

# Understanding the Role of Shipping in Biological Invasions of Coastal Marine Ecosystems

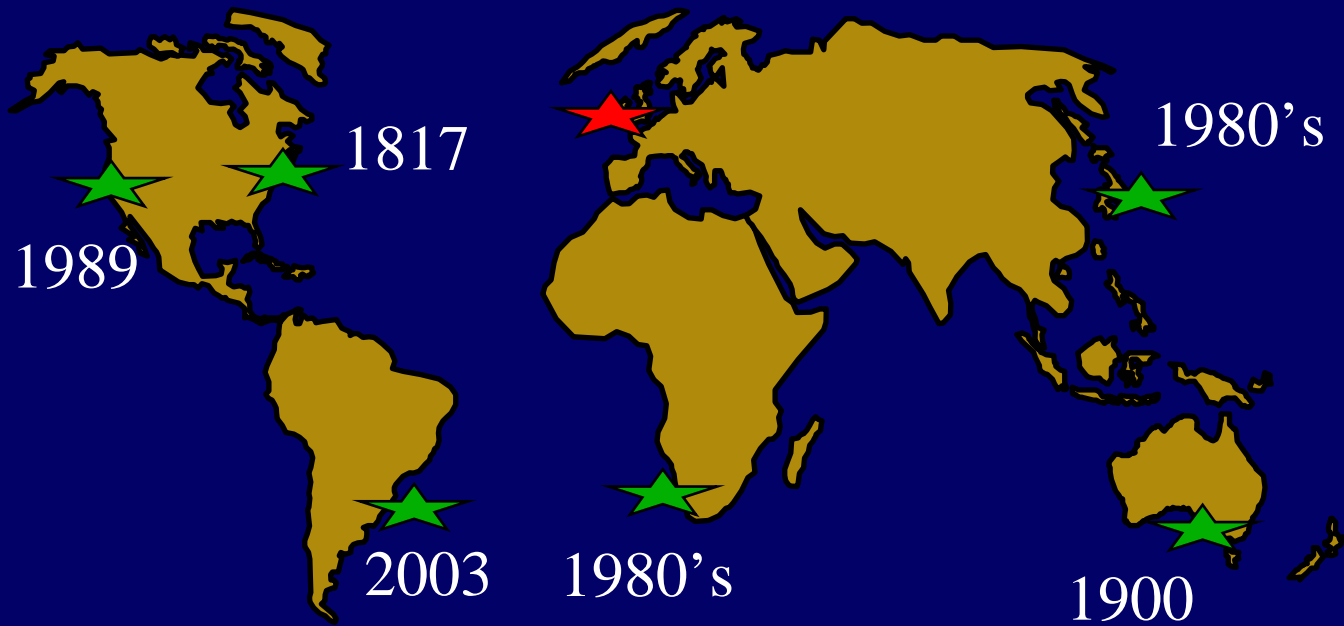
Greg Ruiz

Smithsonian Environmental Research Center  
Edgewater Maryland USA

## Common Terms for Non-Native Species

- Exotic
- Introduced
- Nonindigenous
- Alien
- Naturalized
- Adventive
- Translocation
- Immigrant
- Weed
- Neophyte
- Colonist
- Invader
- Newcomer
- Waif
- Import
- Casual / Transient

