Invasive Species and Plankton Dynamics of the Columbia River Estuary

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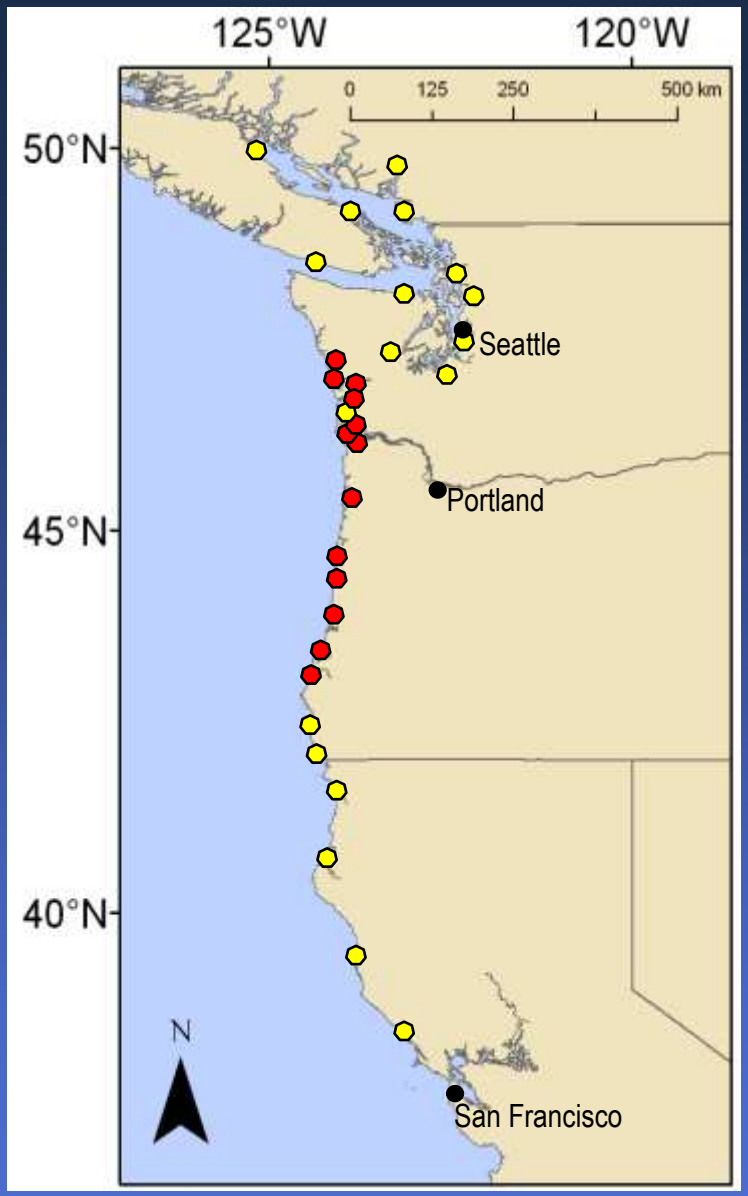


