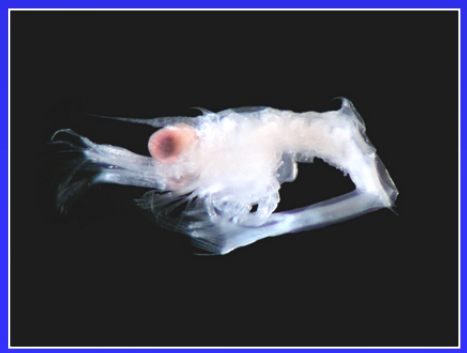
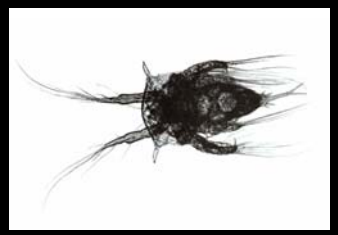
Measuring Residual Risk in Ballast Water after Mid-ocean Exchange using Zooplankton Indicators

Jeffery Cordell, Russell Herwig,
Nissa Ferm
School of Aquatic and Fishery Sciences
University of Washington

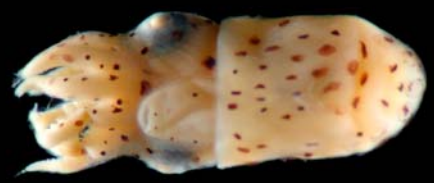


Meroplankton

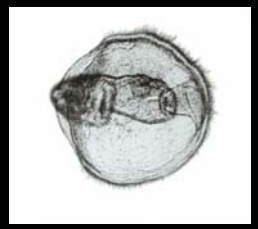
Barnacles



Octopus



Bivalves



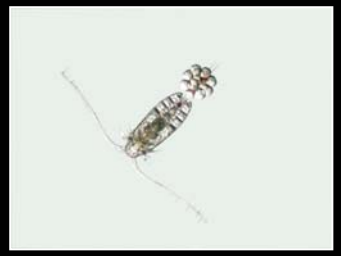
Only larvae live in the water column.

Decapods (crabs, shrimps)

Polychaetes

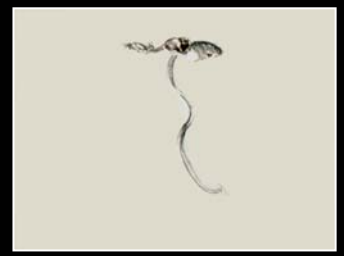
Holoplankton

Complete life history takes place in the water column.