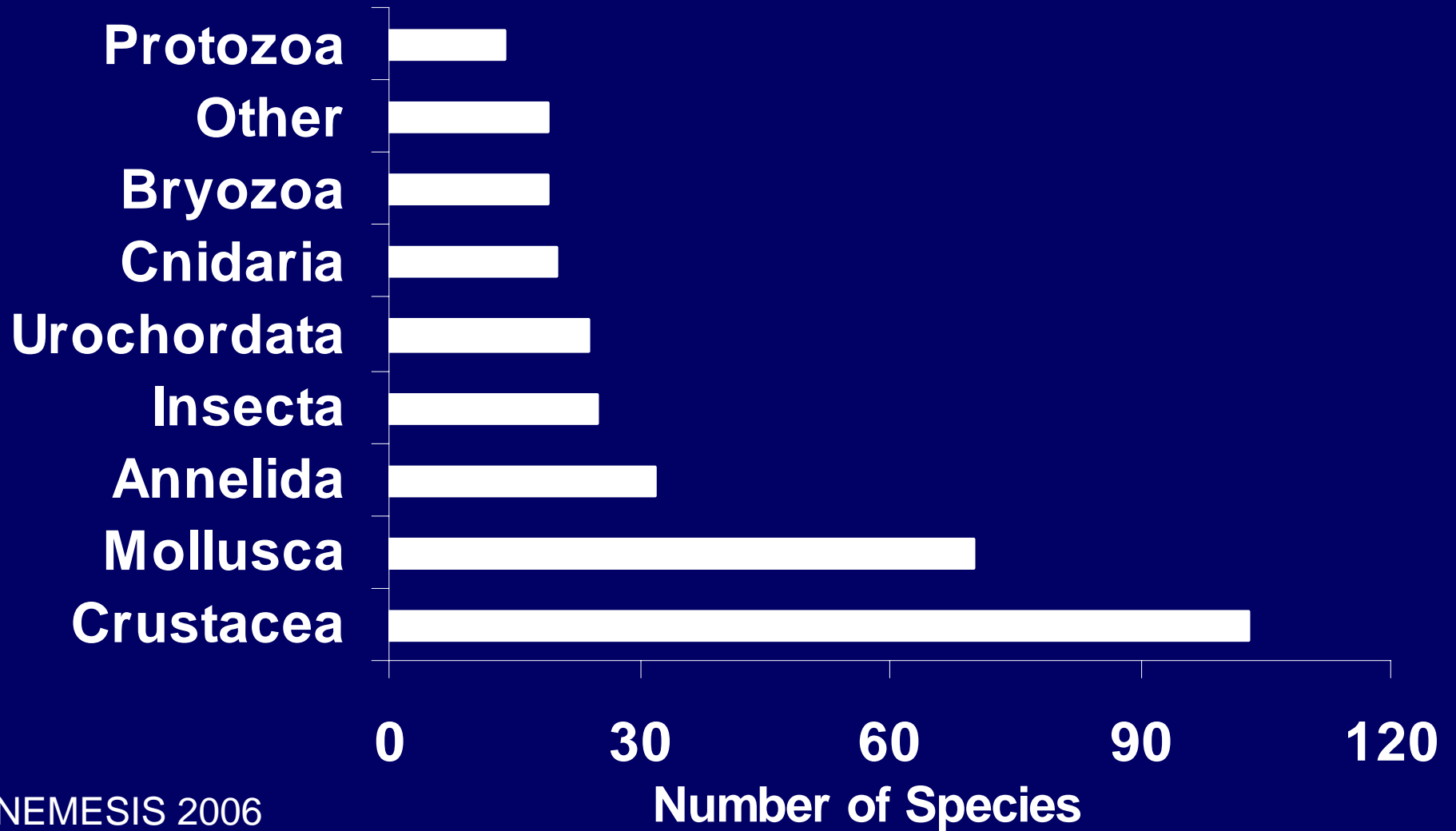
# Invasions by European Green Crabs



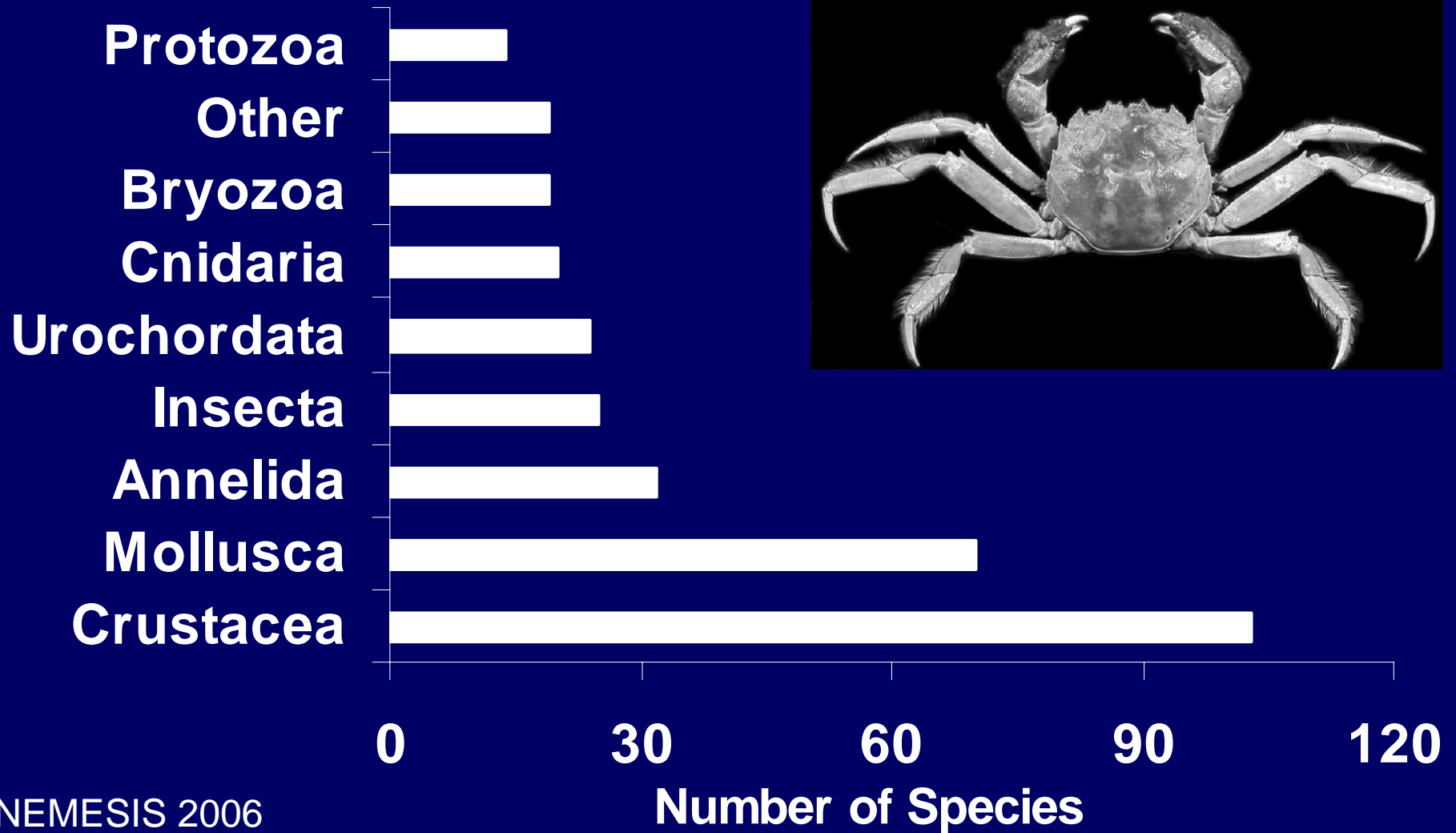
# Overview

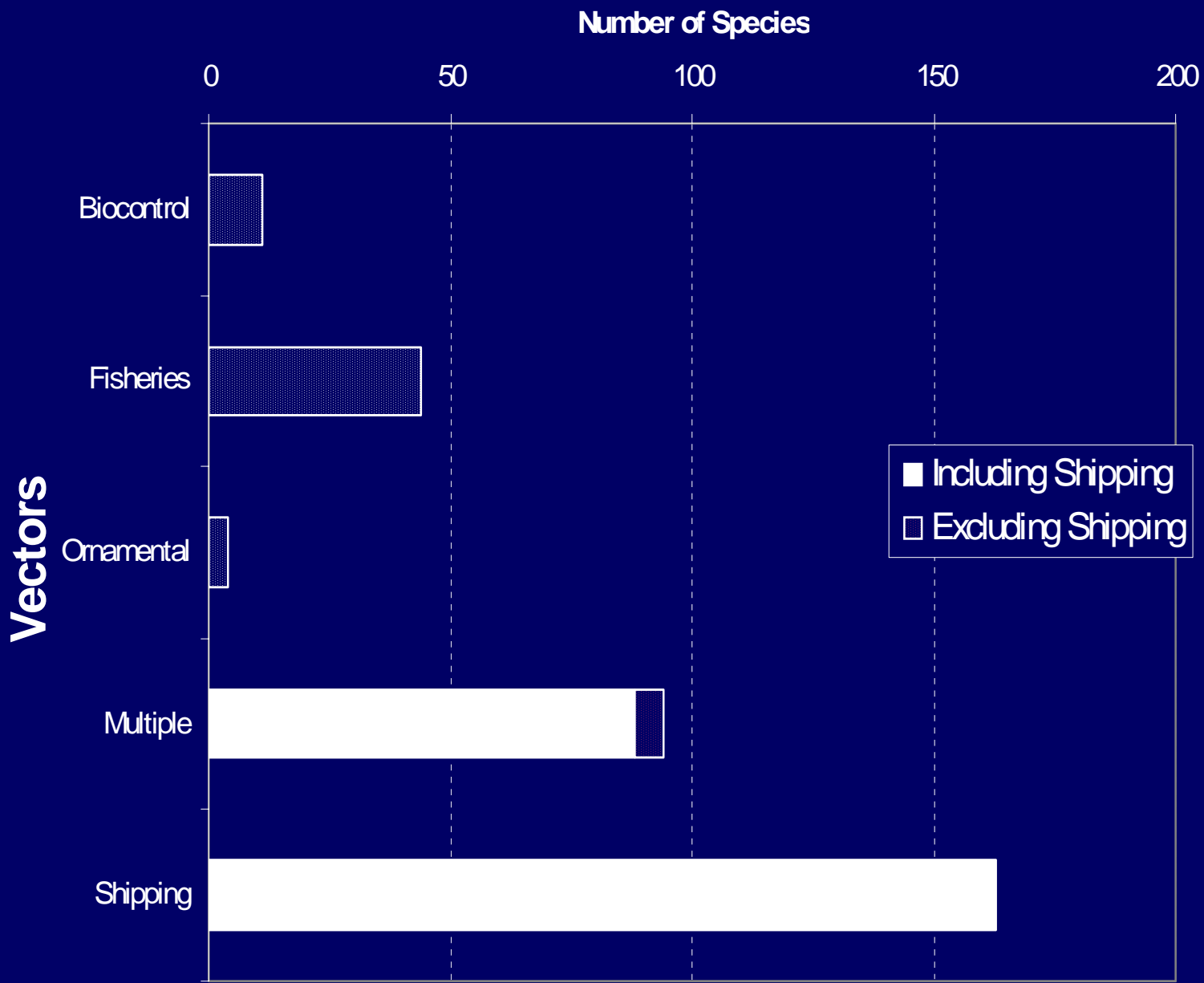
- Patterns of invasion for coastal marine ecosystems:  
→ Focus on invertebrates/algae in the U.S.
- Current state of knowledge about shipping and species transfer in U.S.
- Latitudinal pattern of invasions (non-native species richness) for western North America
- Comparative research in Panama

# Non-native Invertebrates & Algae Reported in Coastal Waters of Continental U.S.



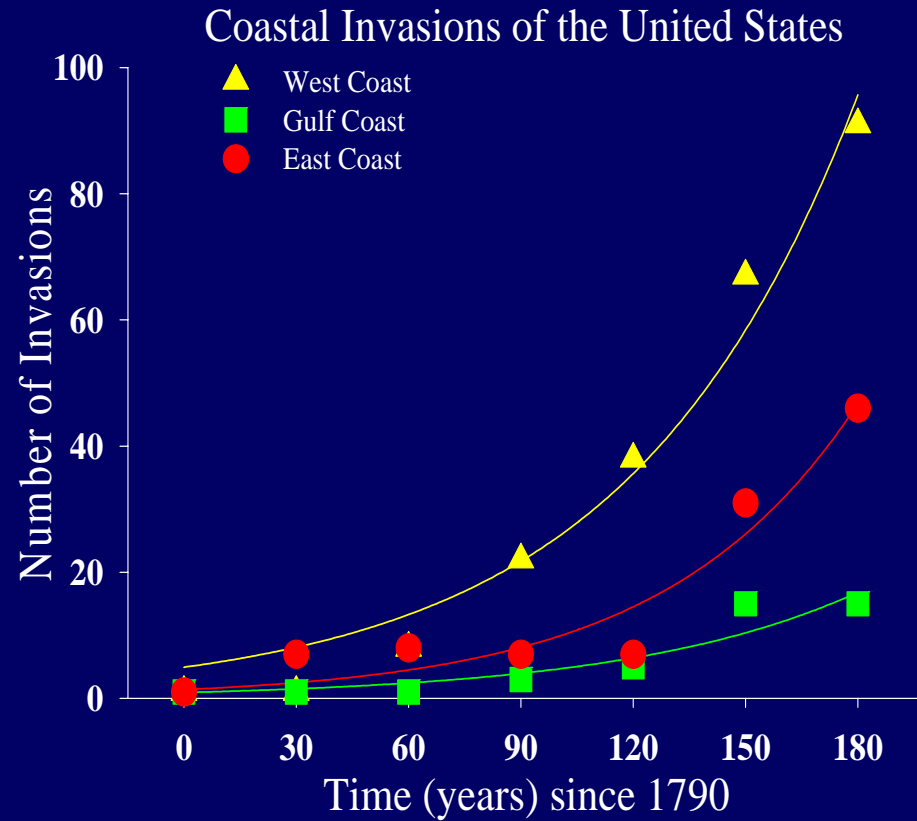
# Non-native Invertebrates & Algae Reported in Coastal Waters of Continental U.S.