P. inopinus

present

absent

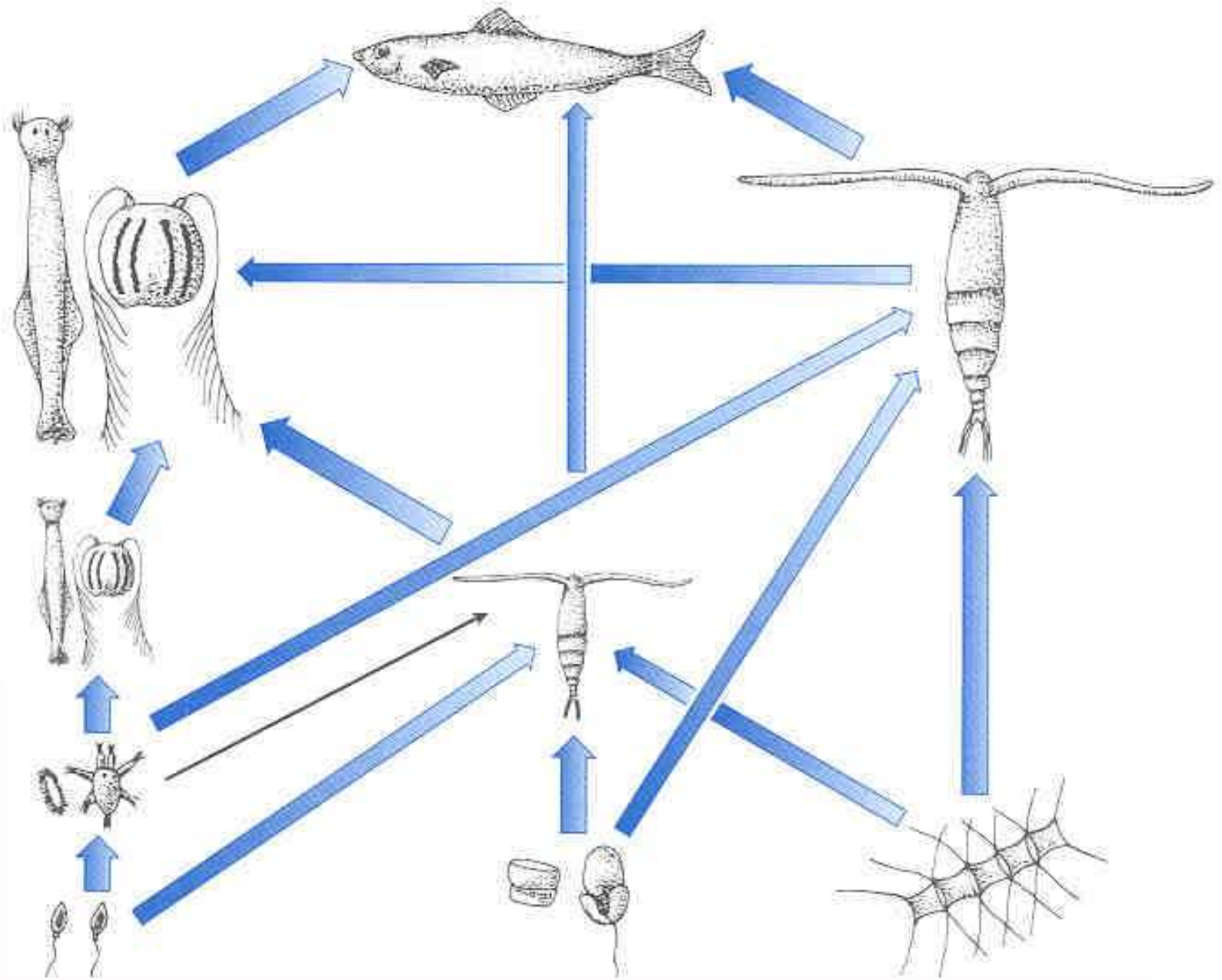
The beginning …

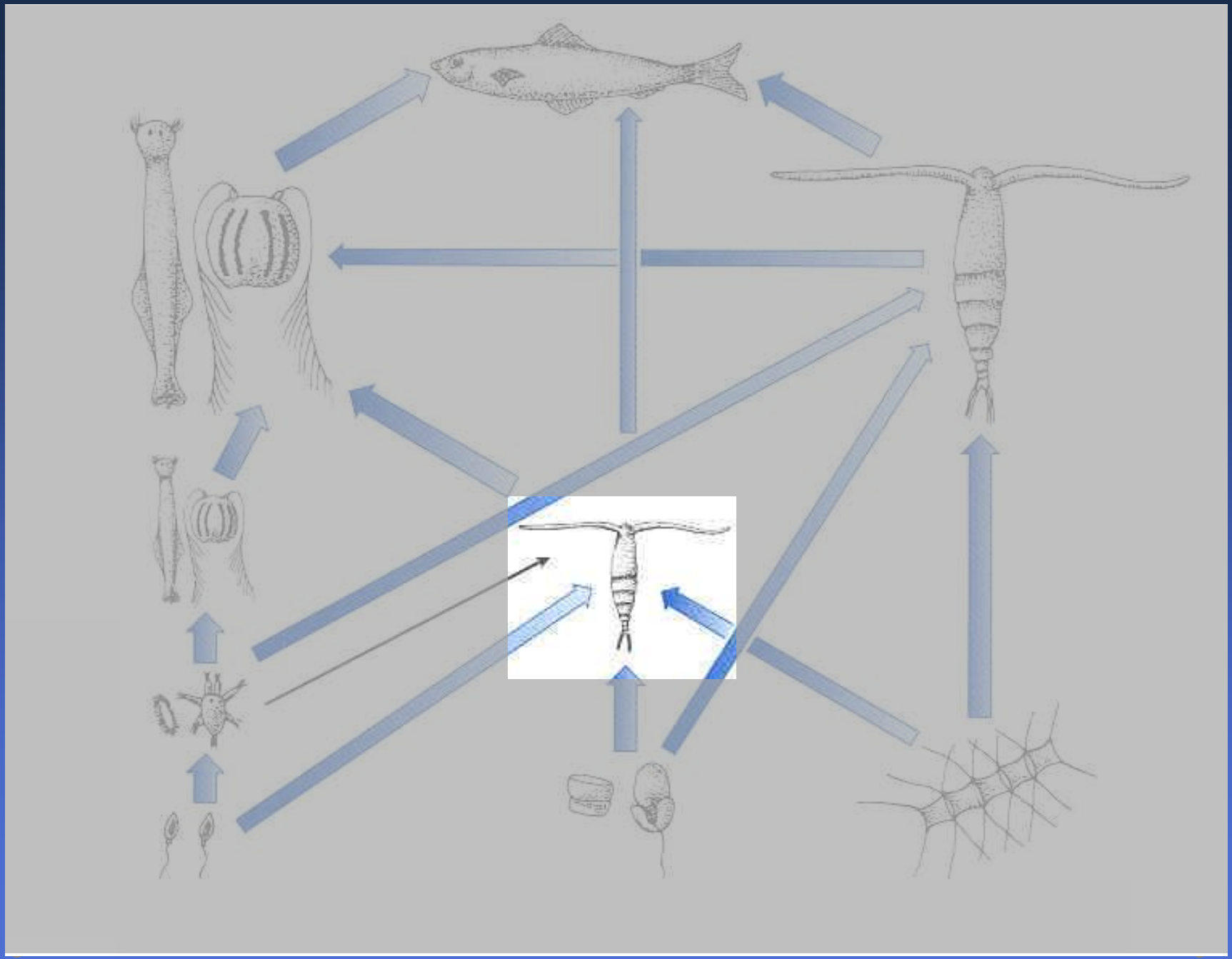
We have undertaken quadrennial plankton surveys of ~18 river estuaries since 1992.

The Asian copepod *Pseudodiaptomus inopinus* is broadly distributed in Washington & Oregon estuaries

But what are the consequences for:

* *community ecology?*
* *trophic interactions?*
* *ecosystem productivity?*





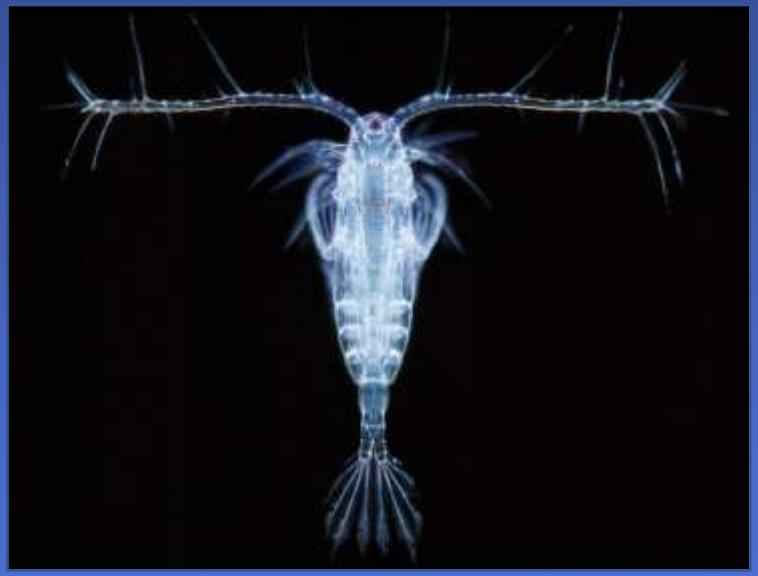
Invasive zooplankton

Mnemiopsis leidyi
(Black and Caspian Seas)

Bythotrephes longimanus
(Great Lakes)

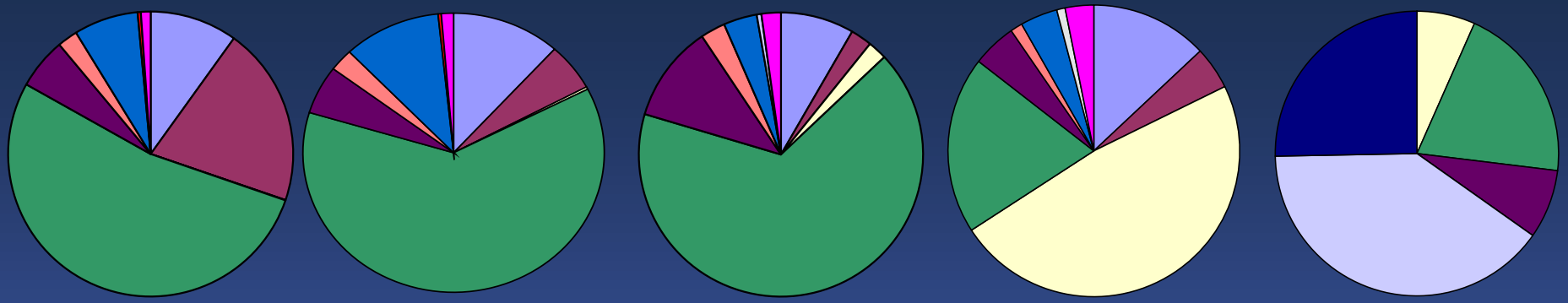
Copepods in Northeast Pacific Estuaries

Acartia sp.
(Native)



Pseudodiaptomus inopinus
(Invasive)

Percent numerical composition of copepods across salinity gradient in 14 west coast estuaries without *P. inopinus*