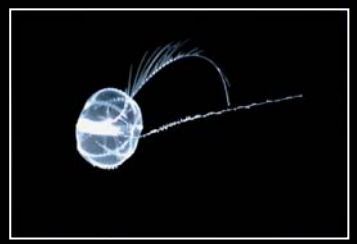




Copepods

Larvaceans



Jelly Plankton

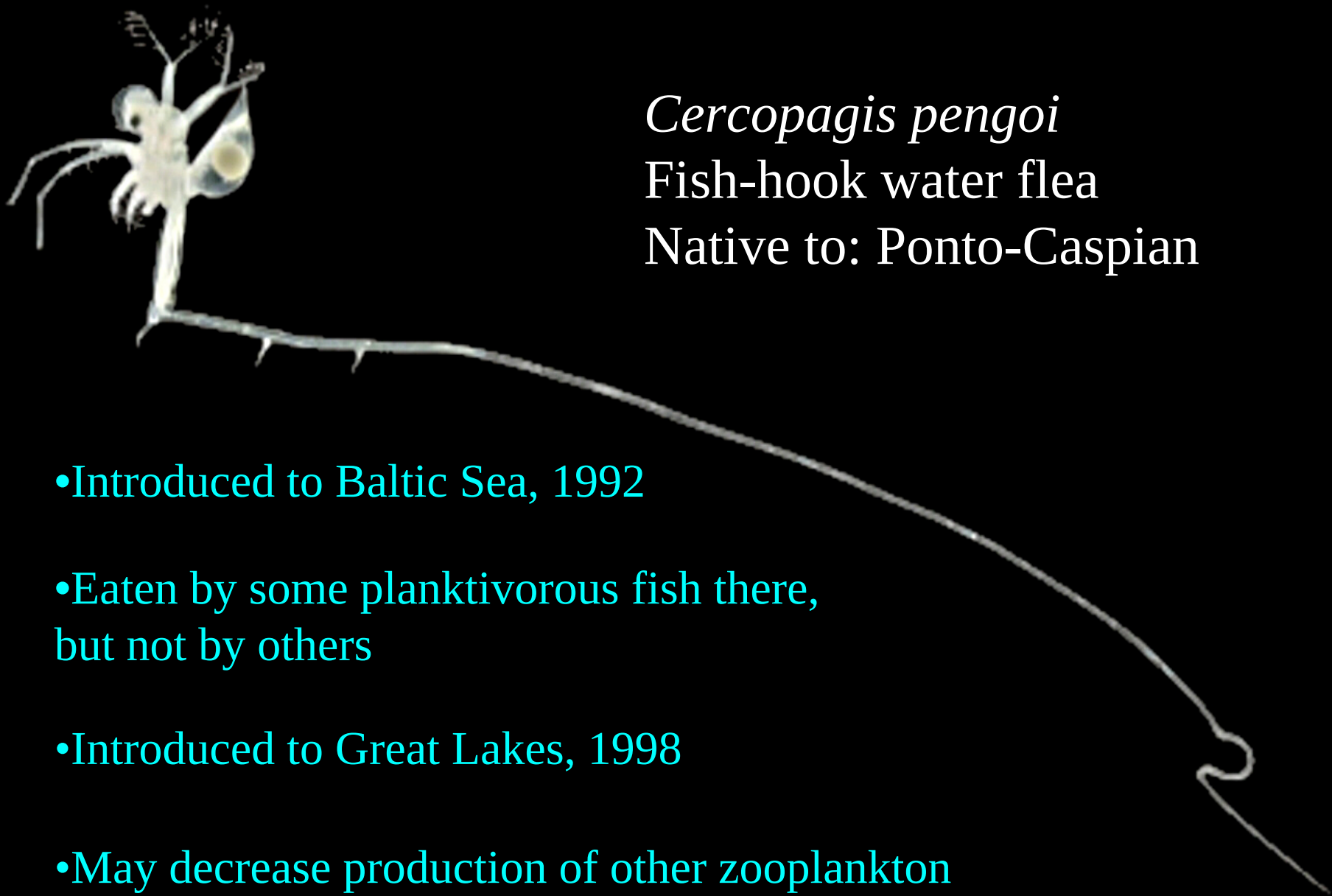

Cladoceran

Other Crustaceans

Mysid Shrimp

Bythotrephes longimanus
Spiny water flea
Native to: Northern Europe

- Appeared in Great Lakes, early 1980s
- Rapid and long-lasting reduction in the average species richness of other zooplankton