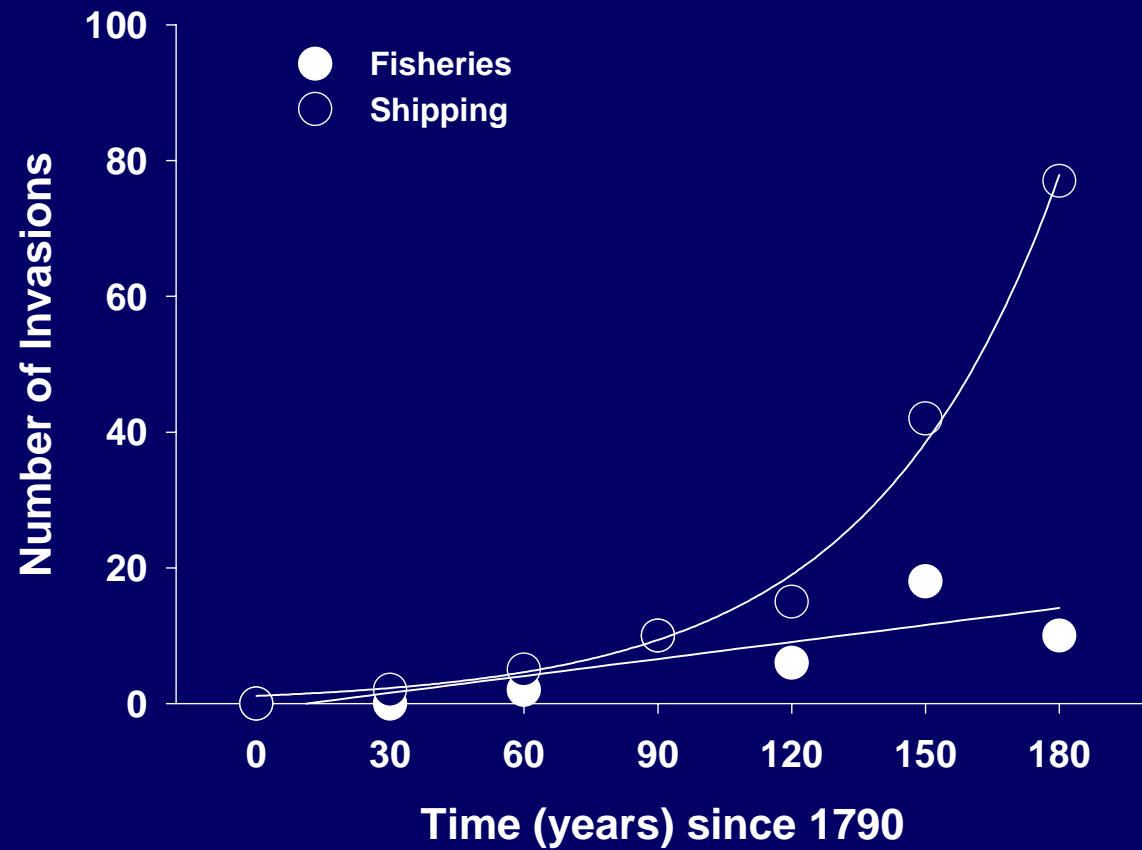
Fofonoff et al. 2003

# Increasing Discovery Rate





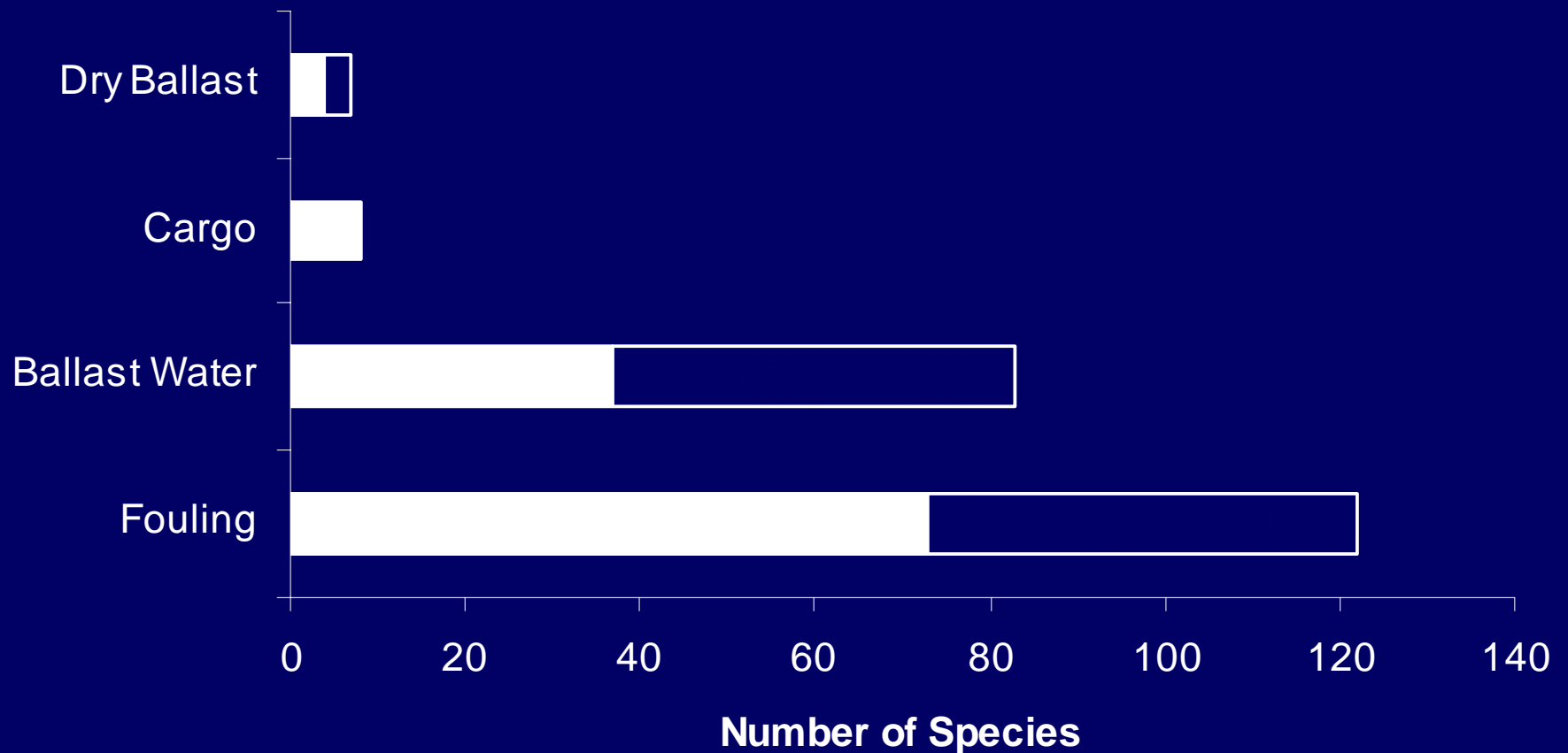
# Discovery Rate of Coastal Invasions by Vector



## Trade by Ships

- Global Scale
- Ships carry >90% world trade
- > 85,000 ships in world fleet
- > 5.4 billion tonnes cargo / year
- Underpins global economic development
- Modern society is shipping dependant
- Continuing to increase

# Vector(s) for coastal species introduced to North America by shipping (n=171)



# Current Magnitude & Behavior of Shipping to U.S. ?

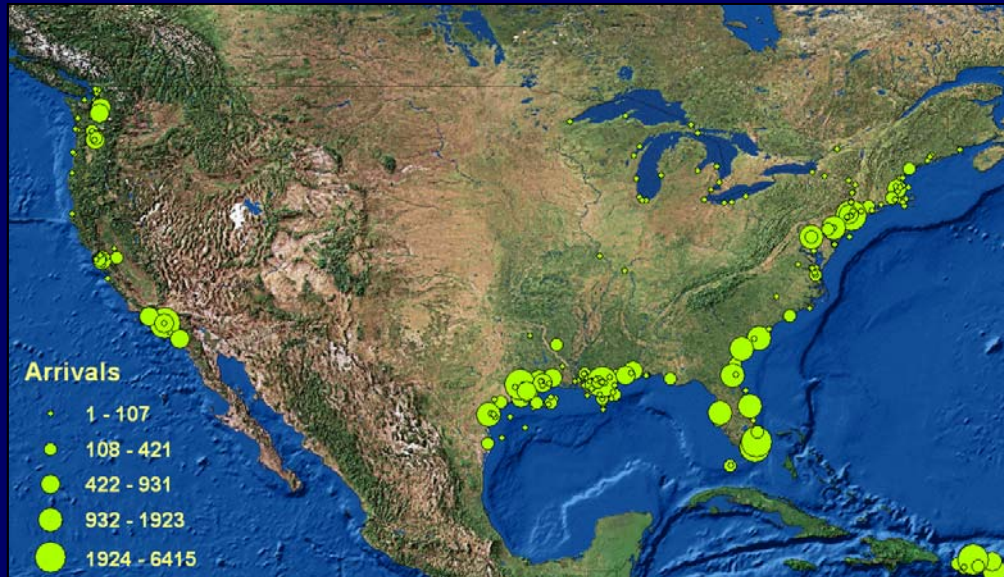


# National Ballast Information Clearinghouse

- Mandated by U.S. Congress via the National Invasive Species Act of 1996 (P.L. 104-332)
- Cooperative effort of USCG and SERC
  - USCG – Regulatory Activities
  - SERC – Collection, analysis, interpretation of data on ballast water delivery and management practices of commercial ships



# Spatial Distribution of Arrivals and BW Discharge Events in the U.S. (2004-2005)



## Reported Arrivals / Year

Foreign: 56,095 (70.8%)

Domestic: 57,081 (60.8%\*)