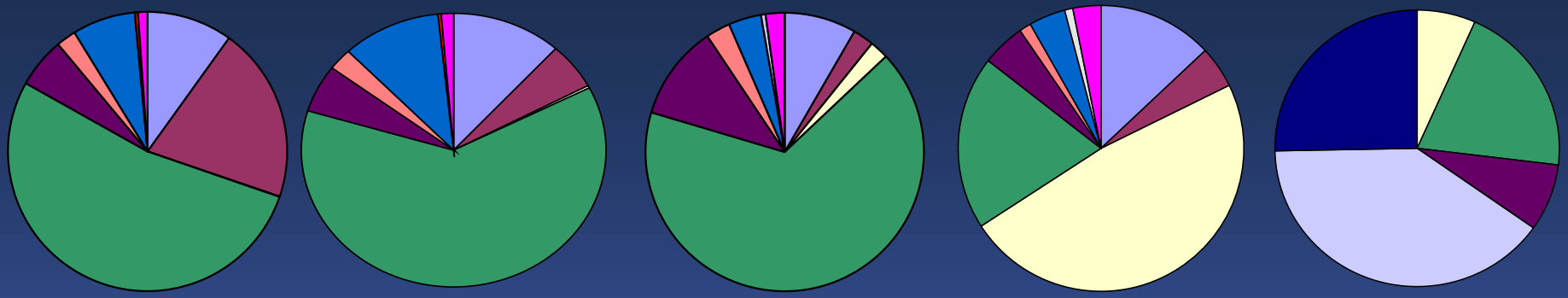


> 10 psu → 0 psu

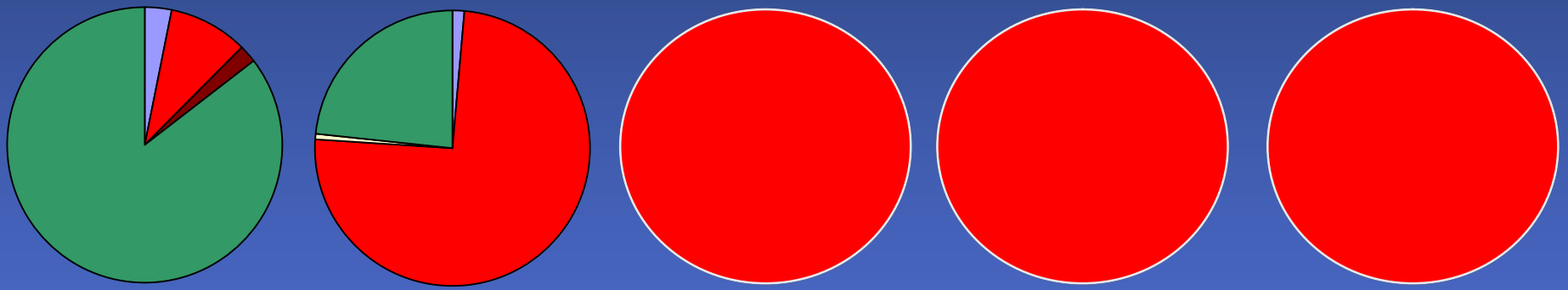
- *Paracalanus* sp.
- *E. americana*
- Cyclopidae
- *Corycaeus* sp.
- *P. inopinus*
- *Acartiura* spp.
- *Acartia tonsa*
- *E. affinis*
- *Oithona similis*
- Other Copepods

Bollens et al. (2002), Hydrobiologia, 480: 87-110

Percent numerical composition of copepods across salinity gradient in 14 west coast estuaries without *P. inopinus*



in 7 west coast estuaries with *P. inopinus*



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E. americana
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E. affinis
Corycaeus sp.
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P. inopinus
Other Copepods

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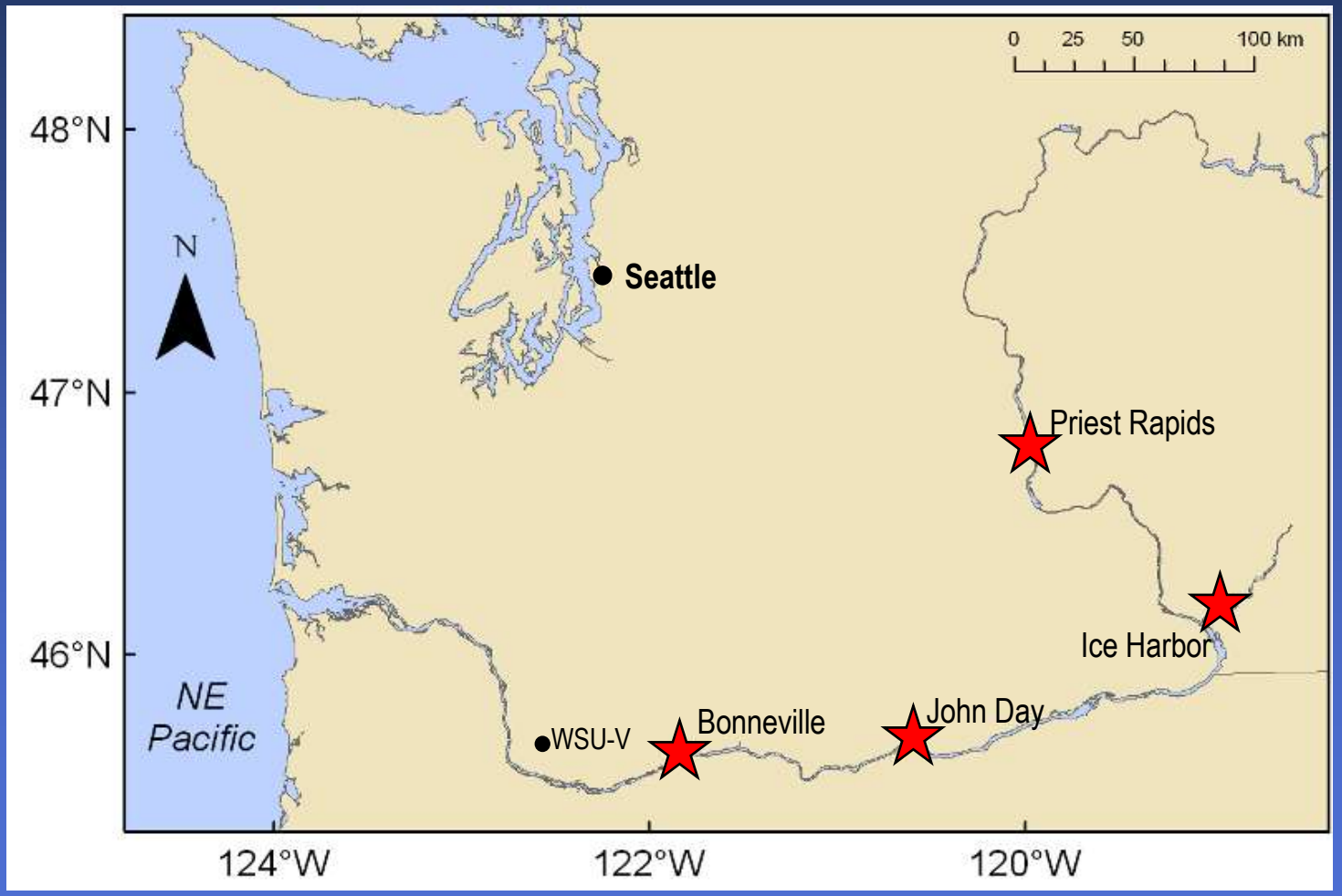
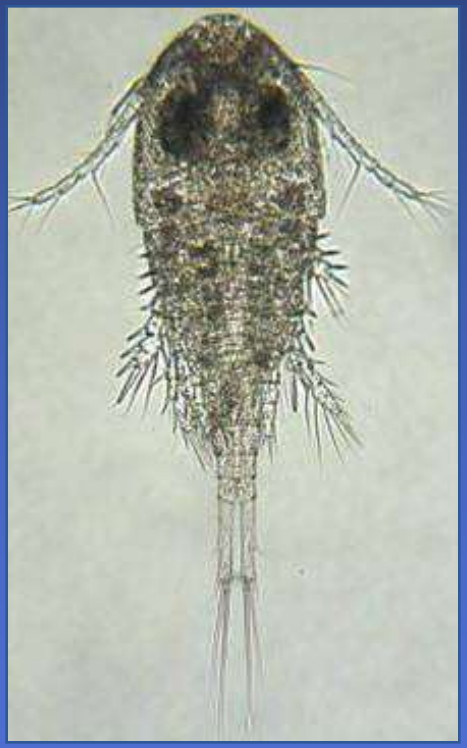
Zooplankton in Columbia/Snake River Reservoirs