- Eaten by a variety of fish



Cercopagis pengoi
Fish-hook water flea
Native to: Ponto-Caspian

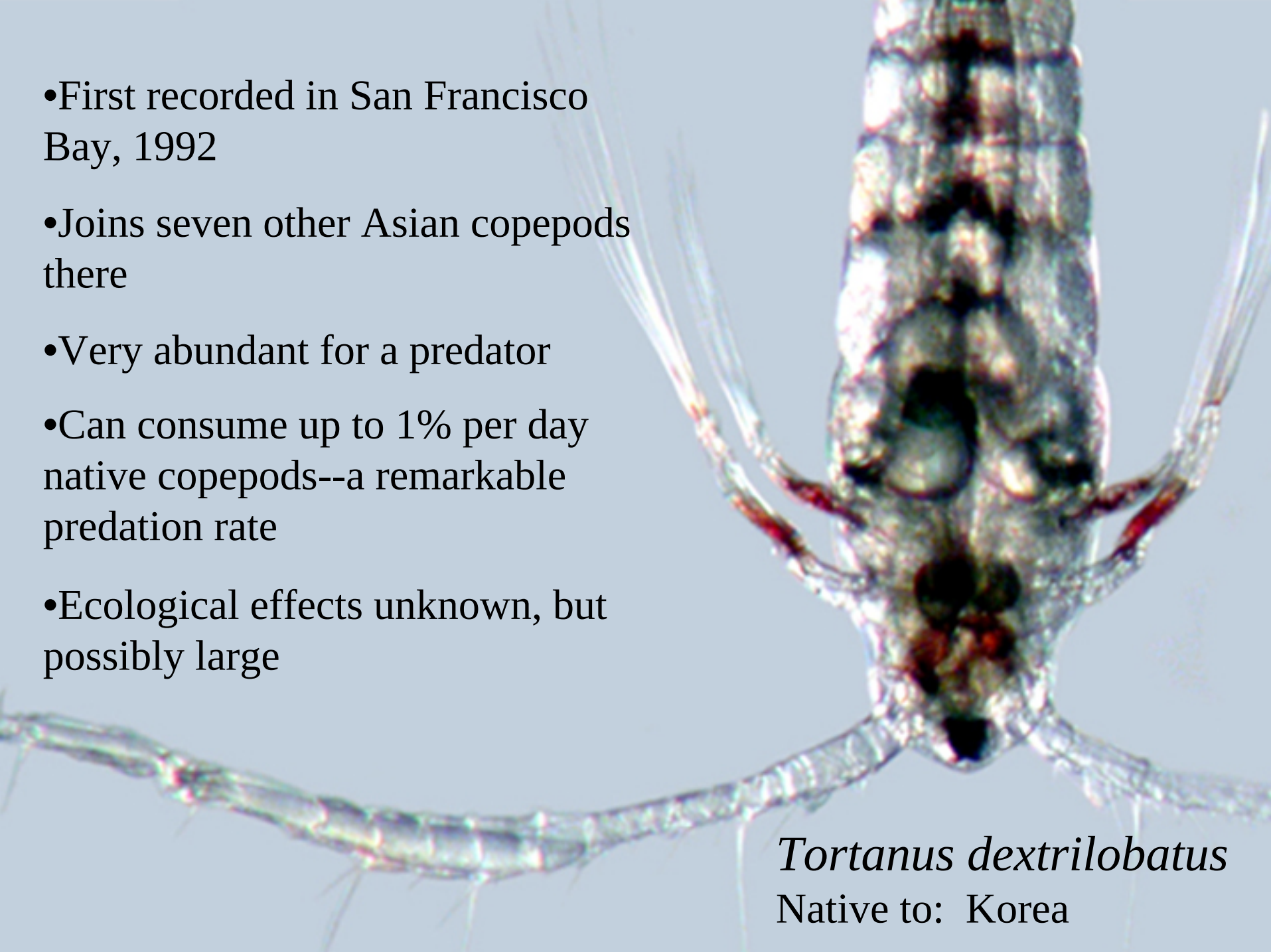
- Introduced to Baltic Sea, 1992
- Eaten by some planktivorous fish there, but not by others
- Introduced to Great Lakes, 1998
- May decrease production of other zooplankton