## Total Reported BW Discharge

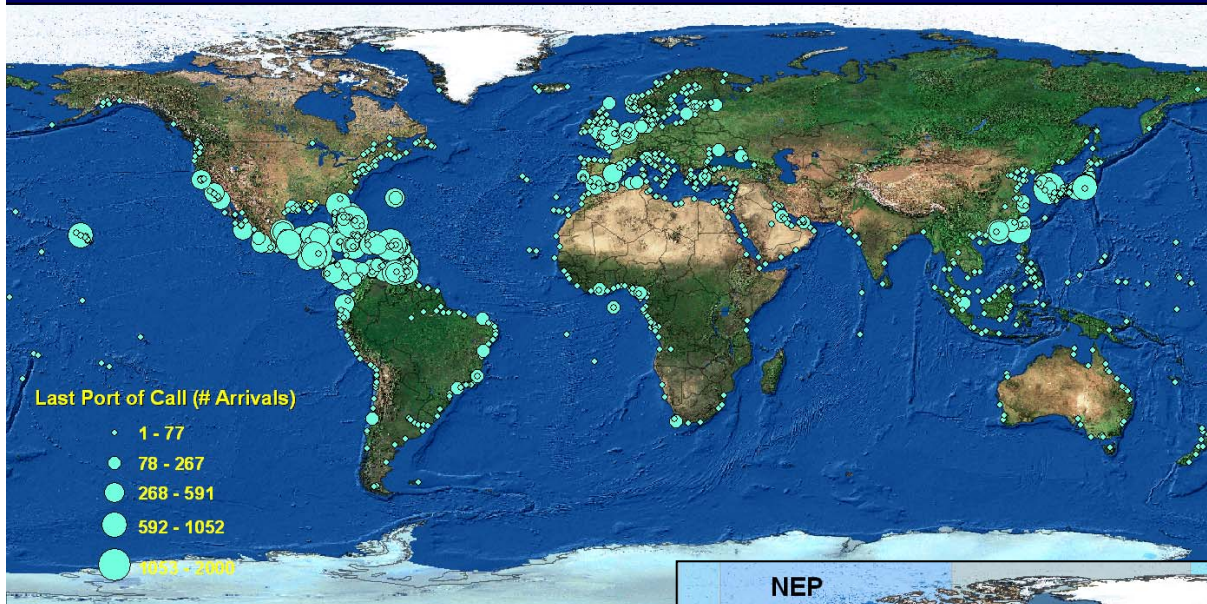
Foreign: 73,720,448 MT

Domestic: 183,802,033 MT



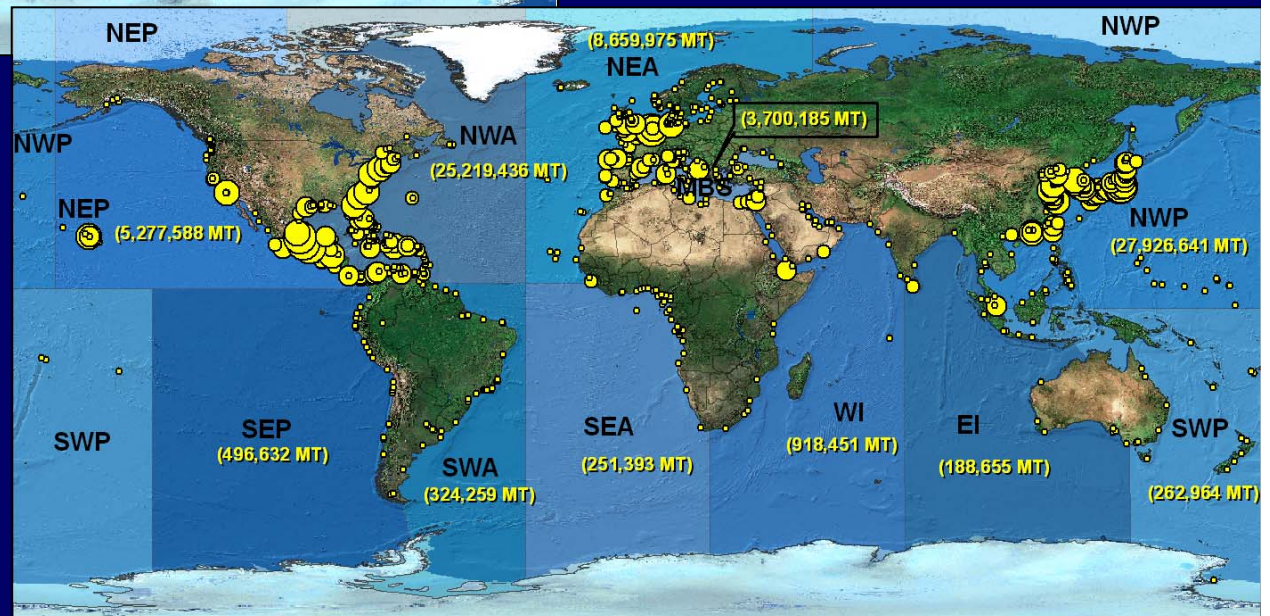


# Last Ports of Call and Ballast Water Source Locations for arrivals to US ports of places (2004-2005)

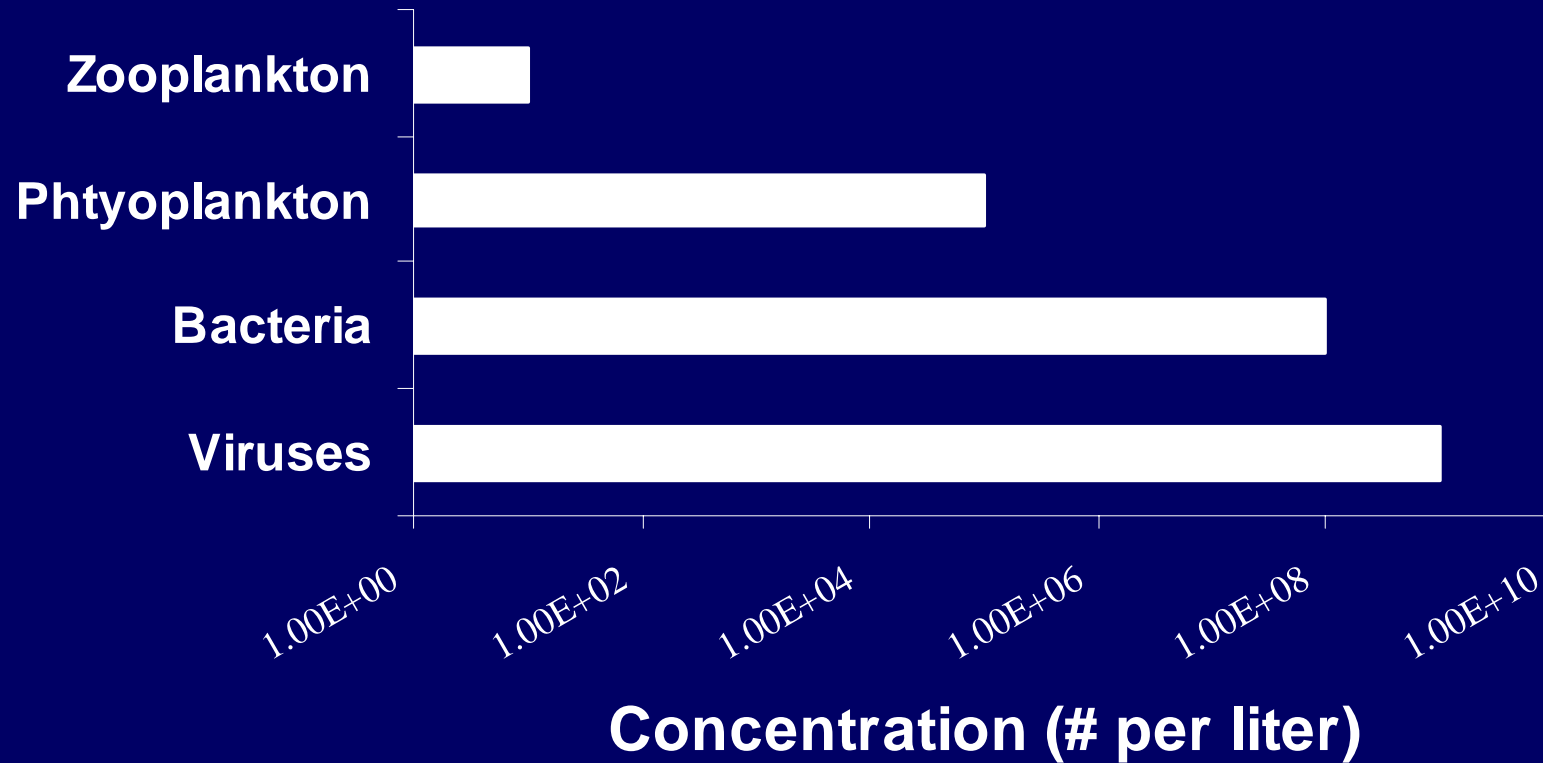


Last Ports of Call

Ballast Water Source Locations



# Average Concentrations of Organisms in Untreated BW

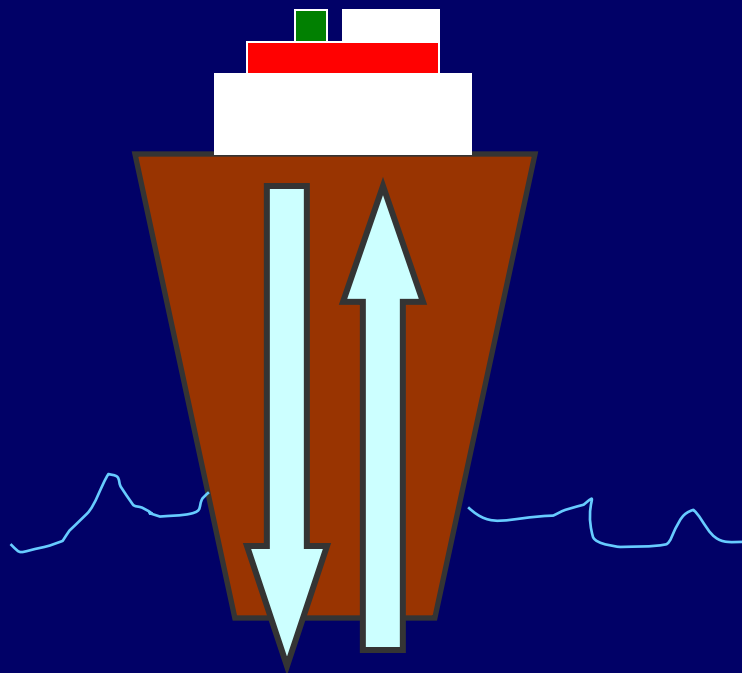