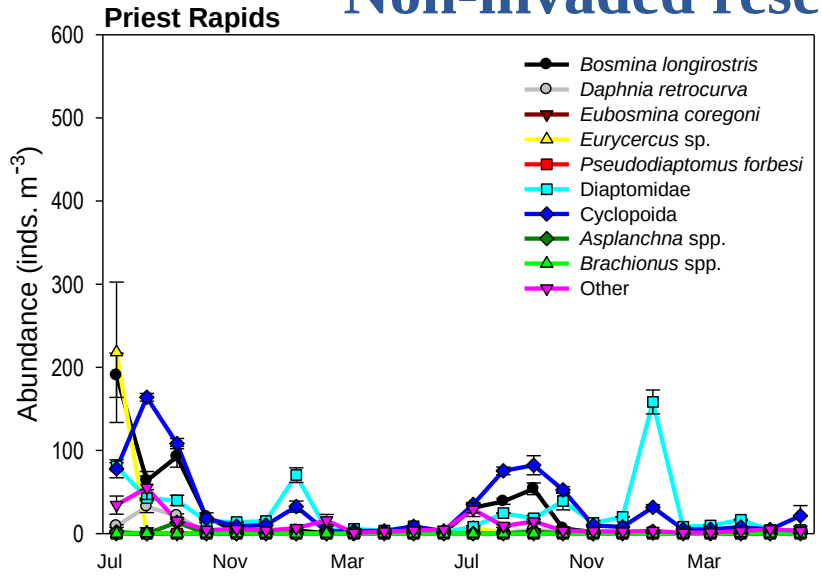
Copepods in the Columbia River

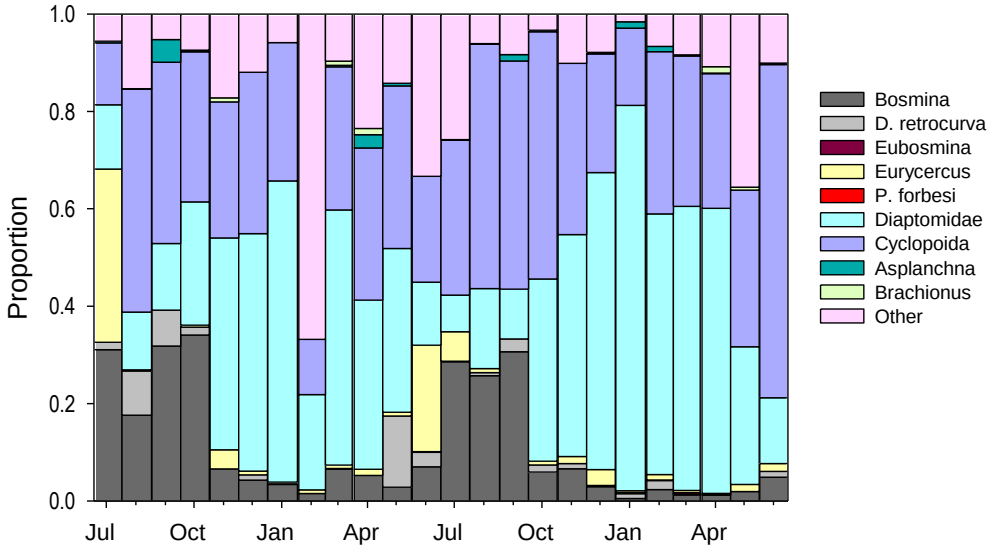
Diacyclops thomasi
(Native)



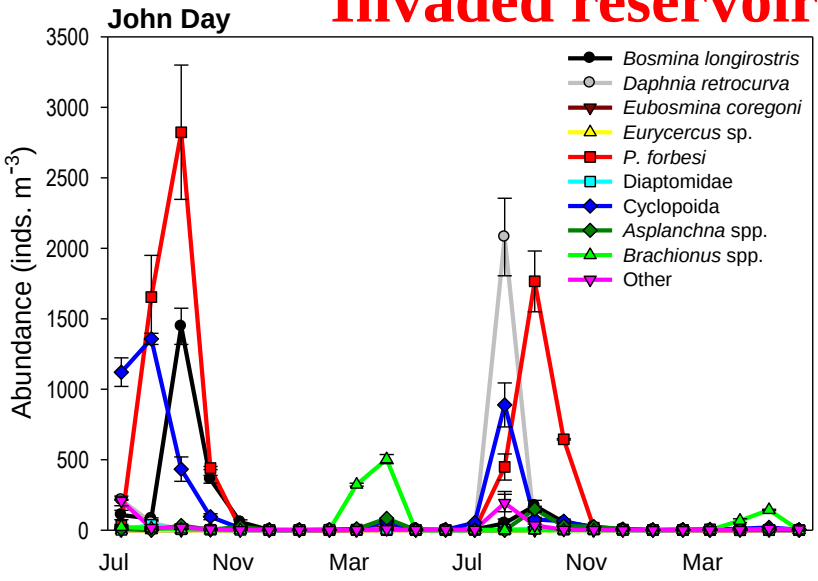
Pseudodiaptomus forbesi
(Invasive)

