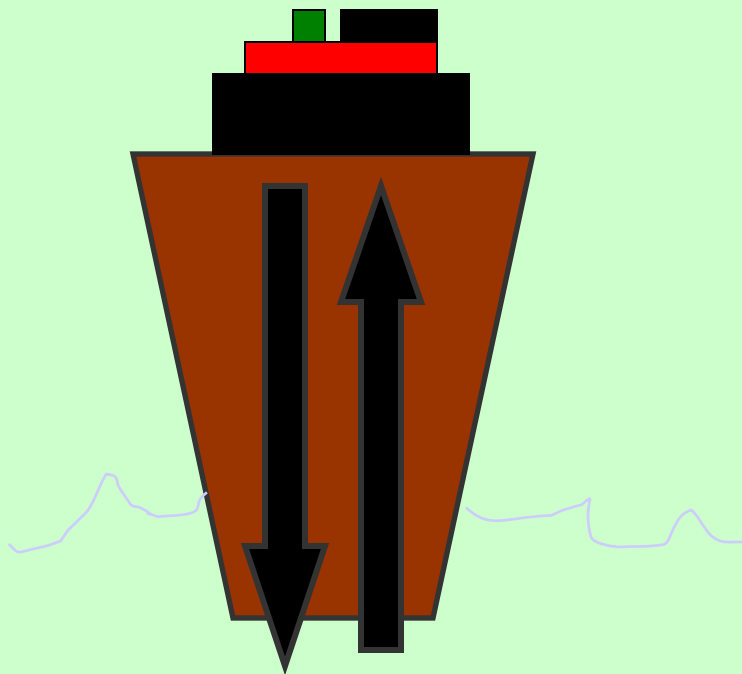




# Mid-ocean ballast water exchange