# Mid-ocean Ballast Water Exchange (BWE)

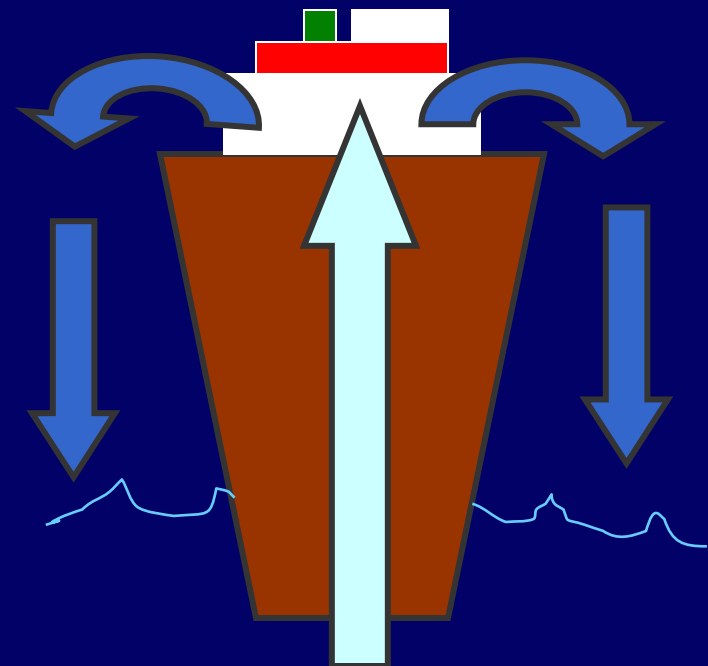
Empty/Refill

100%



Flow-Through

300%



Approach: Vector Management

## Hull Fouling

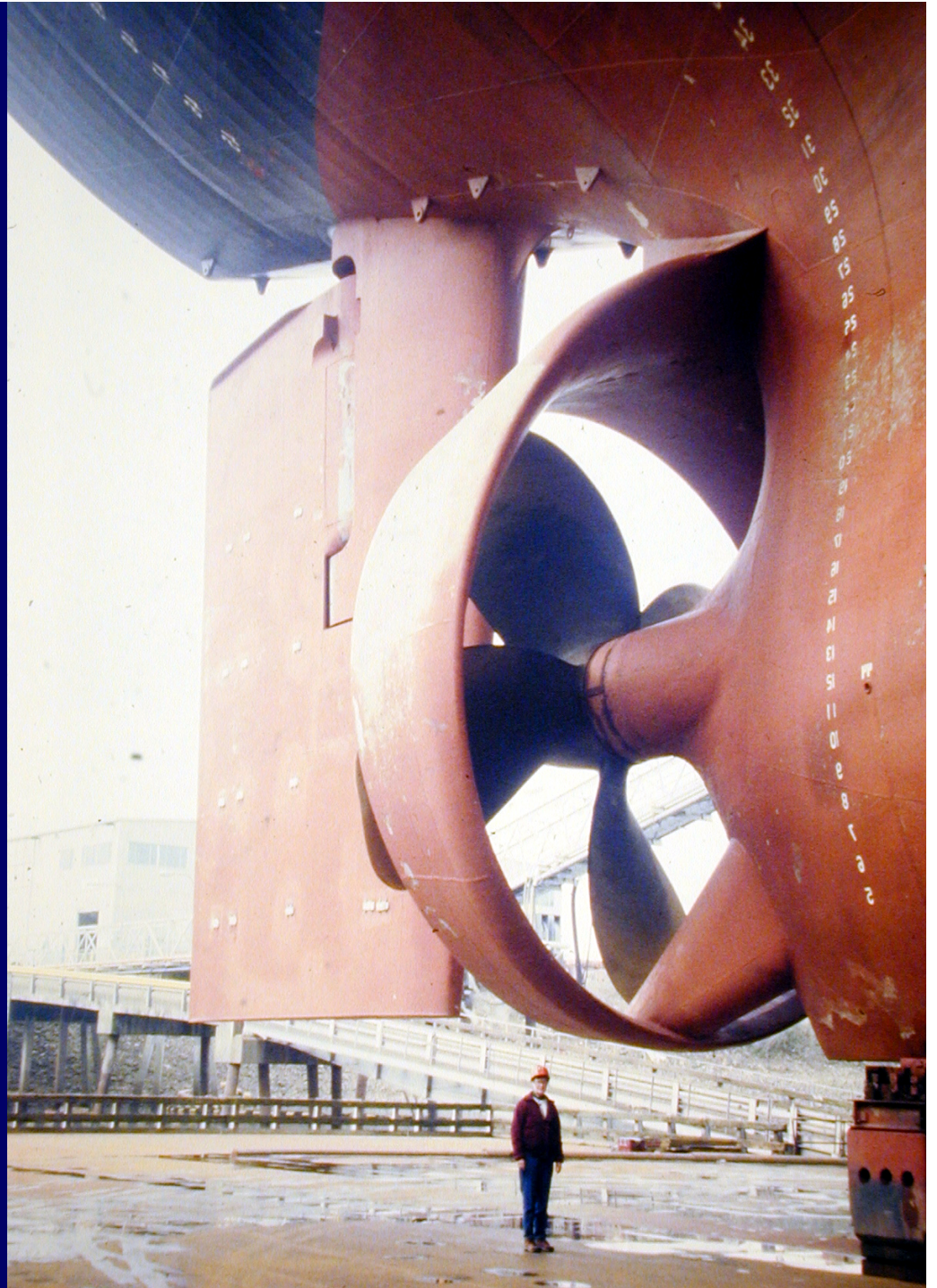
- Important Historically



# Hull Fouling

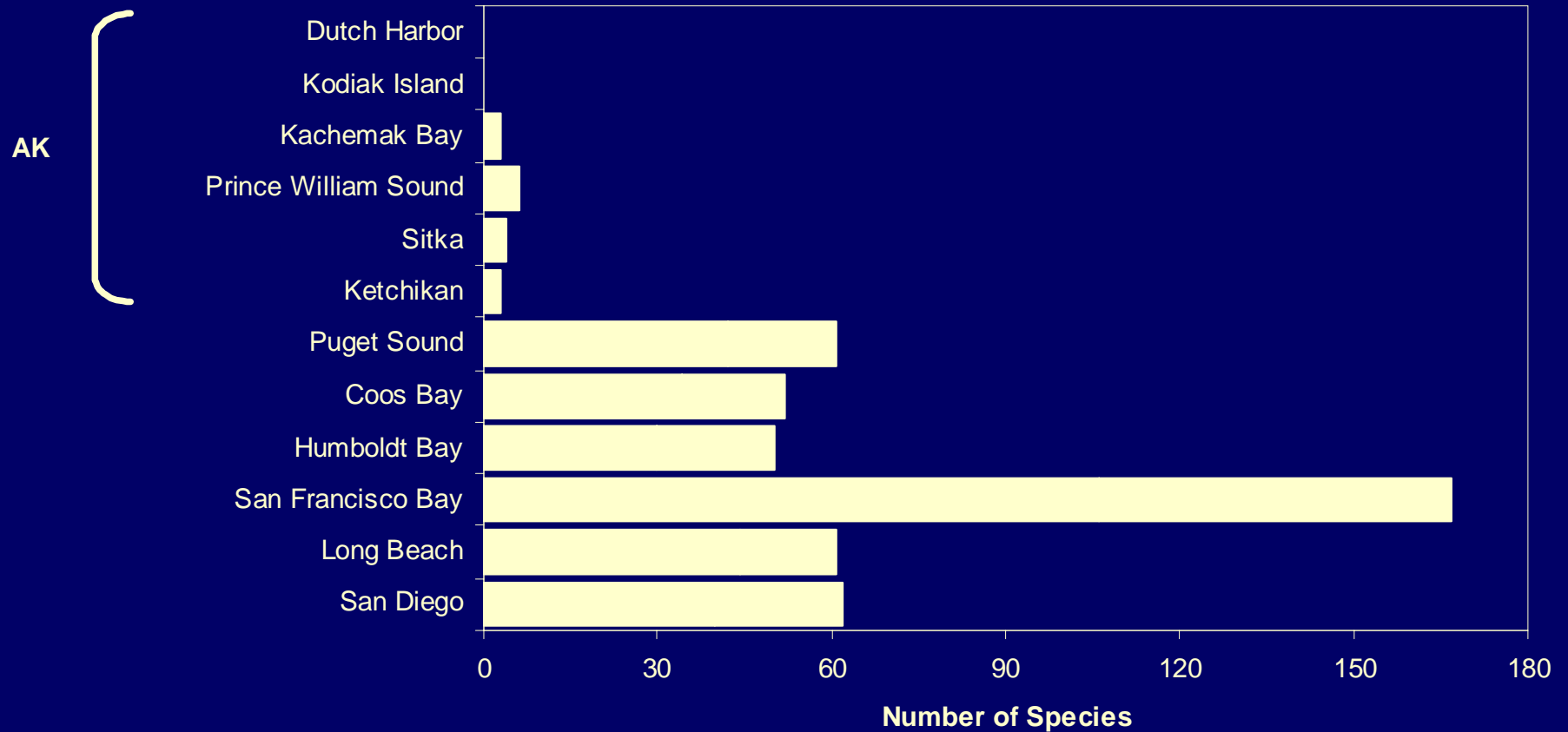
Important Today:

- bigger ships
- travel farther, faster
- WSA = ~335M sq meters/yr from overseas vessels