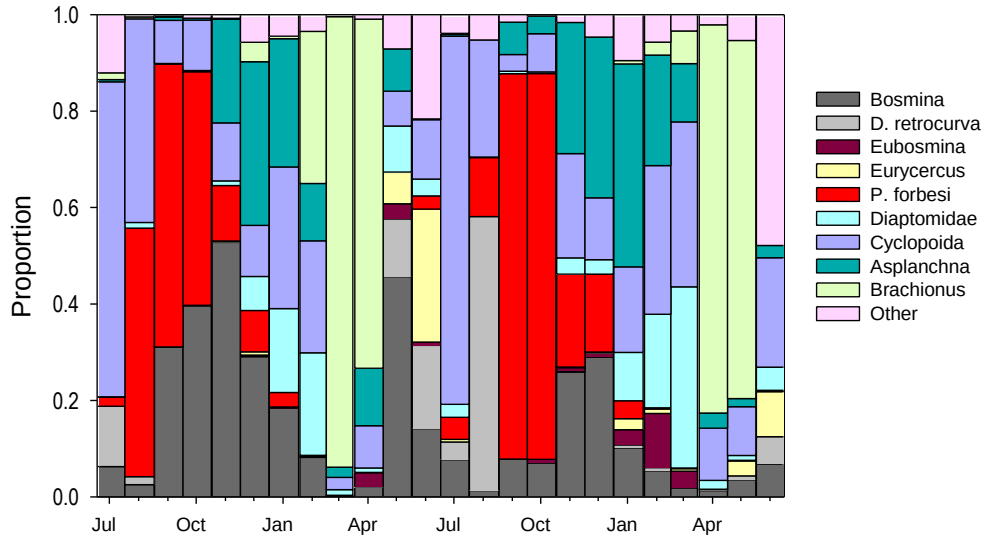
Non-invaded reservoir





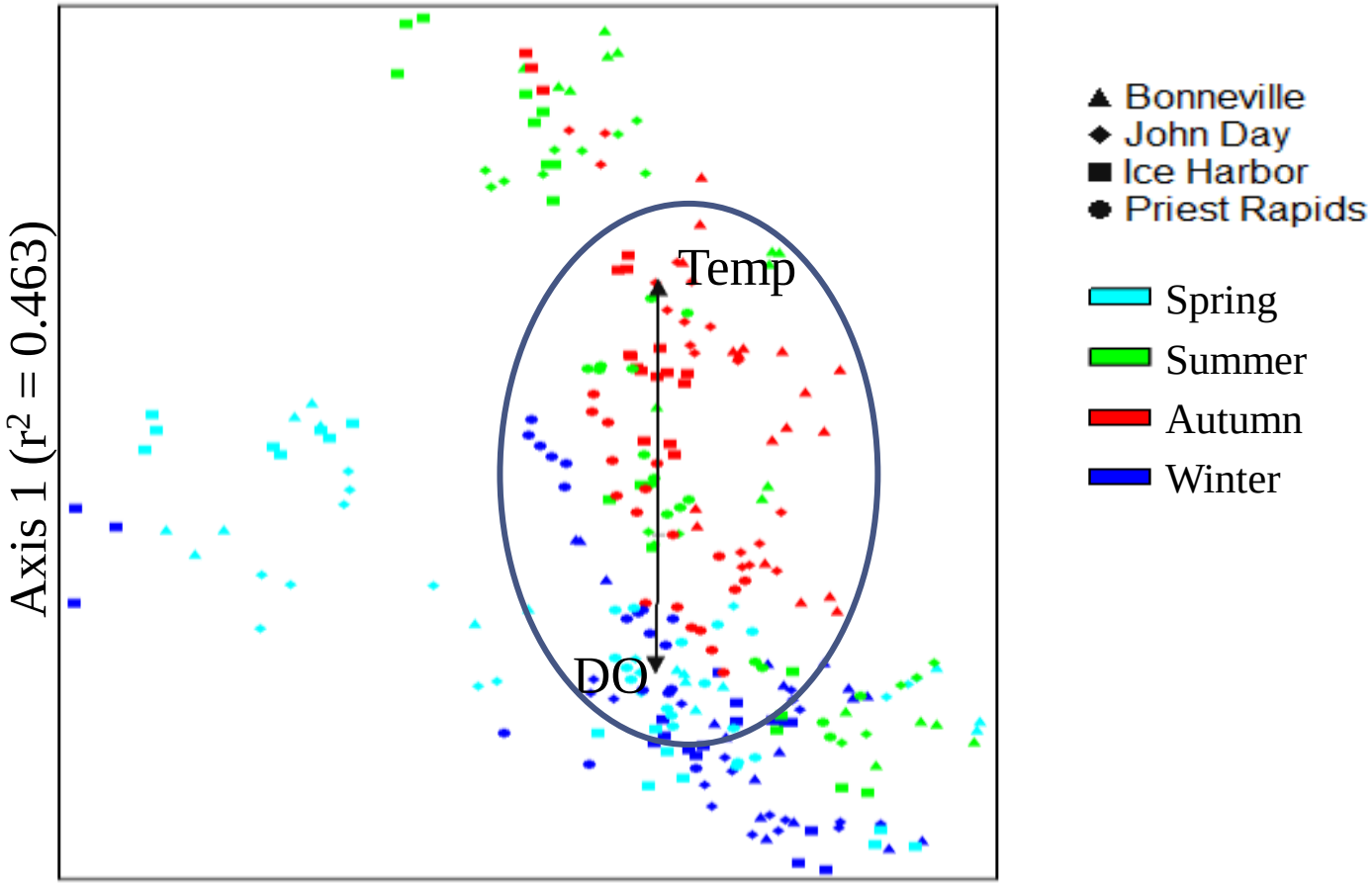
Invaded reservoir





Emerson et al. (2015), Aquatic Invasions, 10: 25-40

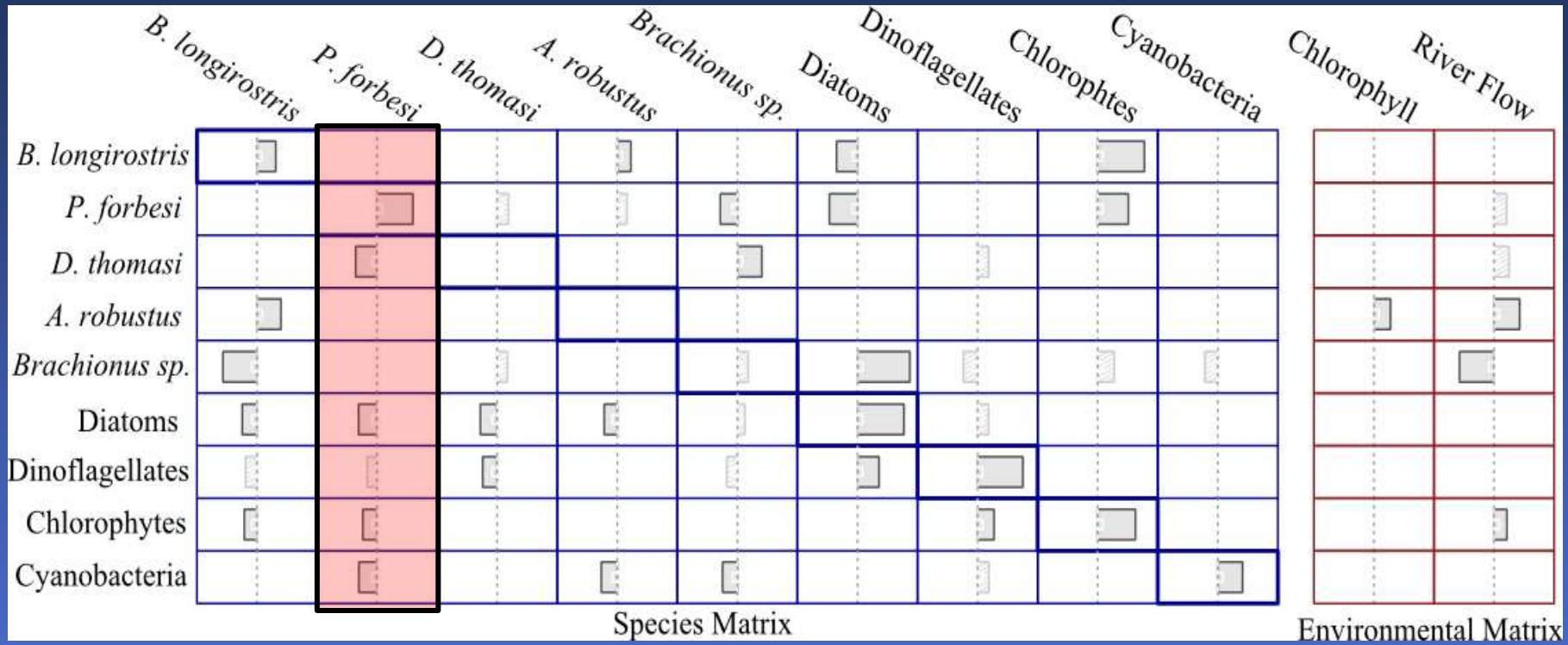
Relationship to Environmental Variables



Joint plot of zooplankton samples from Middle Columbia and Snake River reservoirs, July 2009 – June 2011. Vector cutoff is r^2 = 0.3. Stress = 7.02. NMS explains 67.4% of variation between samples.

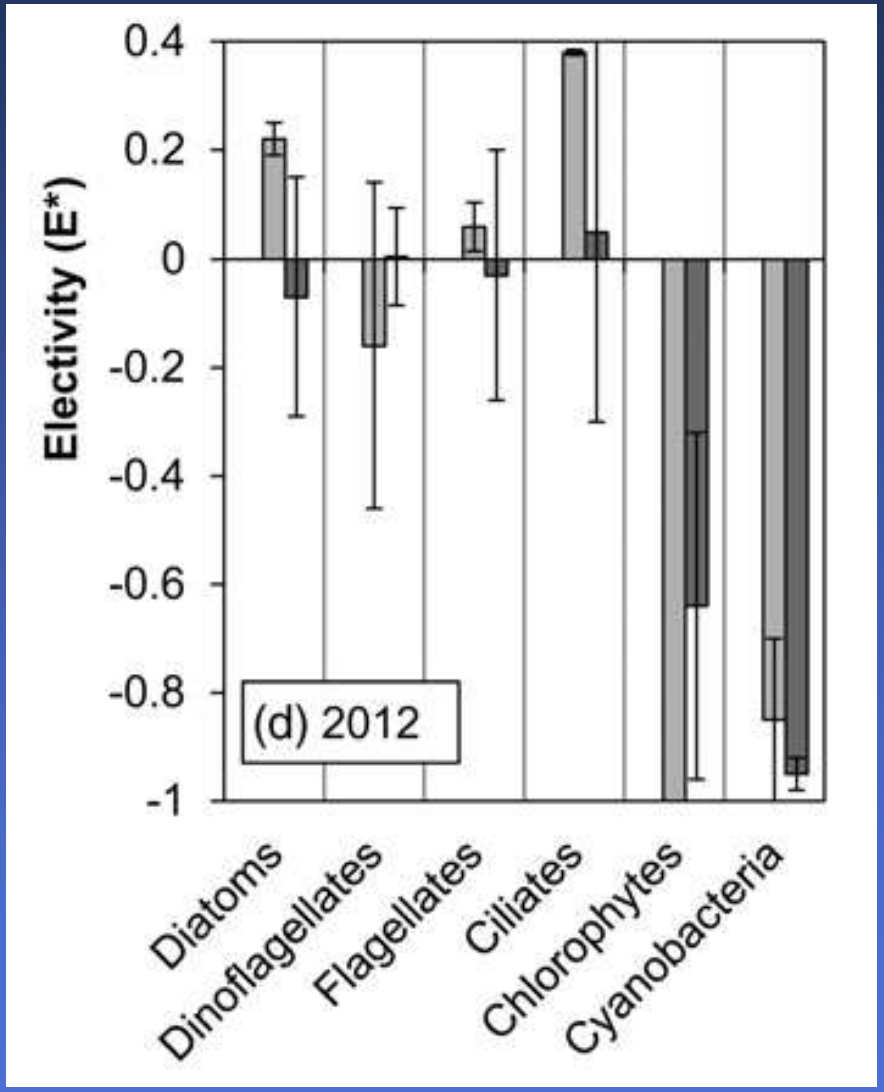
Emerson et al. (2015), Aquatic Invasions, 10: 25-40