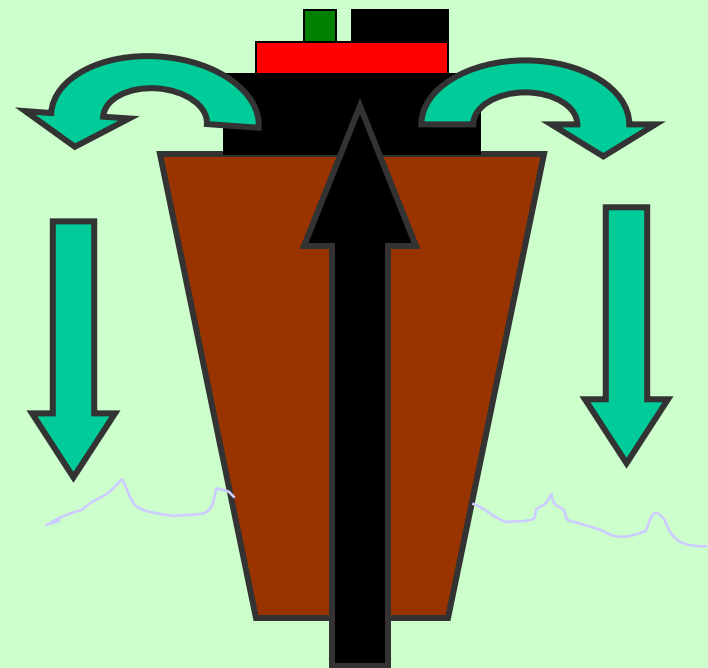
Empty/Refill

100%



Flow-Through

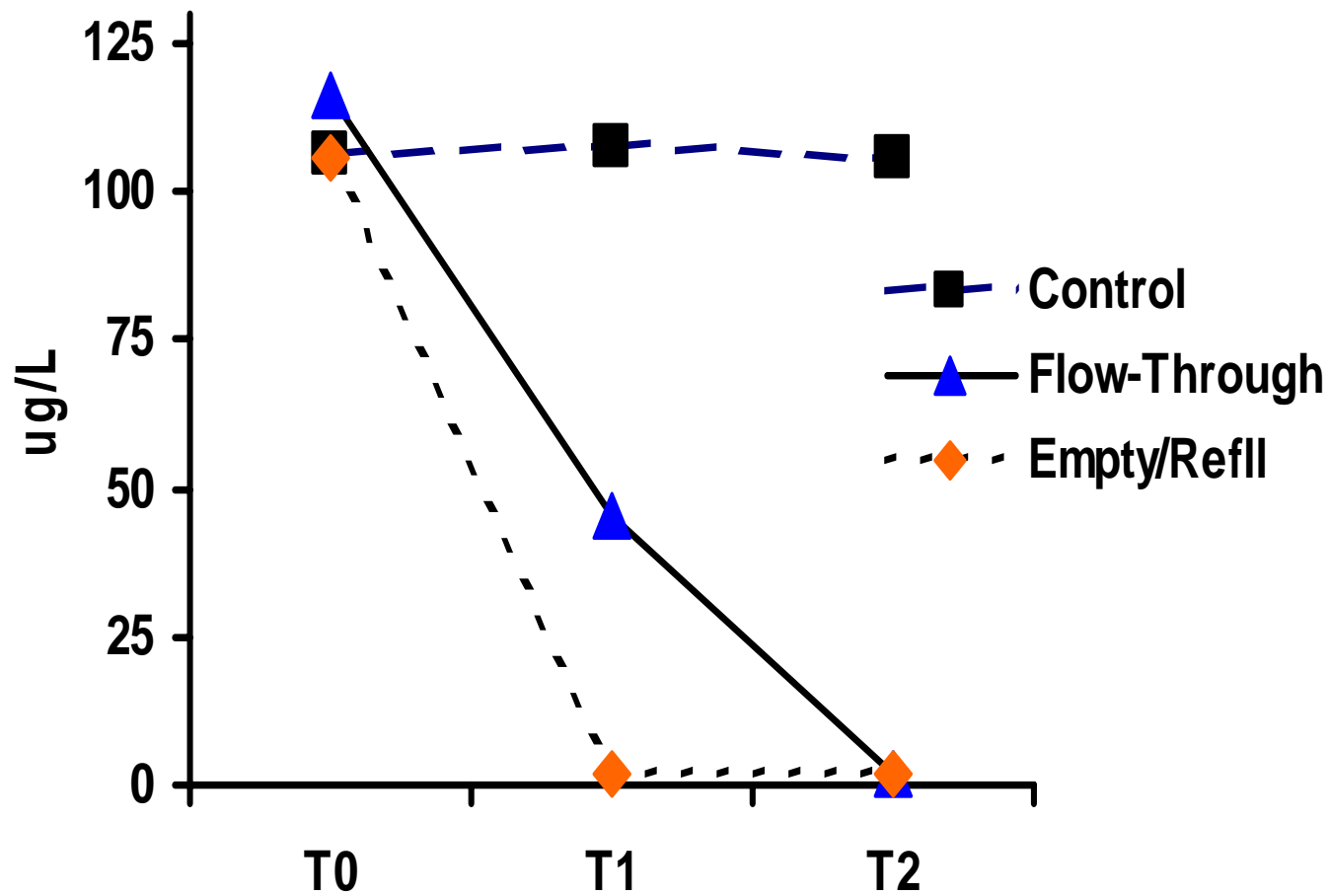