Photo: http://venus.uwindsor.ca/courses/biology/macisaac/pages/exotic_images.htm

Photo: Brian Low, from MBL website

Mnemiopsis leidyi
Ctenophore
Native to: Atlantic N. America

- Introduced to Black Sea, early 1980s
- Reached enormous biomass, summer 1989
- Sharp declines in other types of plankton
- Large economic losses due to decrease in fisheries
- Another ctenophore, *Beroe*, introduced in 1997
- *Beroe* preys on *Mnemiopsis*, and largely eliminated it
- *Mnemiopsis* introduced to Caspian Sea, mid 1990s



- First recorded in San Francisco Bay, 1992
- Joins seven other Asian copepods there
- Very abundant for a predator
- Can consume up to 1% per day native copepods--a remarkable predation rate
- Ecological effects unknown, but possibly large

Tortanus dextrilobatus
Native to: Korea

Pseudodiaptomus inopinus

Native to: Japan, China, Korea

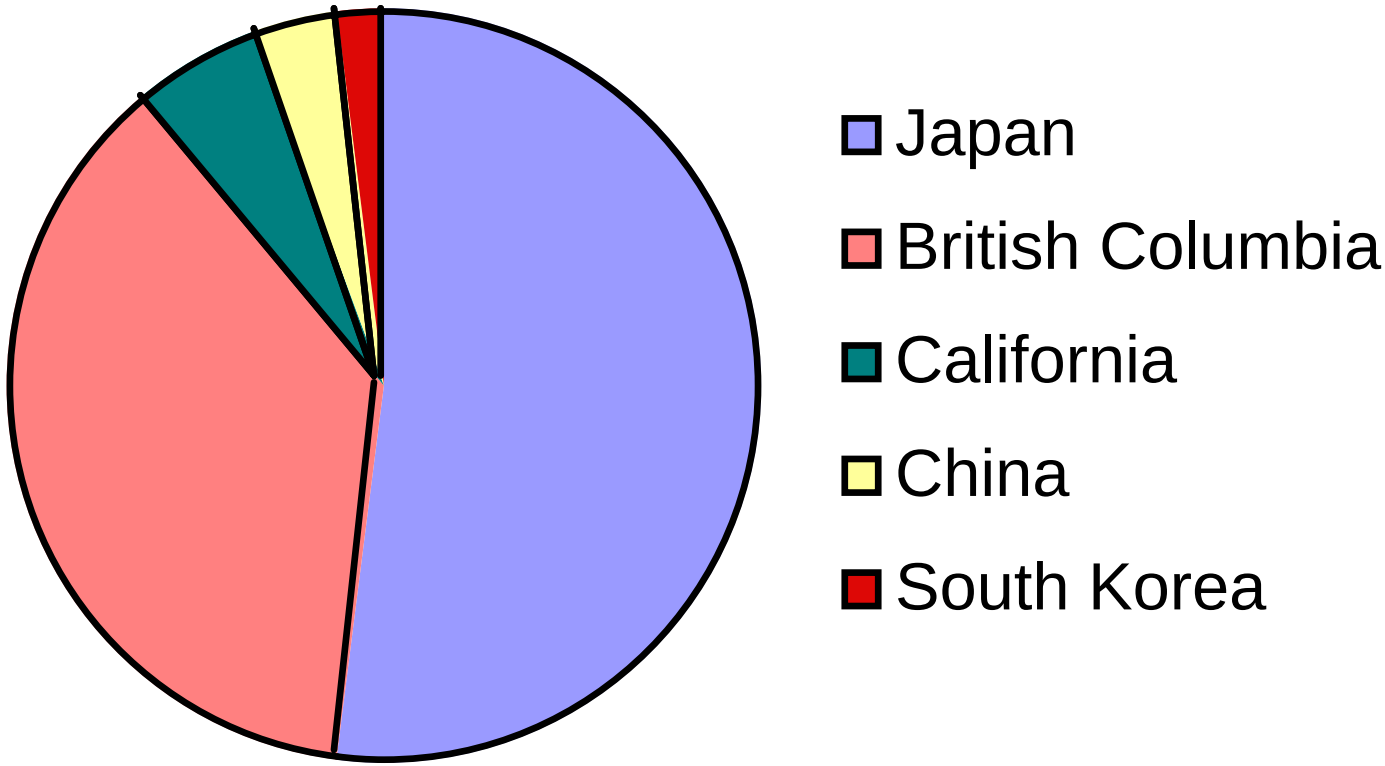
- First appeared in Columbia River, 1990
- Occurs as a “monoculture” in many other west coast rivers
- Appears to displace native copepods in time and space
- Does not co-occur with plankton-eating juvenile salmon
- Important in diet of decapod and mysid shrimp
- Appears to have been replaced in the Columbia River by two new invasives