Species interactions in the Columbia River using multivariate auto-regressive (MAR) modeling



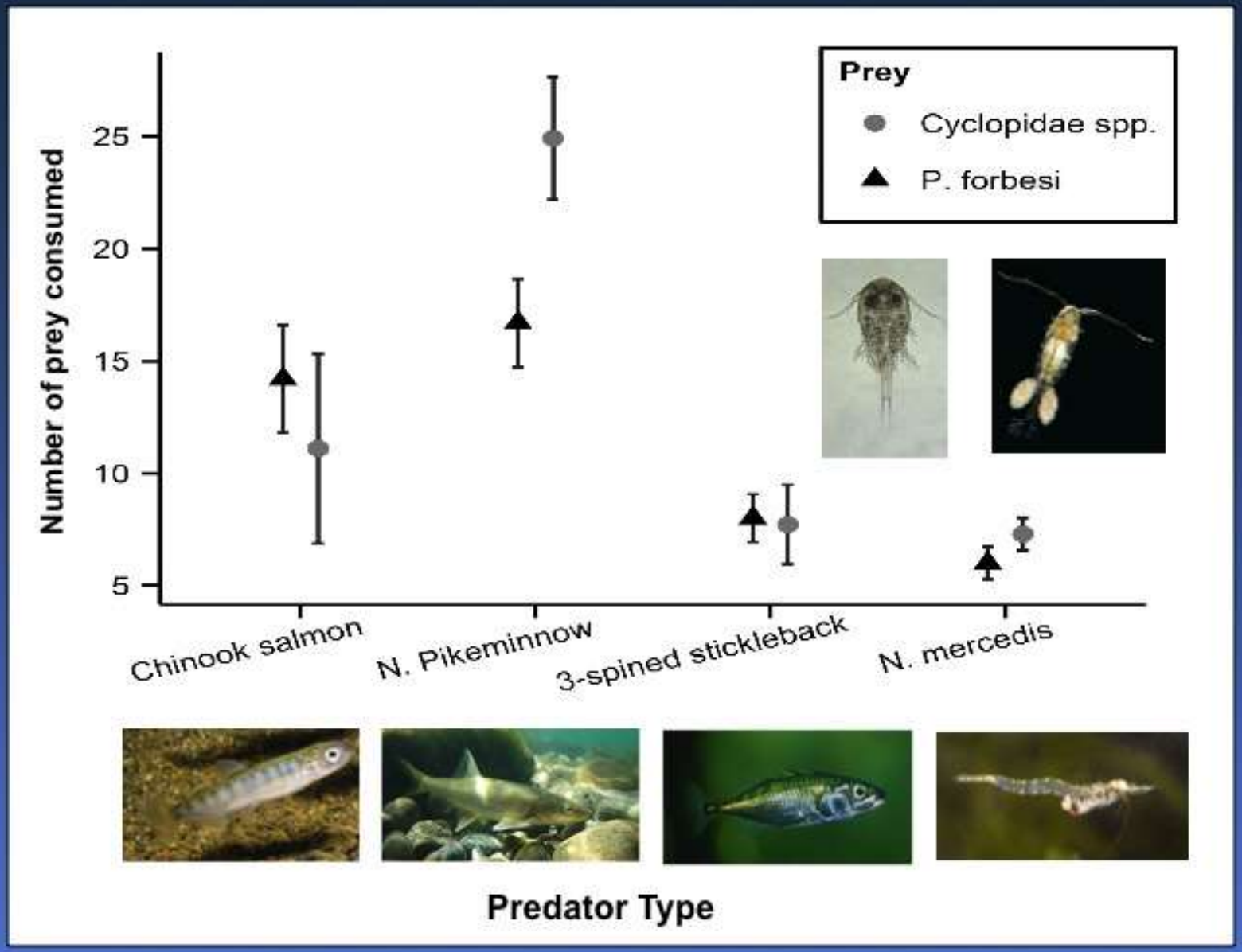
Preliminary MAR model results using 10 years of data from a single upstream station (Vancouver, WA) on the Columbia River. Magnitude and direction of grey bars indicate the effect of column variables acting on row variables. Note the strong negative interactions between the invasive *P. forbesi* and multiple native taxa.

Feeding of the invasive copepod *P. forbesi* on native microplankton in the Columbia River



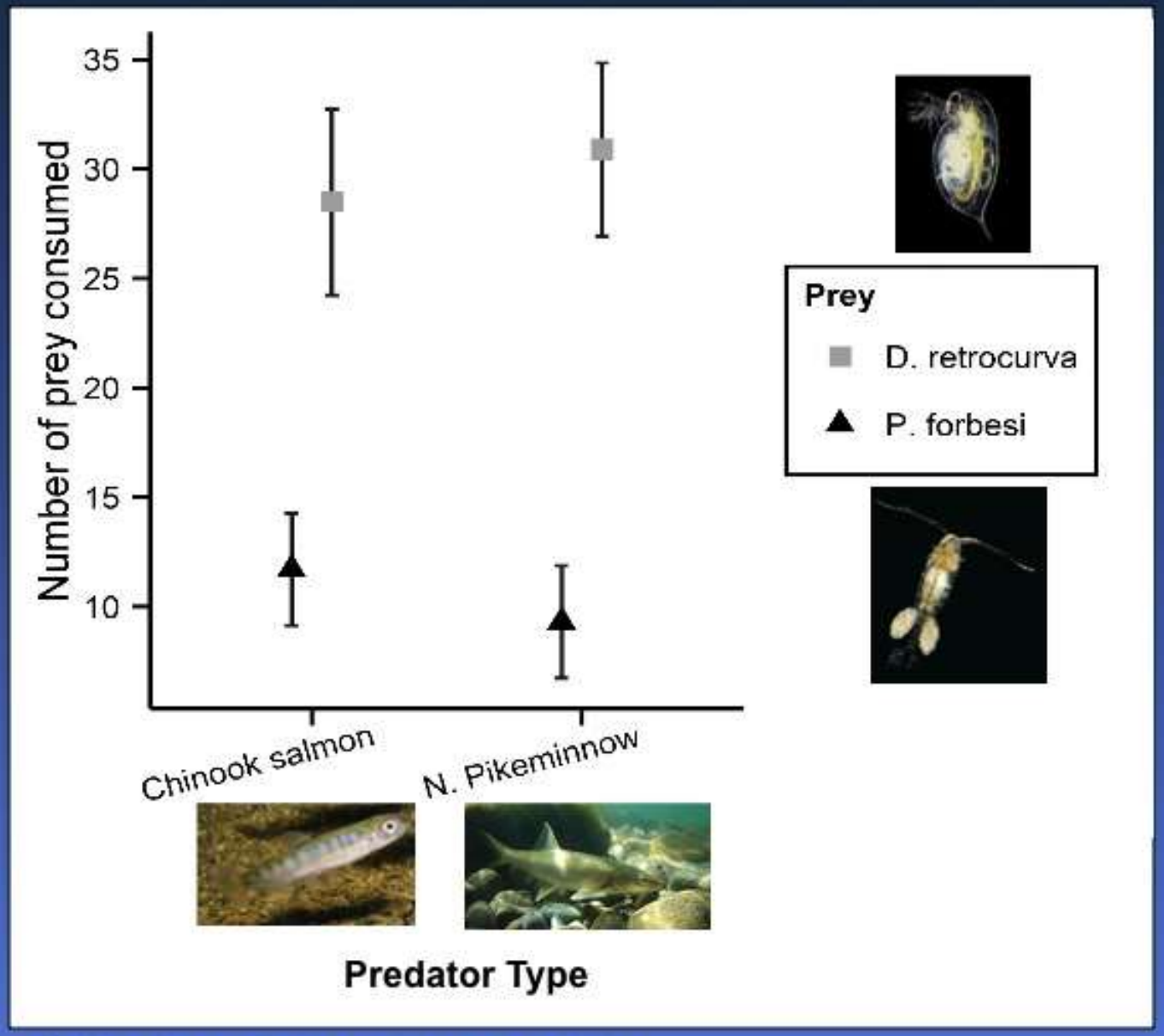
Bowen et al. (2015), Journal of Plankton Research, 37: 1089-1094

Predation by native predators on invasive vs. native zooplankton



Adams et al. (2015), PLoS ONE, 10(11): e0144095.