300%



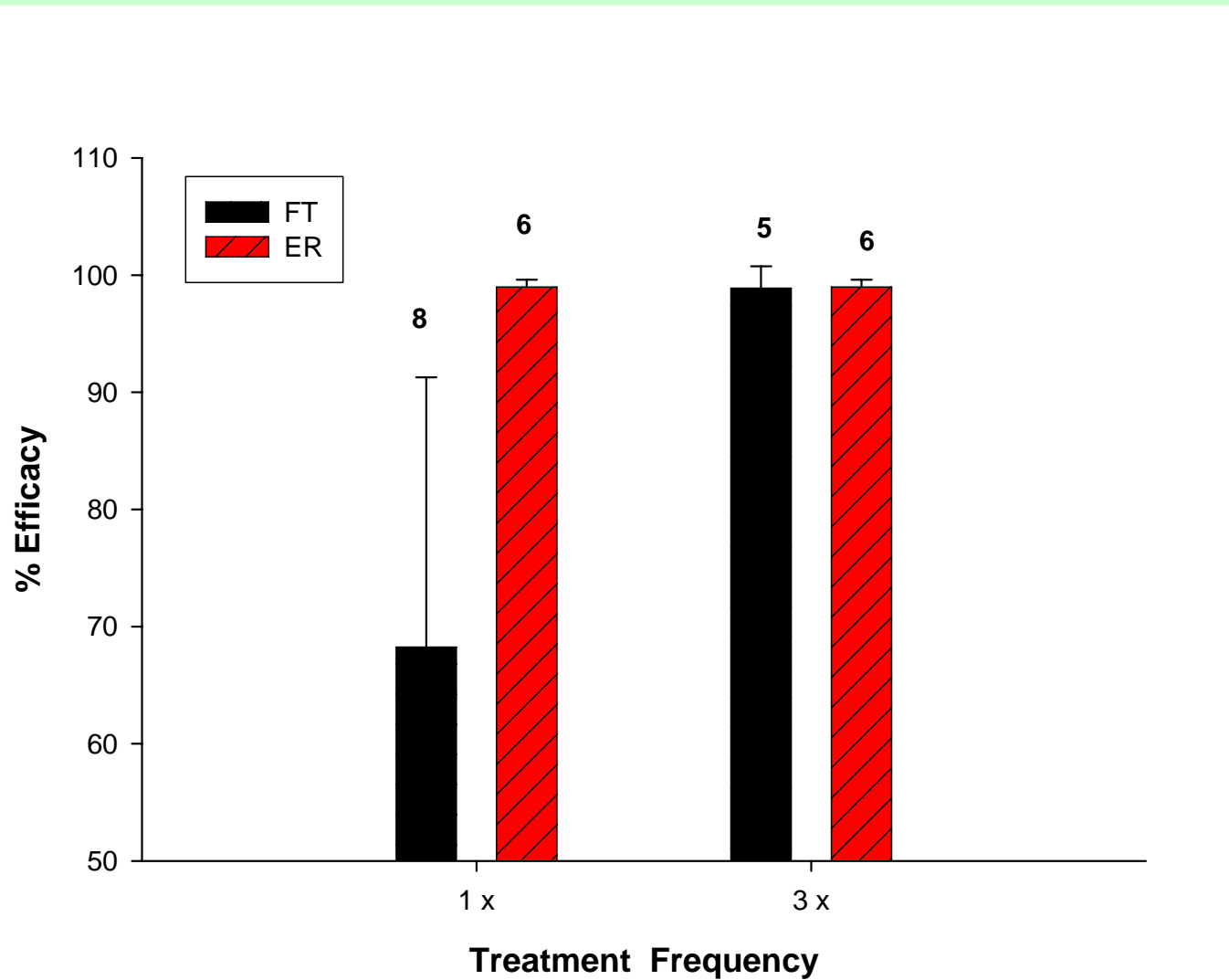
# Exchange Efficacy

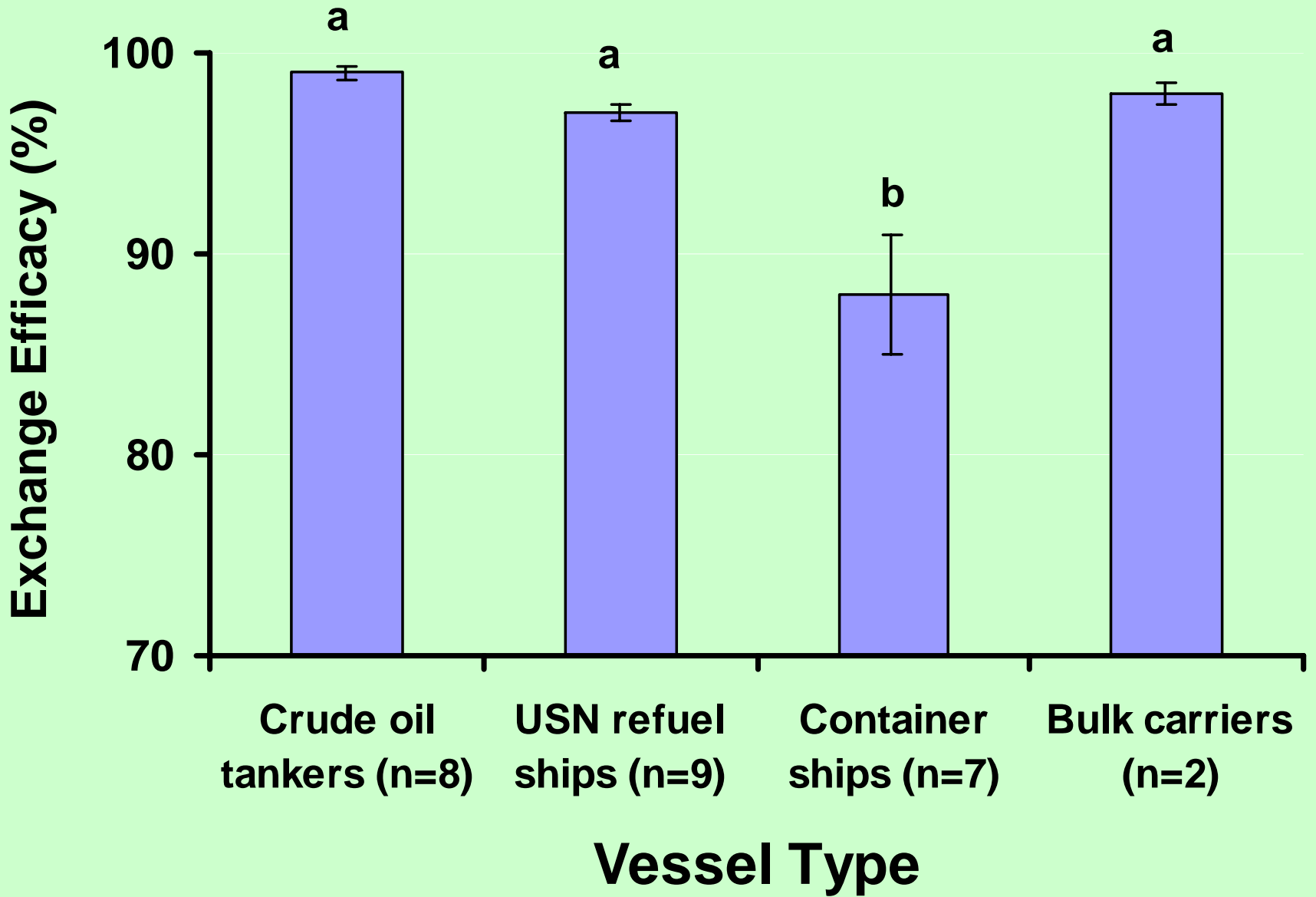
- Rhodamine: fluorescent dye
- Biological tracers: ballast-entrained biota.