Sampling Ship's Ballast in Puget Sound

Seattle Ship Sampling

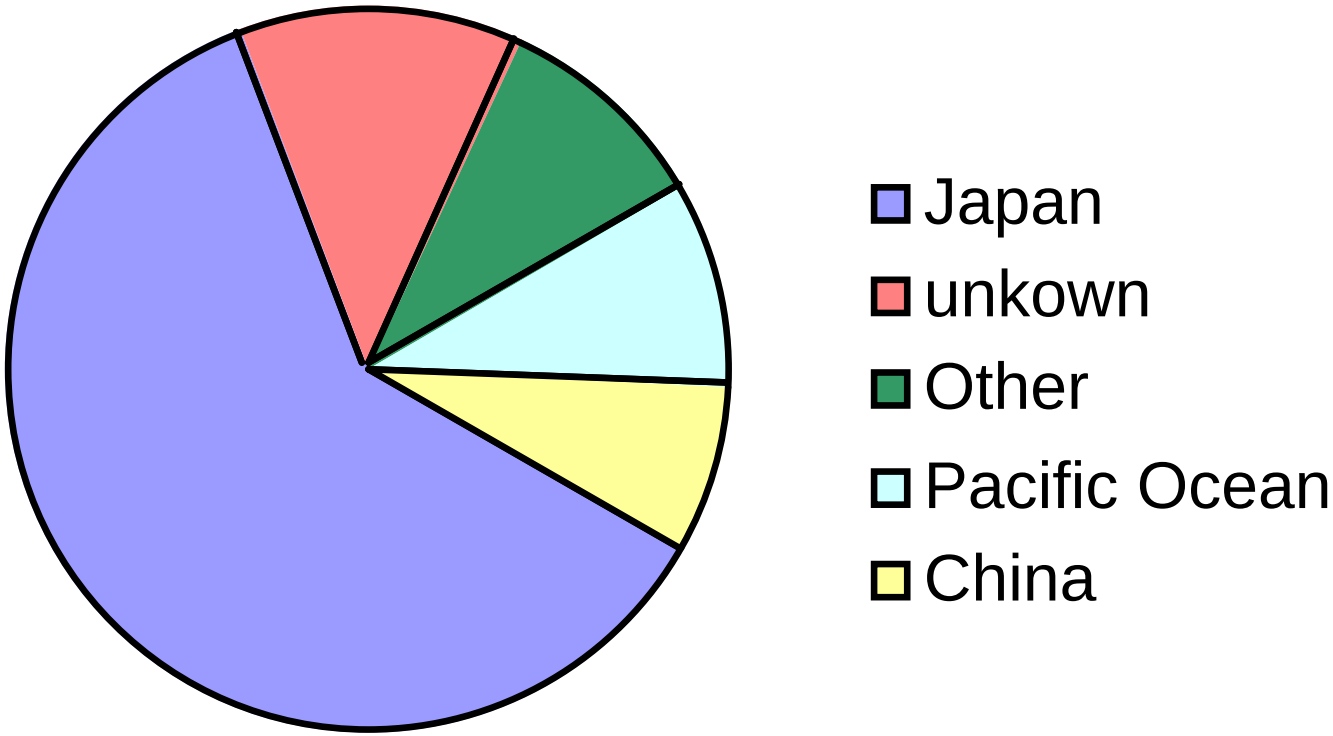
- Ship sampling at Port of Seattle started February 2002, and is continuing
- Replicated plankton sampling of 53 ships has been conducted—32 bulk carriers, 21 container ships
- Three vertical plankton hauls with 73 micrometer mesh net taken on each ship
- Most holoplankton (copepods) identified to species, all taxa assigned as nonindigenous, coastal, oceanic, or unidentified affinity
- Washington Department of Fish and Wildlife is beginning a sampling program that will complement and expand on this work