# Latitudinal Pattern of Invasion

Literature Review of known NIS

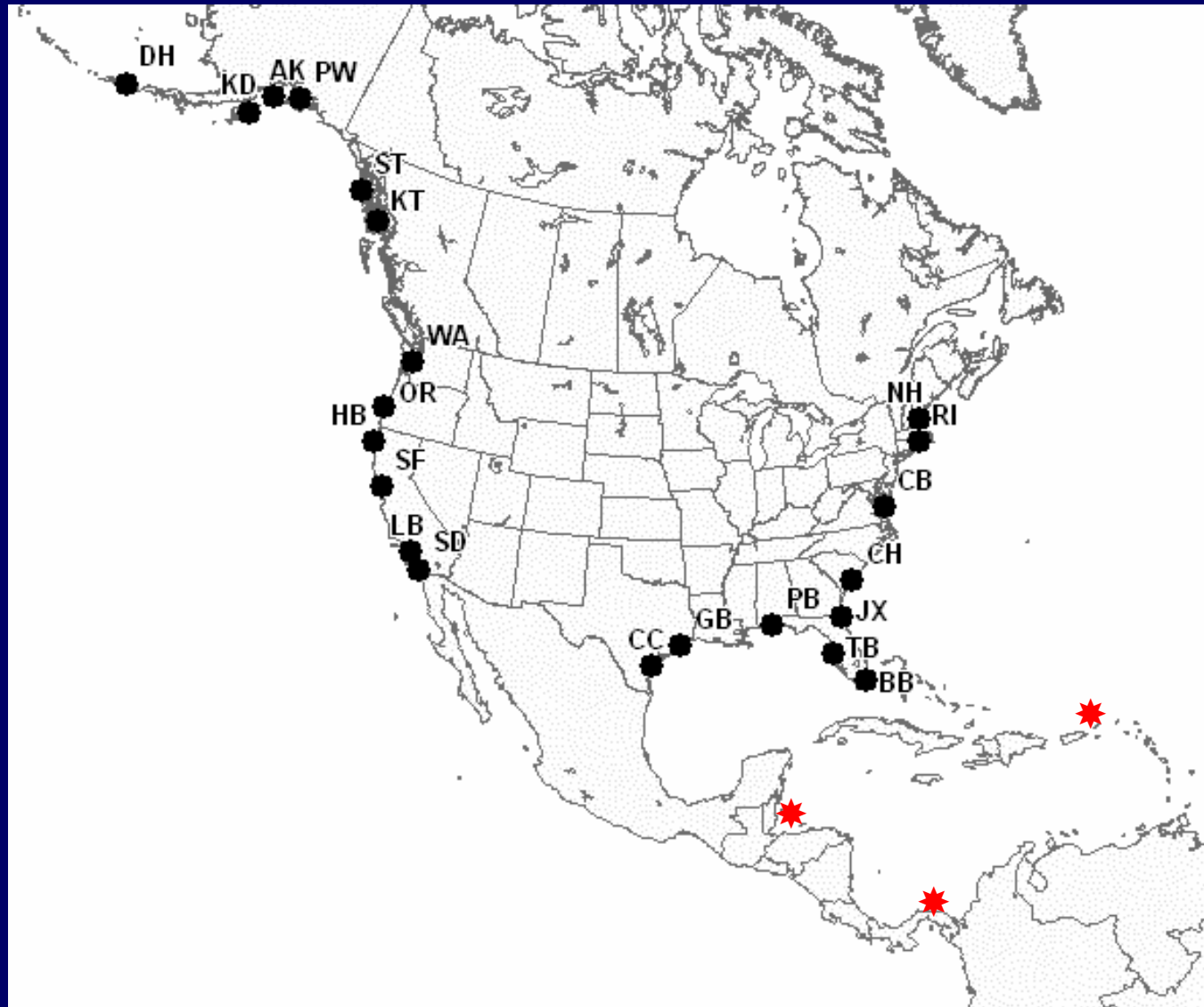




# Explanations (hypotheses)

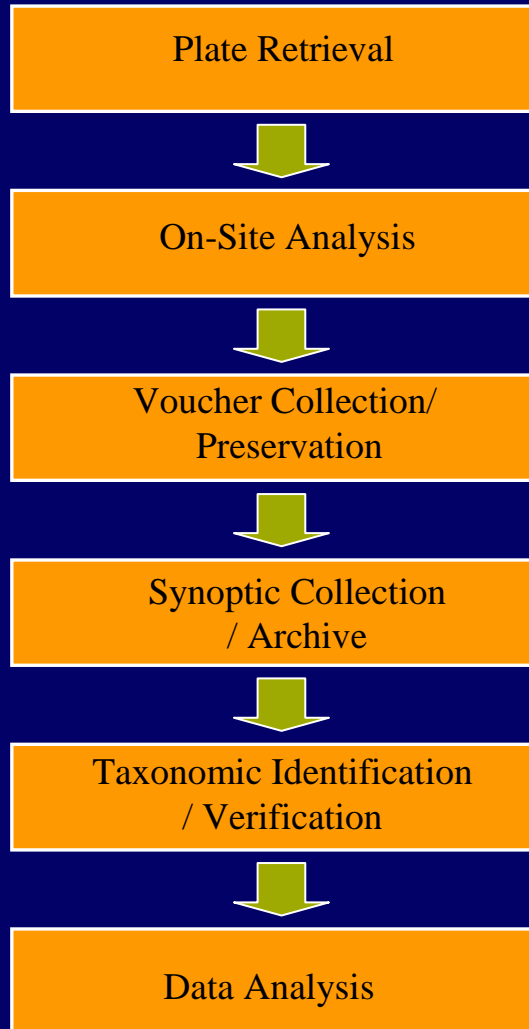
- Biases in Data
- Differences in Susceptibility to Invasions
- Differences in Propagule Supply  
(Propagule Pressure)