Predation by native predators on invasive vs. native zooplankton



Adams et al. (2015), PLoS ONE, 10(11): e0144095.

Hypothesized Changes in Estuarine Food Web

Pelagic Food Web
(pre-invasion)

Bentho-Pelagic Food Web
(post-invasion)

migration

juvenile salmon

Native copepods

Invasive copepods

migration

sculpin

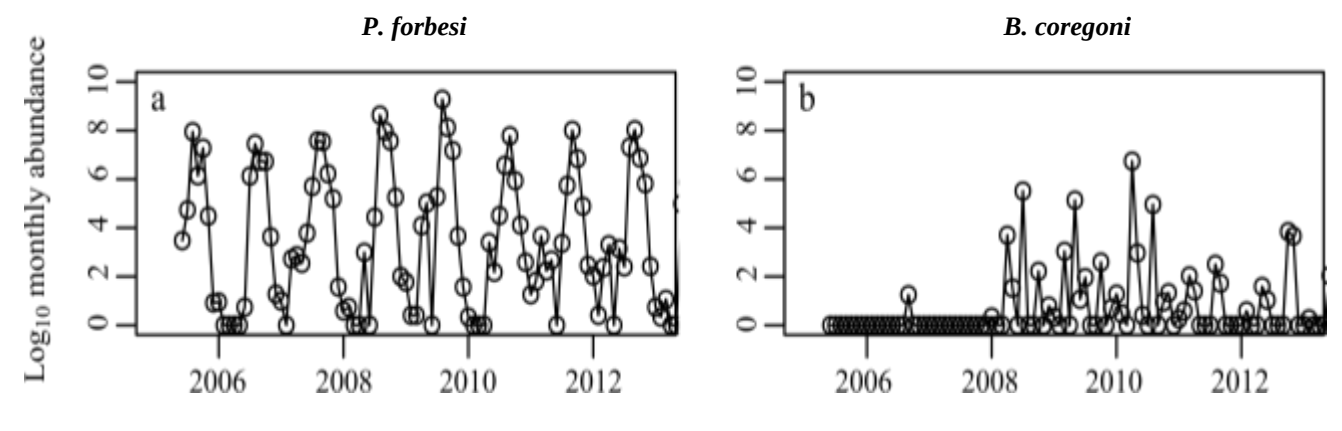
mysids

Summary of Results

- Invasive copepods from Asia have established themselves within the Columbia River Estuary and several hundred miles inland
- Competition with native copepods seems likely, based on habitat overlap, similarity of diets, and MAR modeling results
- Invasive copepods are consumed by higher trophic levels such as fish, although some predators prefer native plankton
- Overall food web impacts are likely to be substantial, although they remain to be fully quantified

Ongoing and Future Studies

Why do some populations persist, while others do not?

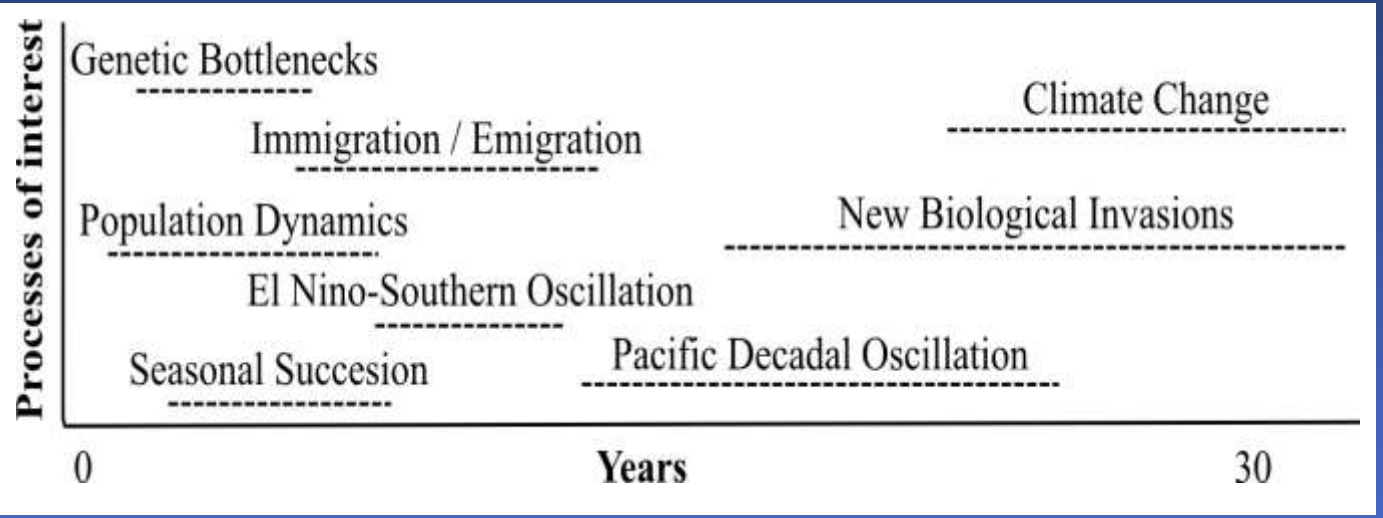


Dexter et al. (2015), Limnol & Oceanogr, 60: 527–539

- We are investigating the phylogeography of *Pseudodiaptomus inopinus* using next-generation genetic sequencing protocols
- Specifically, what transport vectors (i.e. ballast water vs. coastal advection) have mediated the rapid spread of *P. inopinus* throughout the U.S. Pacific Northwest?
- Preliminary findings show very high rates of gene flow between putatively isolated populations in the invaded range. No evidence for isolation by distance.