Last Port of Call For All Ships



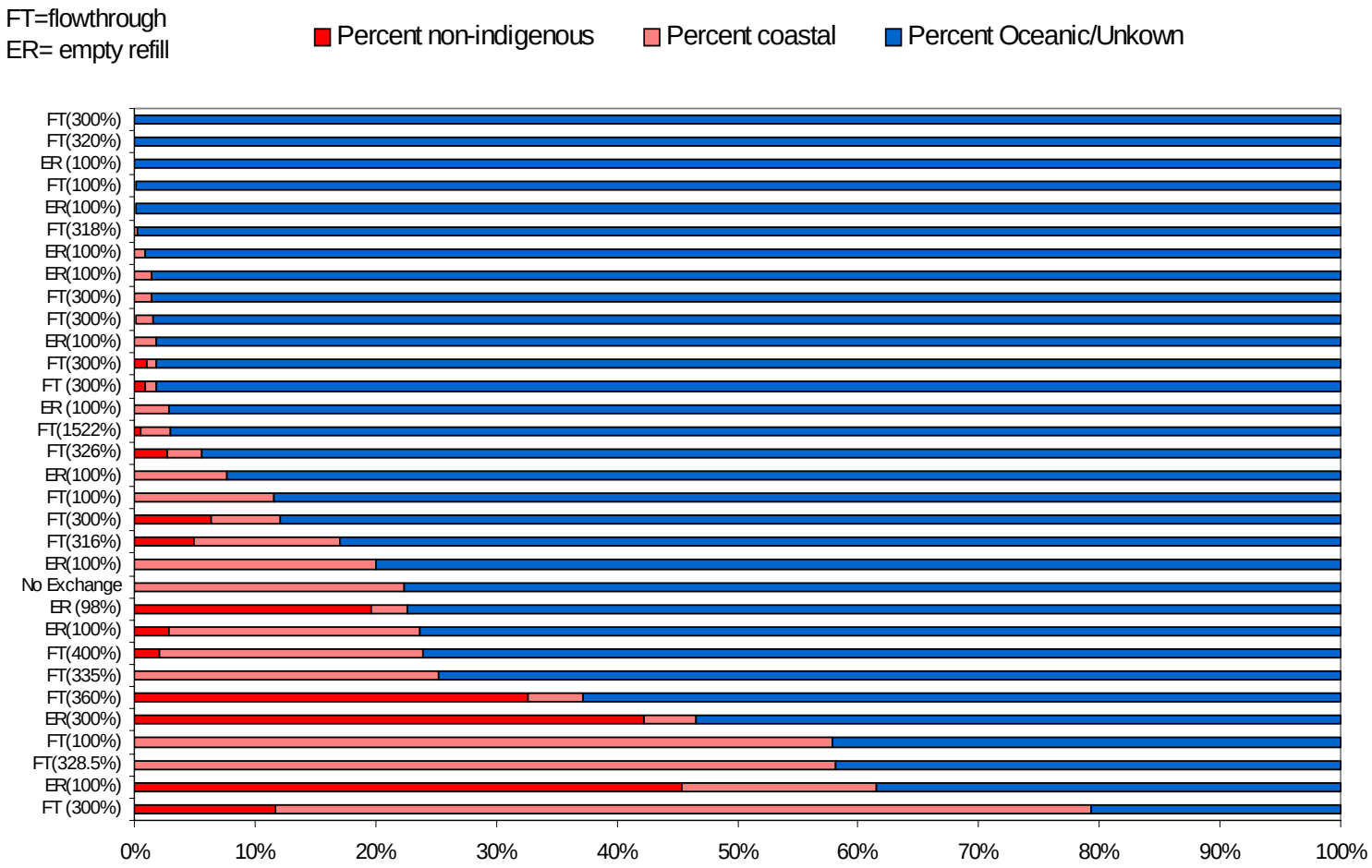
n=53

Source of Ballast Water Before Exchange