# Typical dye trajectory over multiple time points



# Mean effect of exchange treatment on rhodamine dye





## **Criteria for Biotic Tracers:**

- Abundant at T0
- Coastal in Origin
- Easily Recognized & Enumerated

## **Not Included:**

- Microbial Community\*
- Biofilms
- Bottom Communities

# Efficacy of BWE: E/R (1x)

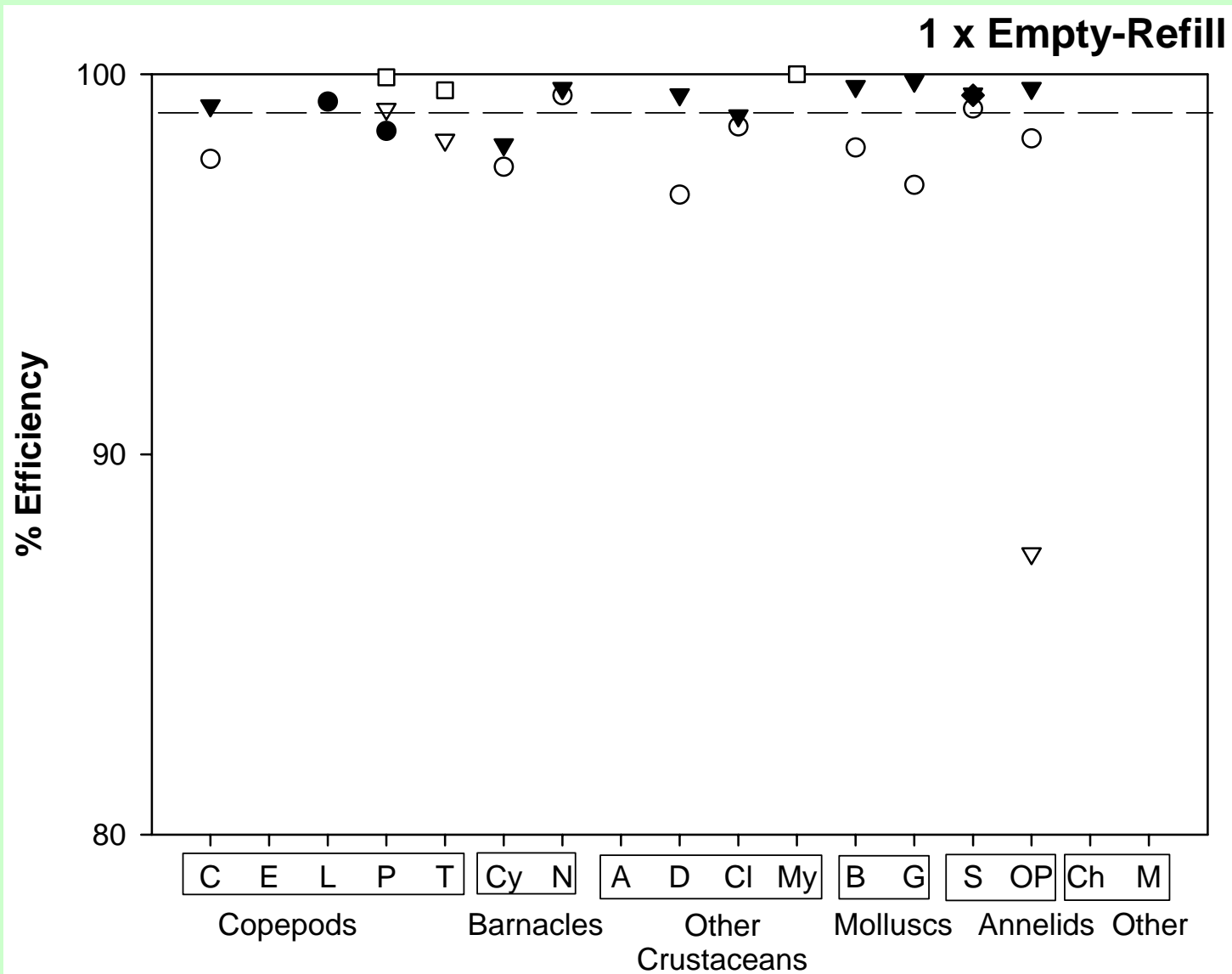


Figure 1

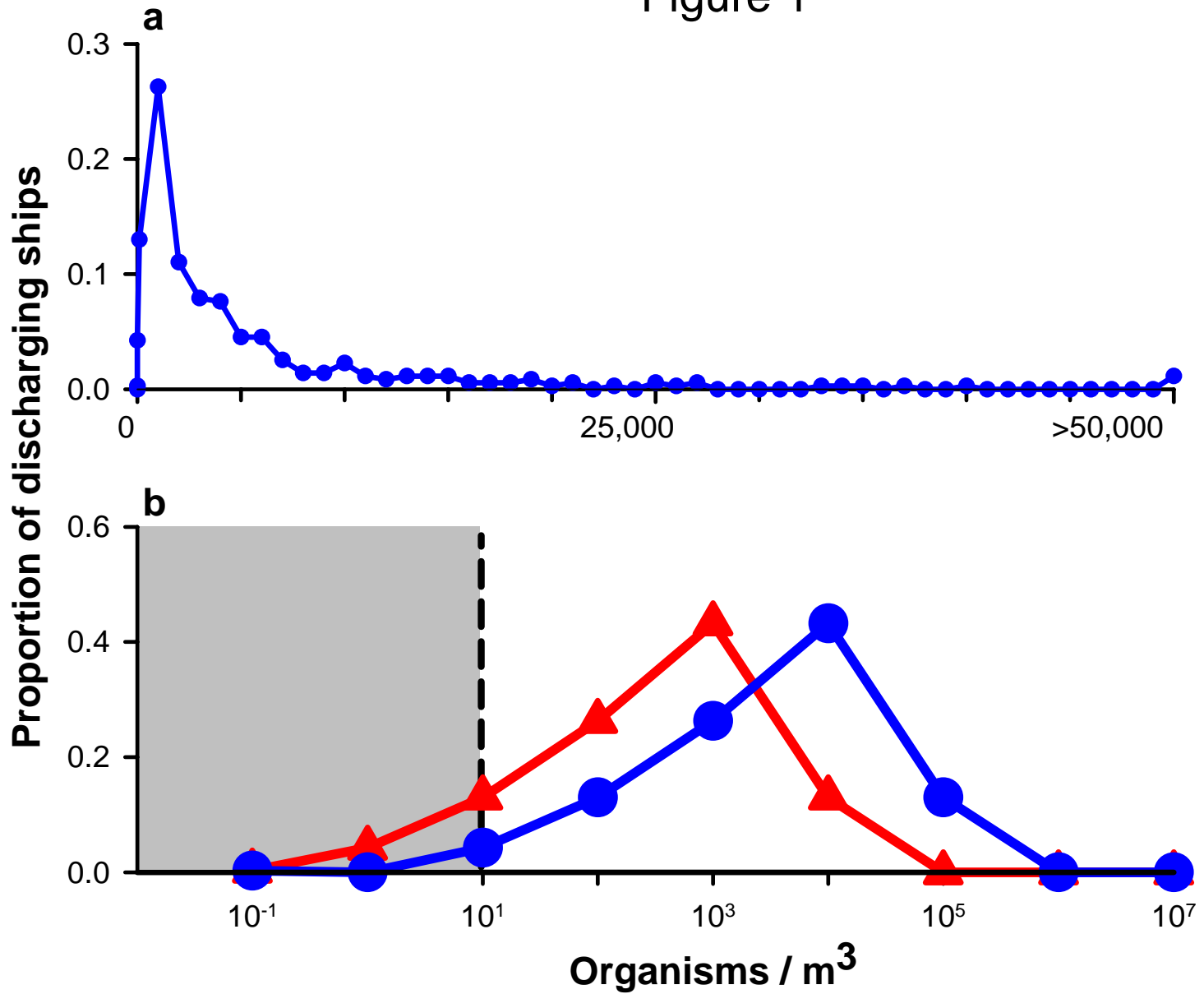
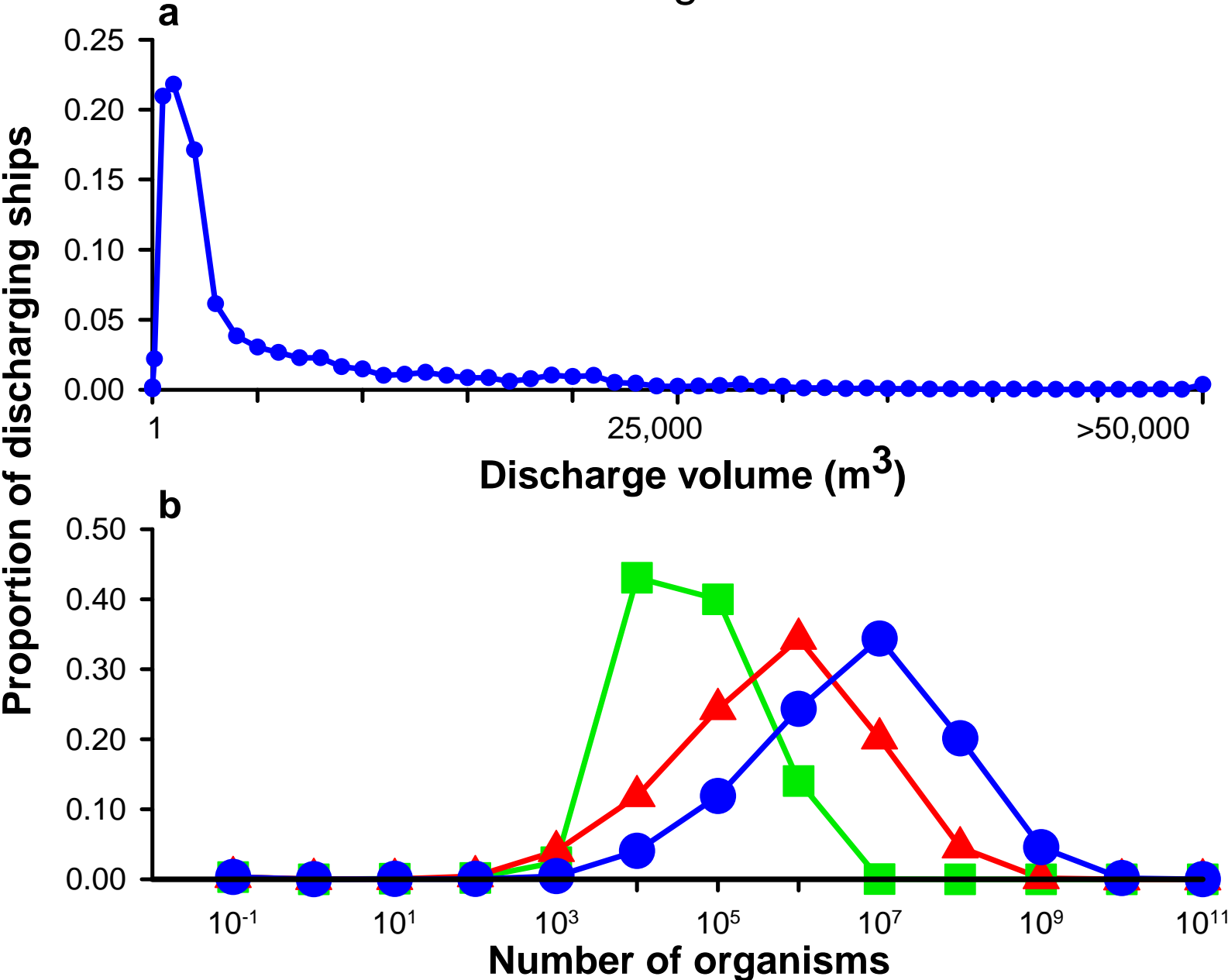
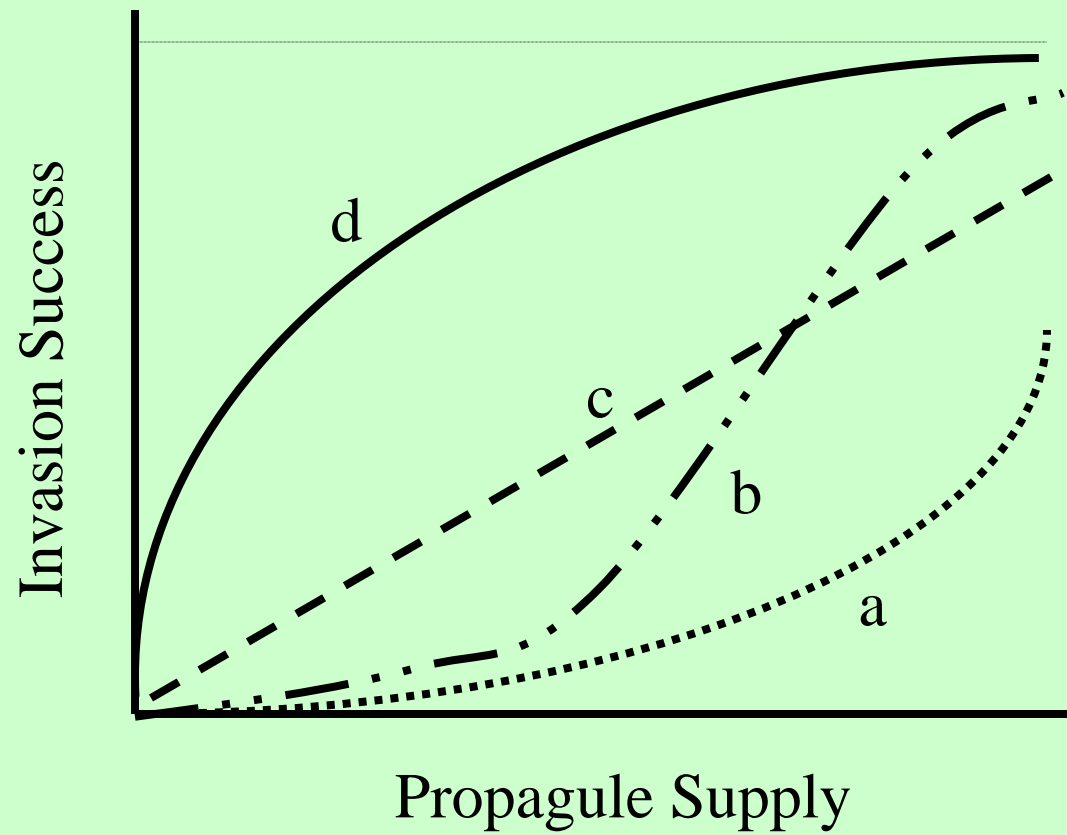