# Standardized Surveys: Sessile Invertebrate Community

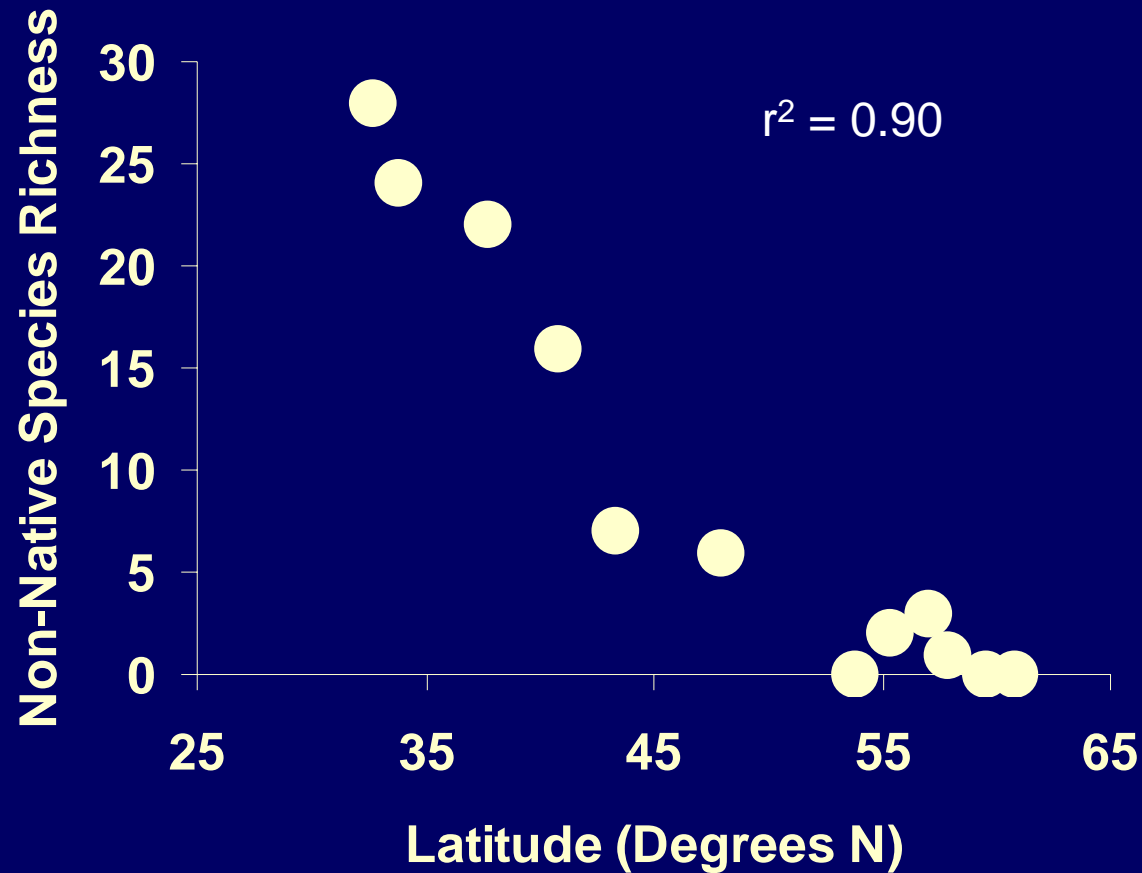


# Standardized Surveys

26 BAYS X 10 BLOCKS X 20 PLATES (n=5,200)



# Latitudinal Pattern of Invasion: Sessile Invertebrates



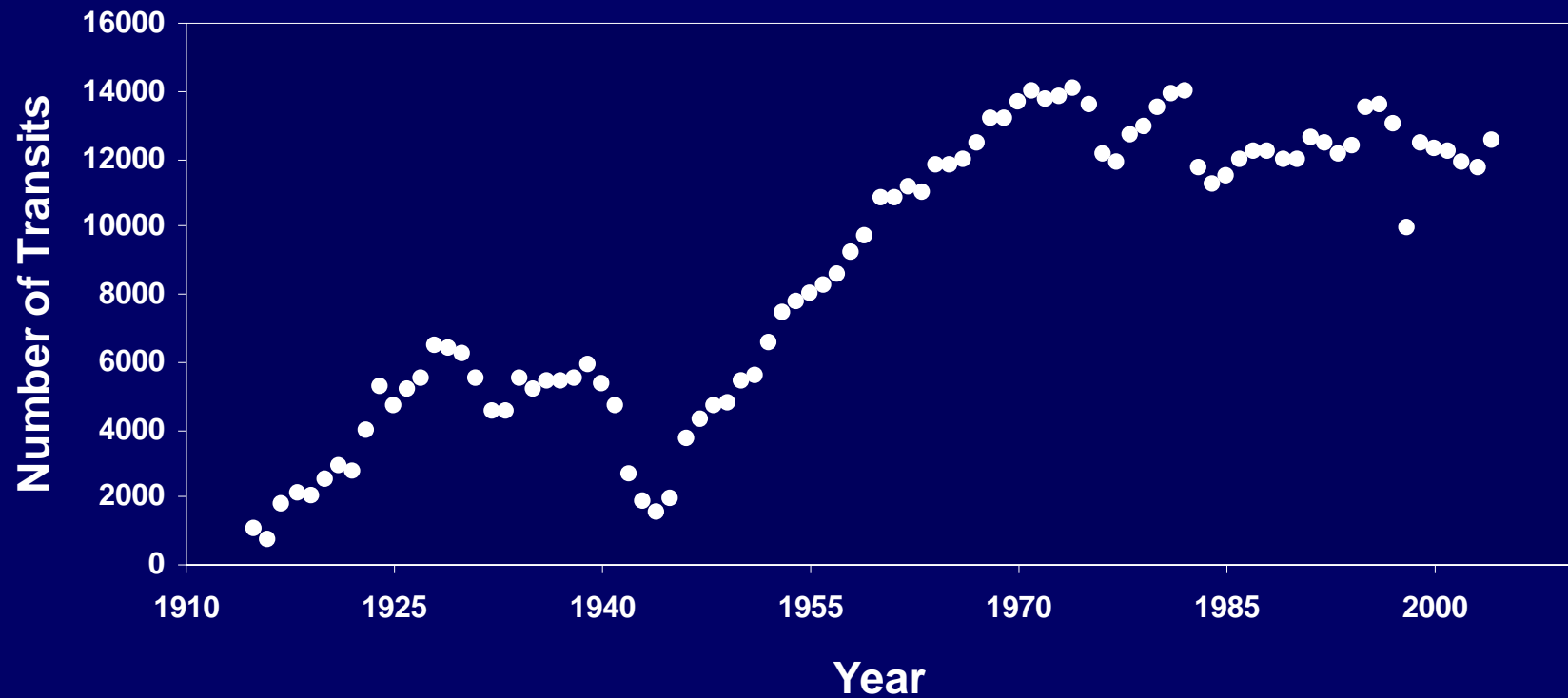
Ruiz et al., unpublished data



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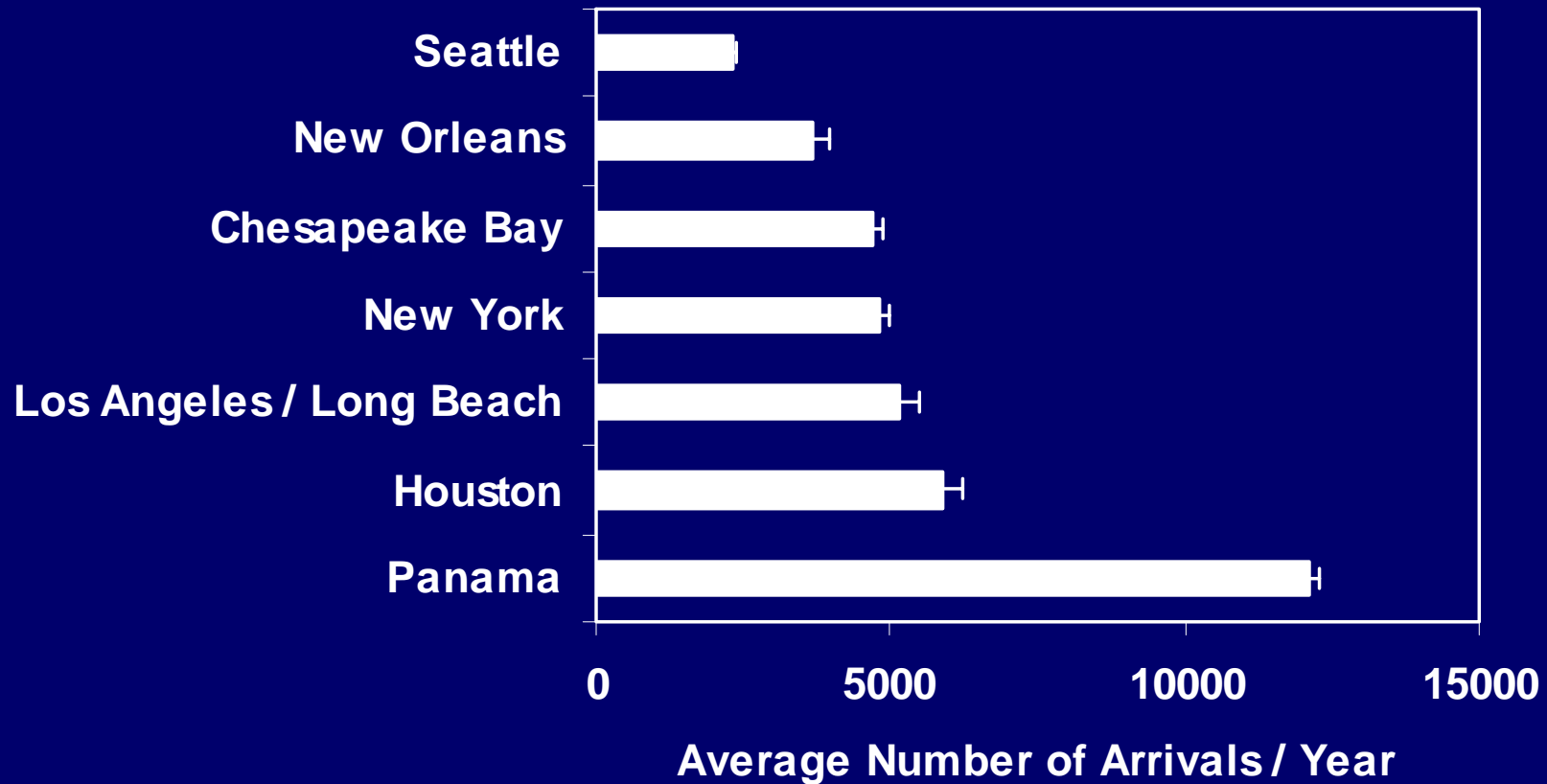
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# Panama Canal Transits (1914-2005)