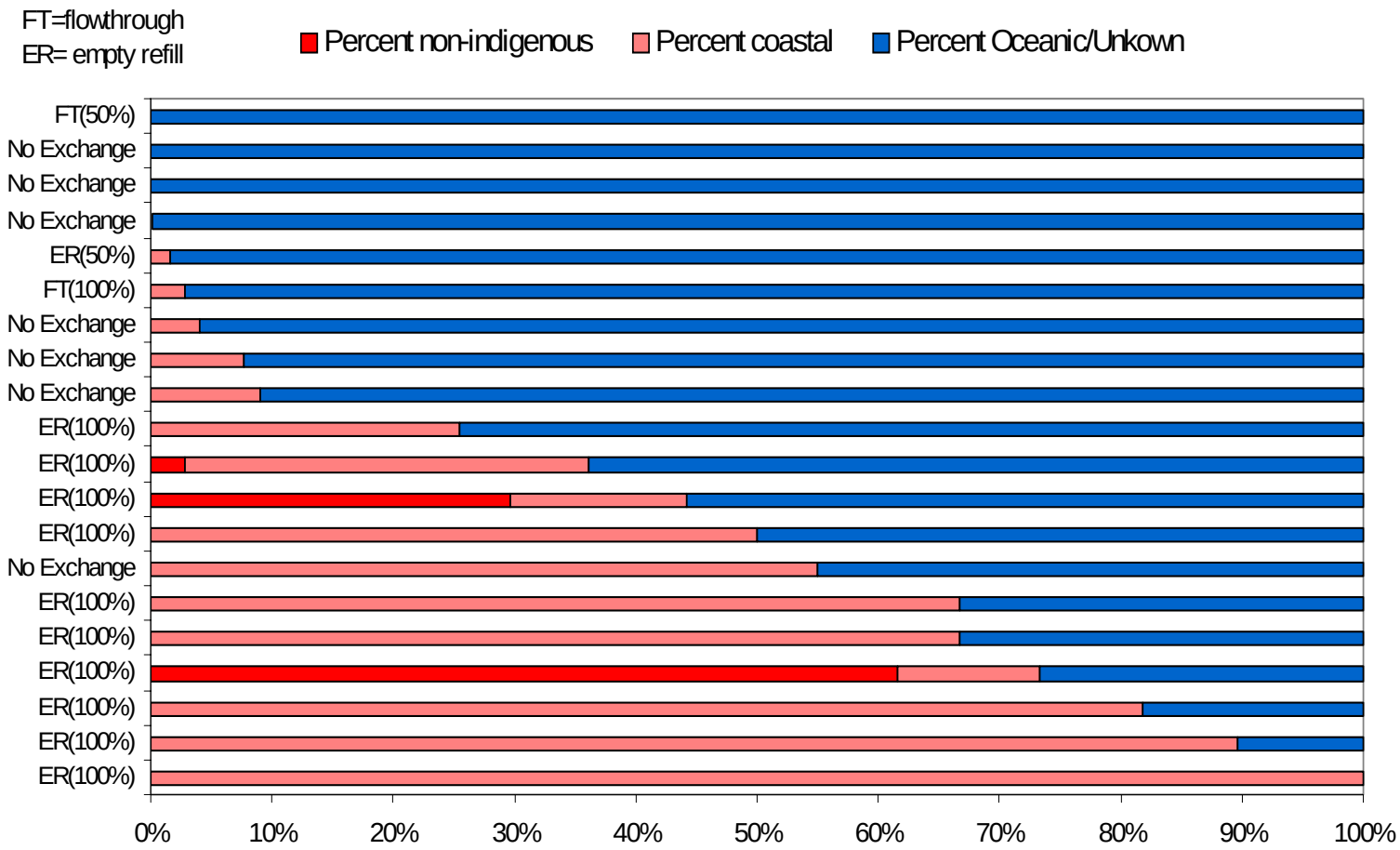


n=53

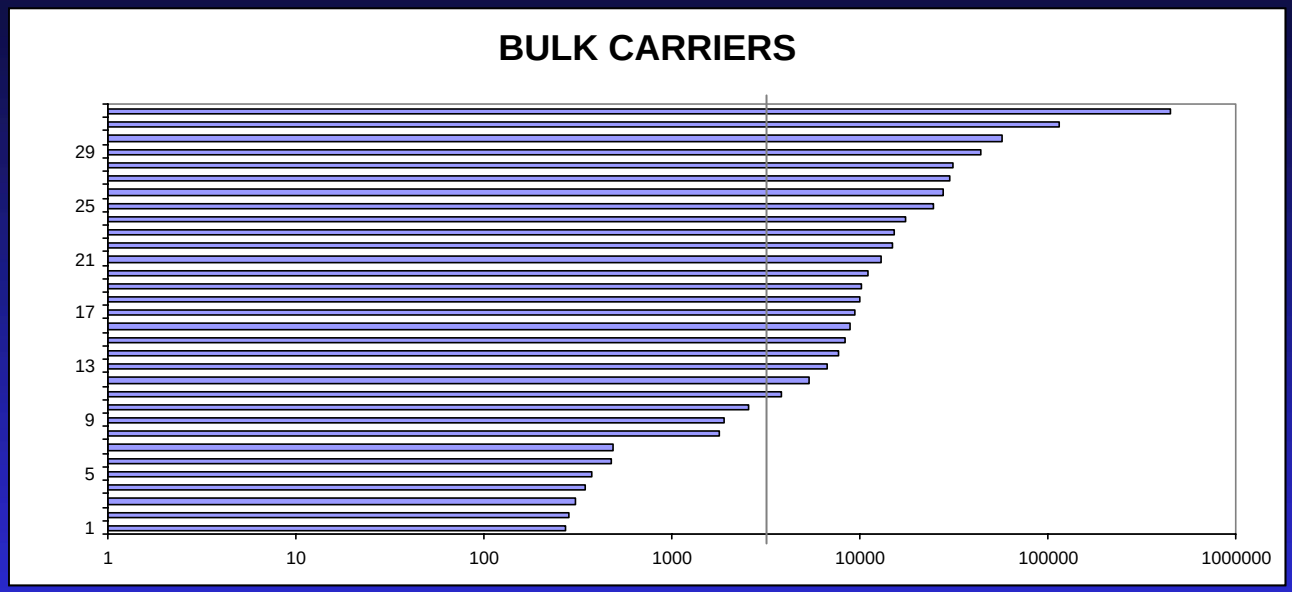
Plankton Composition in Bulk Carriers Entering Puget Sound