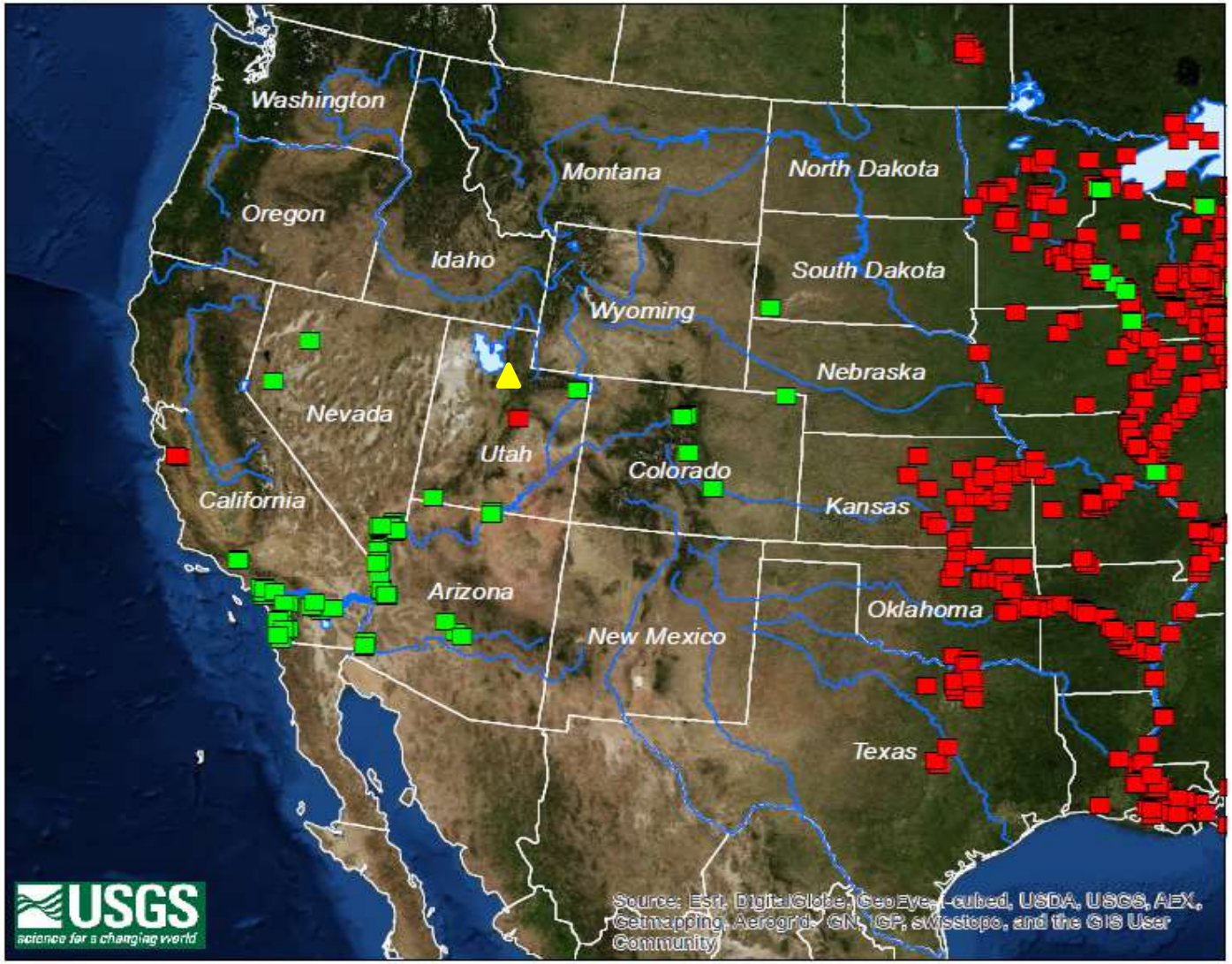
Ongoing and Future Studies (cont)

How are plankton population invasions facilitated or deterred by temporally varying community-level dynamics and abiotic environmental factors?



The need is for long-term (multi-decadal) data and a research approach that combines observation, modeling and experimental manipulation

QUAGGA AND ZEBRA MUSSEL SIGHTINGS DISTRIBUTION IN THE WESTERN UNITED STATES, 2007 - 2014



Quagga mussel sightings

Zebra mussel sightings

Recent veliger detection Dec. 12, 2014

Q&A

Phylogeography of *Pseudodiaptomus inopinus*

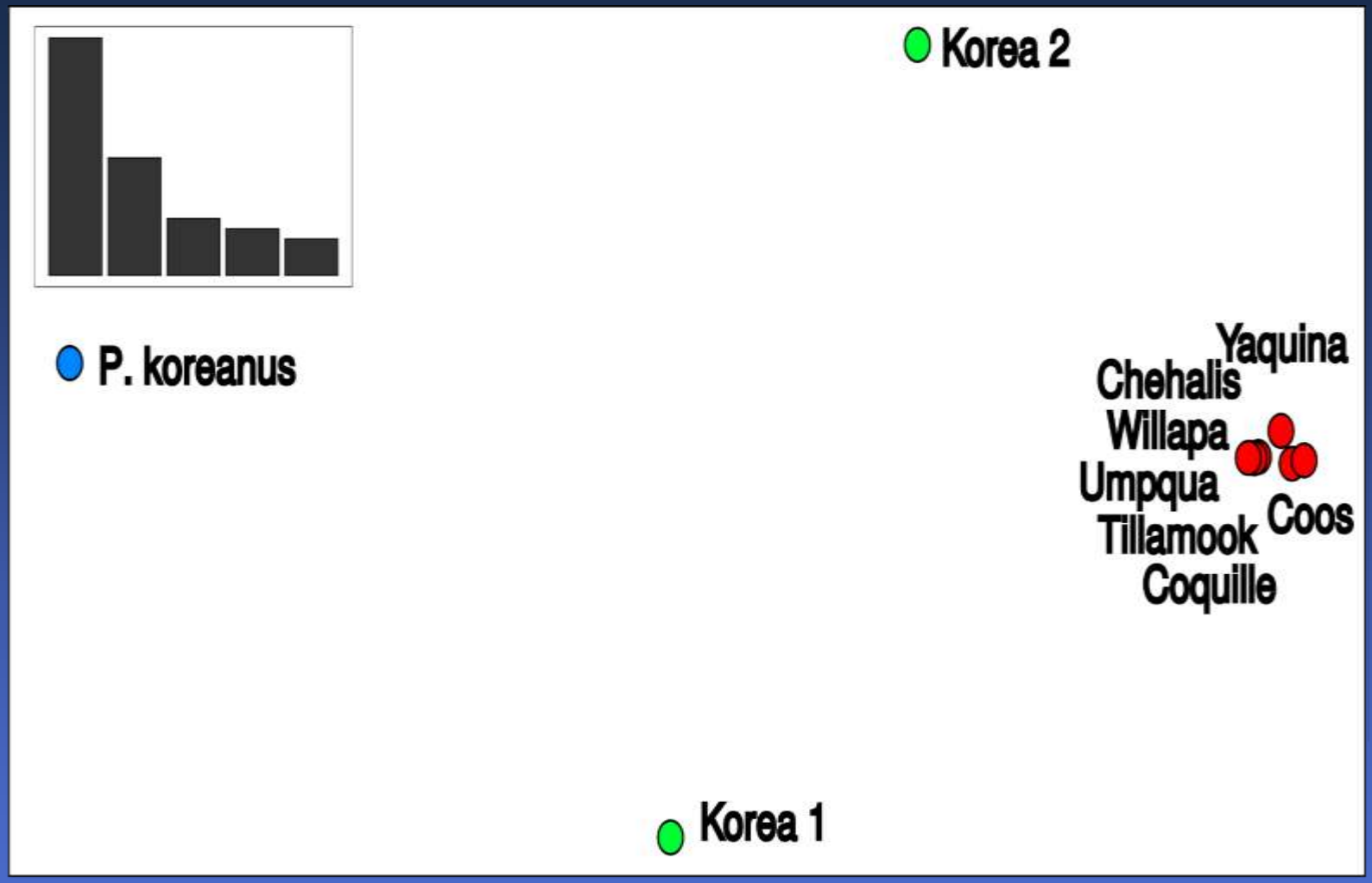
- Phylogeography of *Pseudodiaptomus inopinus* using next generation sequencing techniques. Specific Research Question: What transport vectors (i.e. ballast water vs. coastal advection) have mediated the rapid spread of *P. inopinus* throughout the U.S. Pacific Northwest?

- Study conducted in collaboration with Jerome Goudet (University of Lausanne, Switzerland) and Severine Vuilleumier (Ecole Polytechnique Fédérale de Lausanne)

- Double Digest Restriction-Site Association DNA (ddRAD) sequencing of pooled samples from the native and invaded range. Genetic data evaluated through an Approximate Bayesian Framework using genetic simulation software (quantiNEMO)

- Preliminary findings show very high rates of gene flow between putatively isolated populations in the invaded range. No evidence for isolation by distance.

- Dexter, E., Bollens S.M., Cordell, J., Goudet J., Rollwagen-Bollens, G.R., Soh, H.Y., Vuilleumier, S. (2016*) A Phylogeographic reconstruction of the invasion history of the calanoid copepod Pseudodiaptomus inopinus: scale-dependent migration patterns.* In prep.


Korea 2
P. koreanus
Yaquina
Chehalis
Willapa
Umpqua
Coos
Tillamook
Coquille
Korea 1
Principal component 2 (22% of variance)
Principal component 1 (44% of variance)