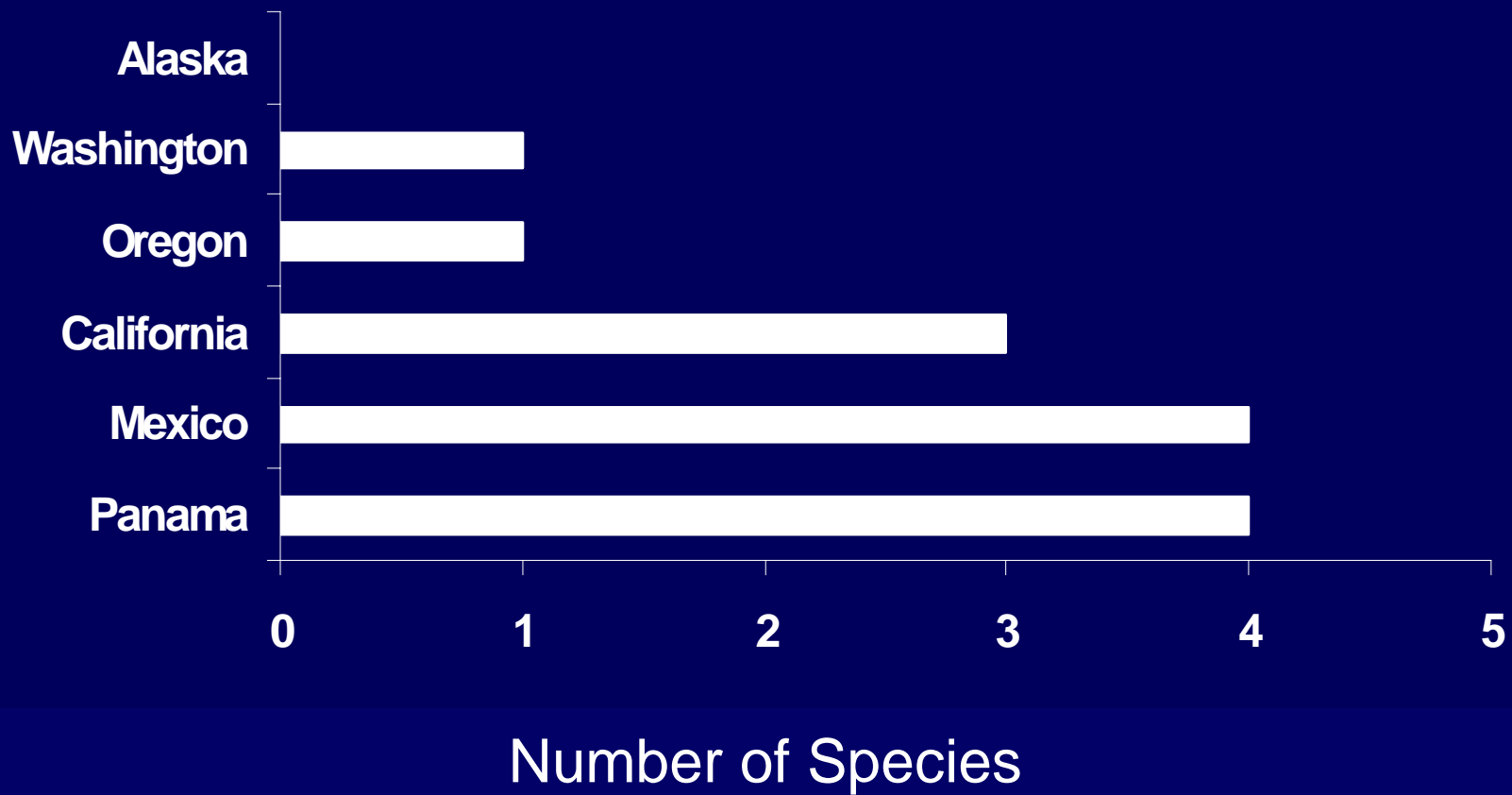


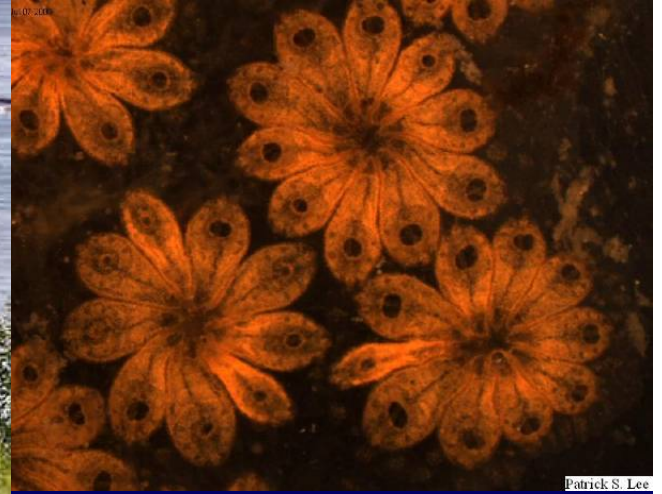
Data from Autoridad del Canal de Panama

# Shipping traffic in Panama vs. major US ports (2000-2004)



# Non-native Barnacle Species by Region (Literature Survey)





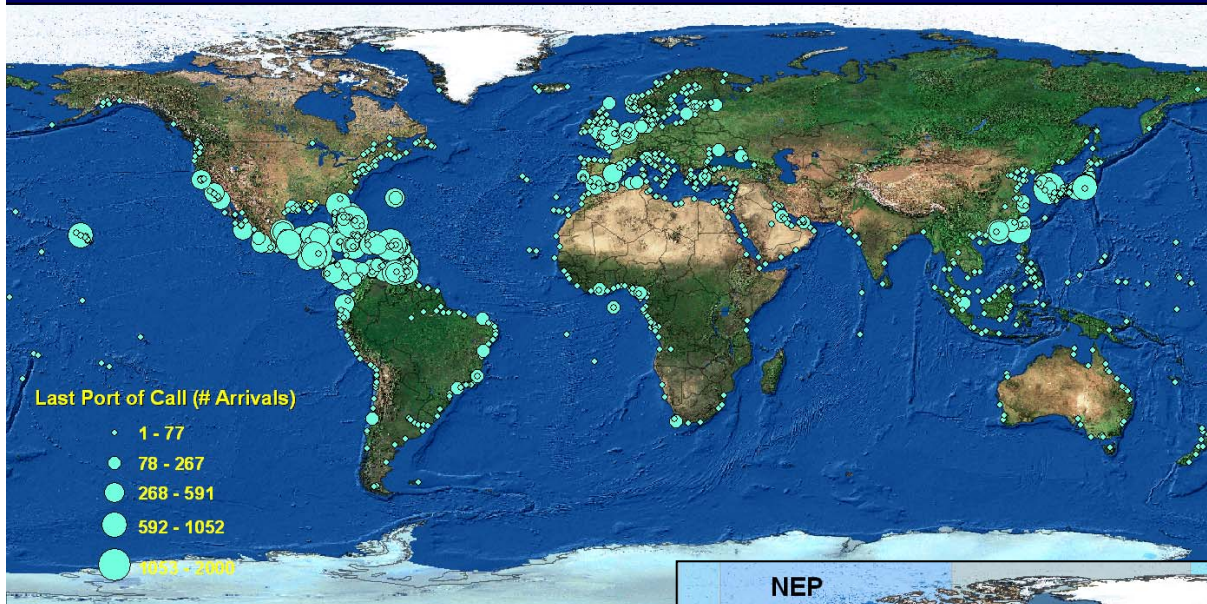
## Funding:

- US Department of Defense
- National Sea Grant Program
- Prince William Sound Regional Citizens' Advisory Council
- Smithsonian Institution
- SENACYT
- US Coast Guard
- US Fish and Wildlife Service



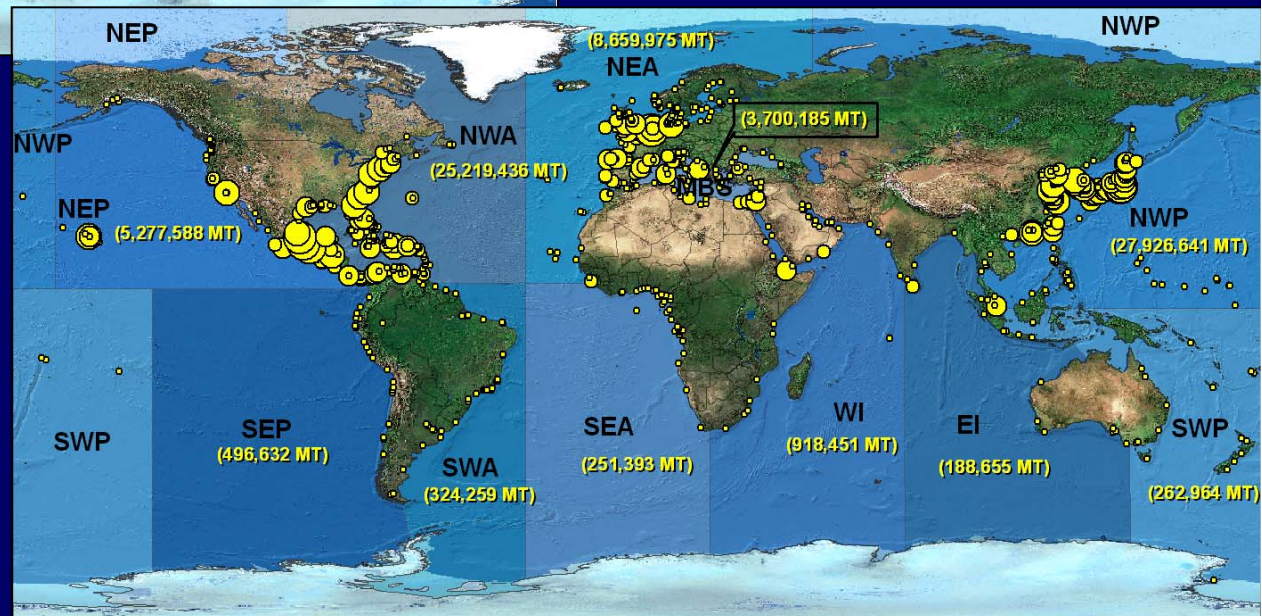


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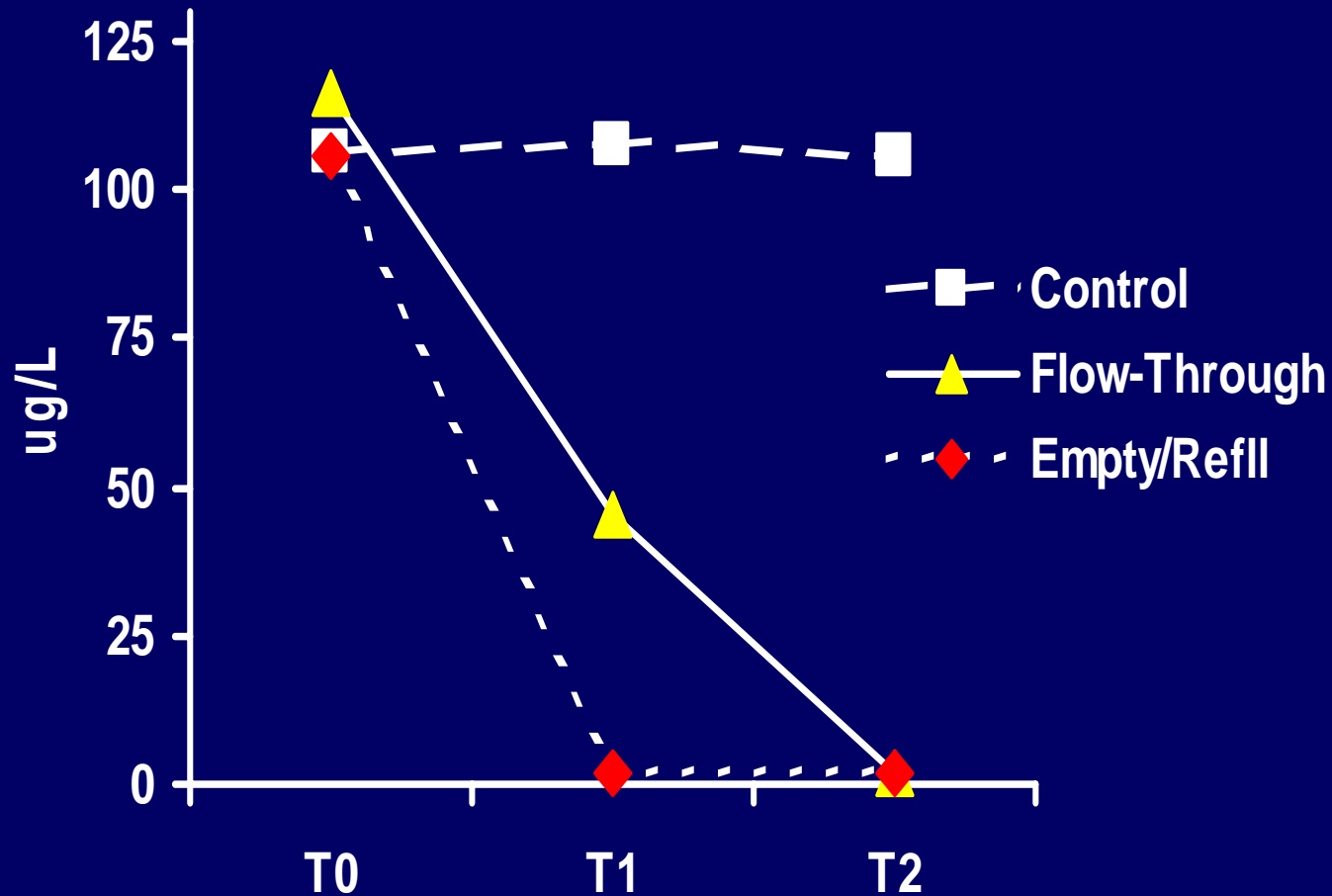


Last Ports of Call

Ballast Water Source Locations



## Efficacy of BWE: Change in Dye Concentration



Summary: BWE causes ~90% reduction in original coastal water & zooplankton concentrations (n>20 shipboard experiments)