Figure 2



# DOSE-RESPONSE RELATIONSHIP?





# Sponsors

- Department of Defense
- National Sea Grant Program
- Office of Naval Research
- Prince William Sound Regional Citizens Advisory Council
- US Coast Guard
- US Fish and Wildlife Service

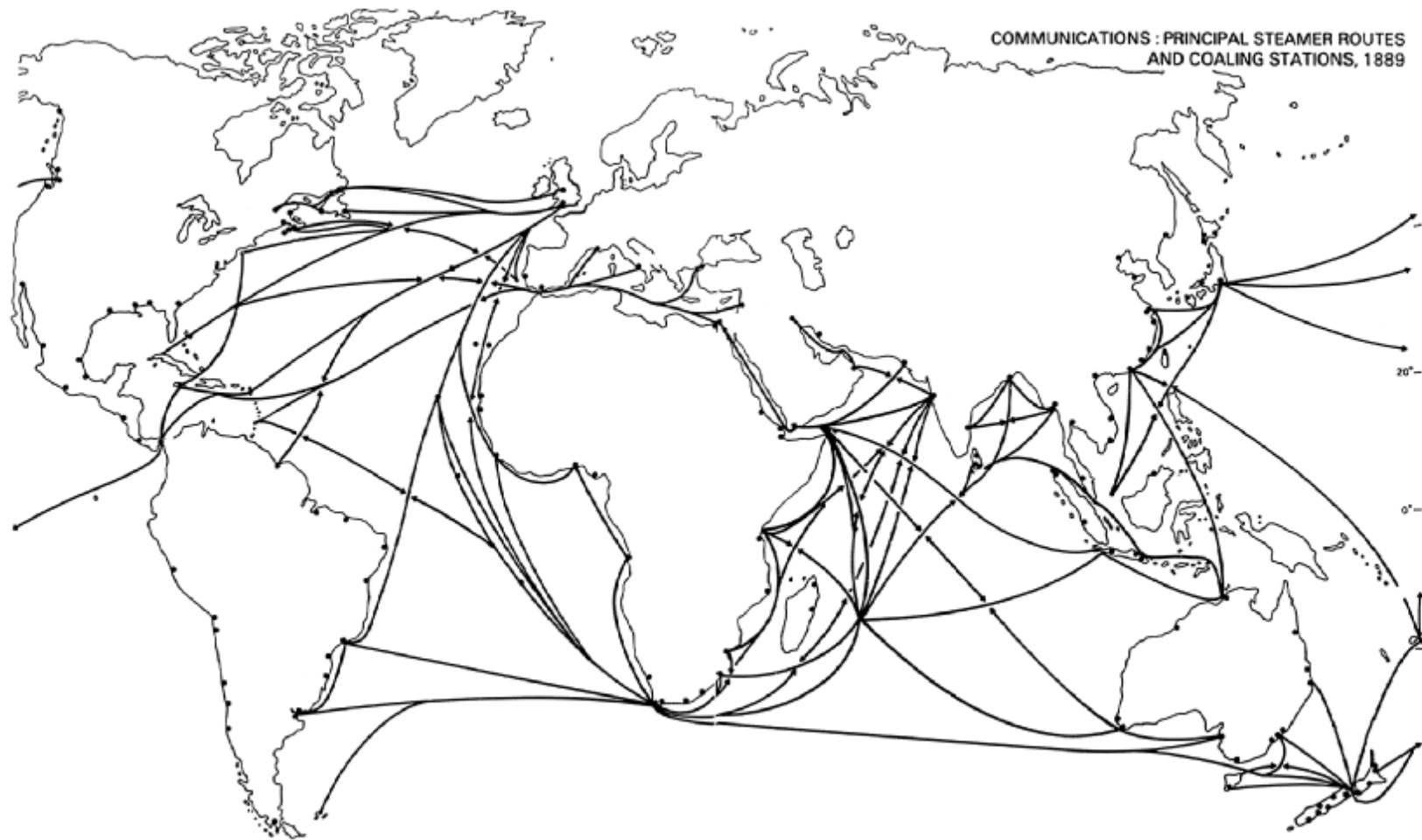


Figure 1.1