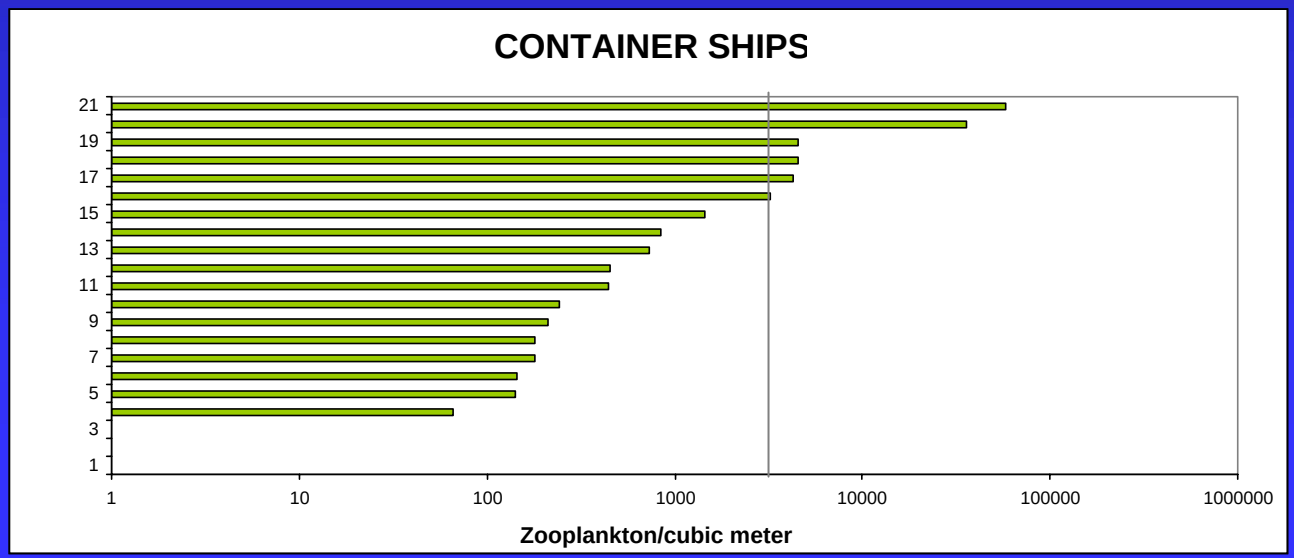


Plankton Composition in Container Vessels Entering Puget Sound

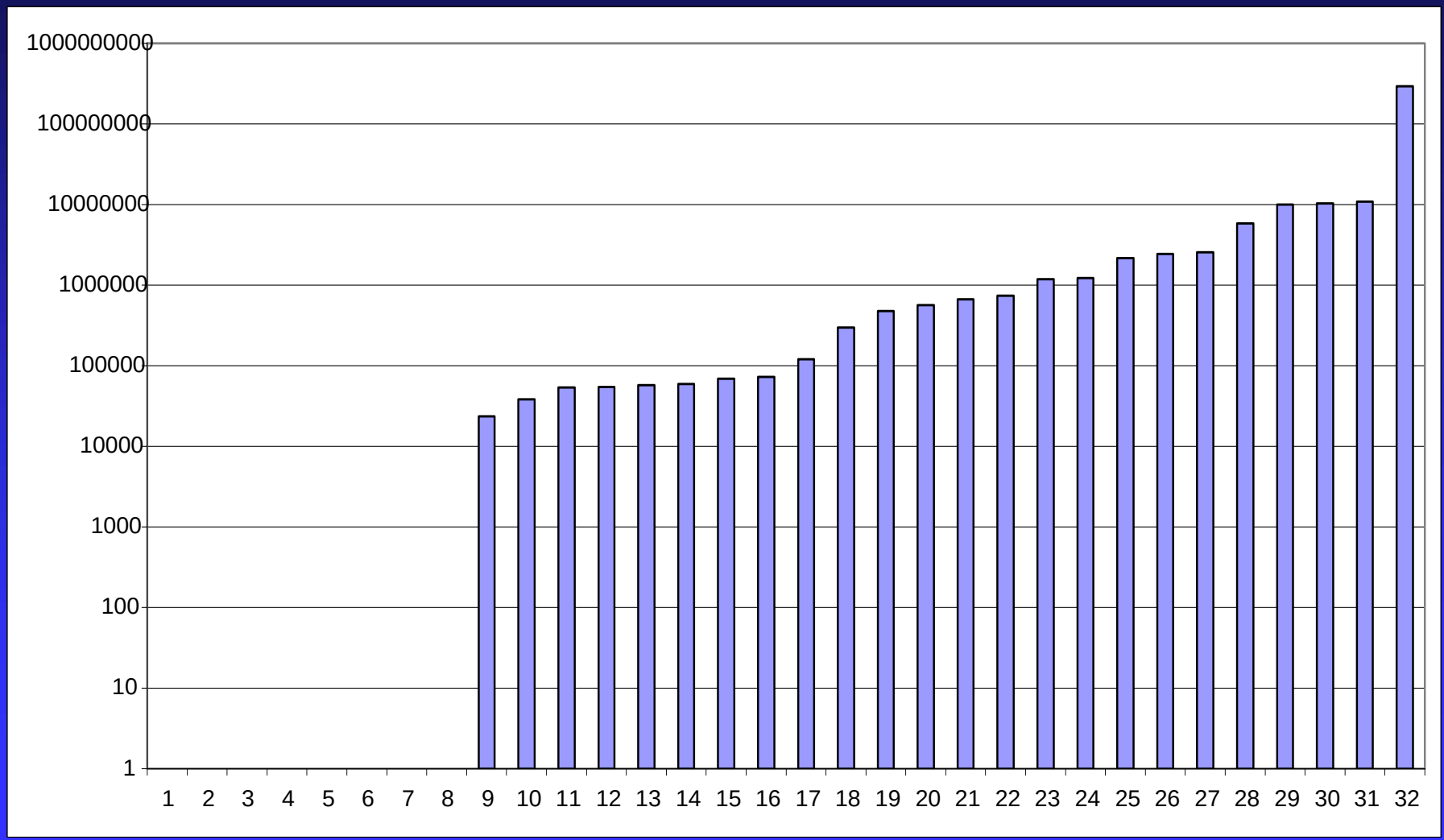


Mean Plankton Densities in Vessels Discharging into Puget Sound





Total number of Nonindigenous/coastal Organisms Introduced to Puget Sound From Sampled Tanks



Rationale for Using Plankton to Measure Ballast Water Exchange or Treatment

- Ballast exchange or treatment will require verification in Washington State, and eventually nationally and internationally
- Certain planktonic invertebrates that only occur near shore may be useful as indicators of risk and/or exchange/treatment effectiveness
- Gives information about risk of water from different sources (e.g., San Francisco Bay vs coastal Asia, high salinity vs low salinity)
- Learning to identify taxa that are indicators of coastal water is relatively easy
- Plankton is easy to sample, and can be preserved and stored for long periods

Proposed Methods

- Sample up to 15 ships/month; selection can be random or based on criteria such as port of origin, ballast volume, etc.
- Take three vertical plankton net tows from bottom to top of tank; fix the samples and return to laboratory
- Conduct microscope examination of zooplankton, count, and categorize as: known native species, known non-indigenous species, oceanic taxa, and coastal taxa
- Take digital photos of each nonindigenous species found, and also of representative oceanic and coastal taxa
- Calculate percentages and densities of species and categories of interest; evaluate results

Expected Results

- A standard protocol for sampling and analyzing zooplankton in ballast for use as a rapid assessment tool and to determine plankton compositon, after exchange, on both per ship and aggregate bases
- A set of bench sheets and accompanying photographs that will enable technicians to learn identifications of coastal forms and important nonindigenous plankton taxa; oceanic species will also be photographed and identified
- Data that will be available to other scientists and to the Washington Department of Fish and Wildlife and other agencies for their regulatory and research use
- Further understanding risks that remain even after "effective" mid ocean exchanges and risks from different regions (i.e., inter- vs intracoastal ballast)

Challenges

- What constitutes risk--do we know enough about it to "pass" or "fail" ship's ballast based on zooplankton composition?
- Measuring zooplankton in ballast can determine compliance if it is based on absolute numbers per unit area of target organisms, but not efficiency of exchange (unless before-and-after exchange samples are taken).
- Most of the nonindigenous taxa identified to species in our ship samples are copepods, and it is unknown if there is a relationship between them and other nonindigenous meroplankton taxa.
- Can determination of coastal and/or nonindigenous "risky" taxa be standardized and made reliable enough for routine application?