Variability in zooplankton exchange between the coastal ocean and an estuarine fjord.

Julie Keister and Bethellee Herrmann
University of Washington, Seattle, WA, USA

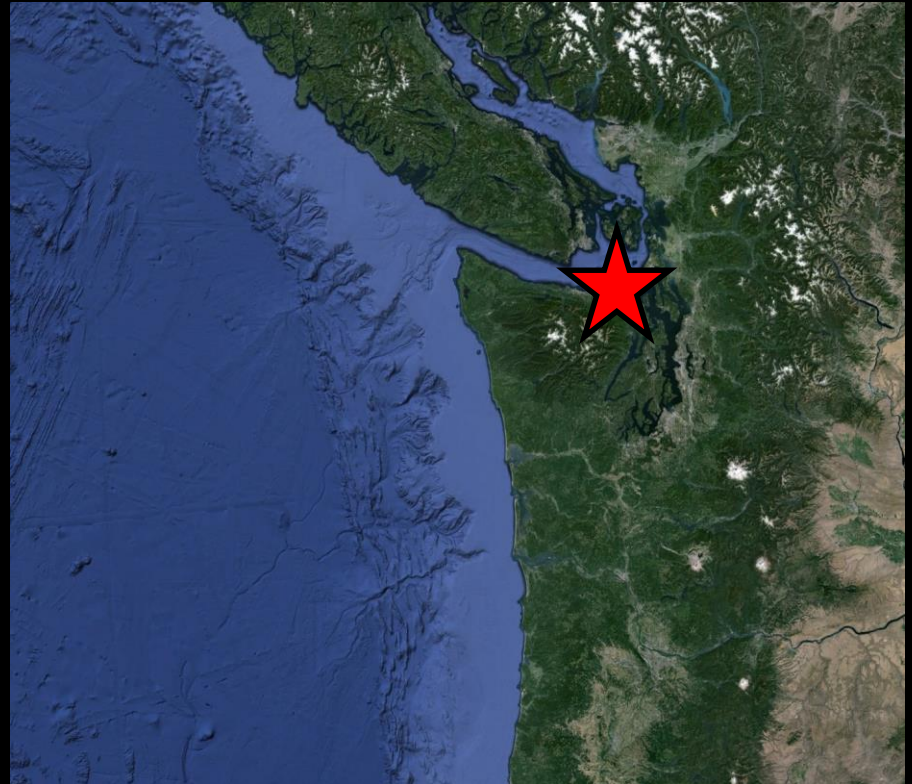MacCready, MOSSEA model, SSS

JEMS

Joint Effort to Monitor the Strait

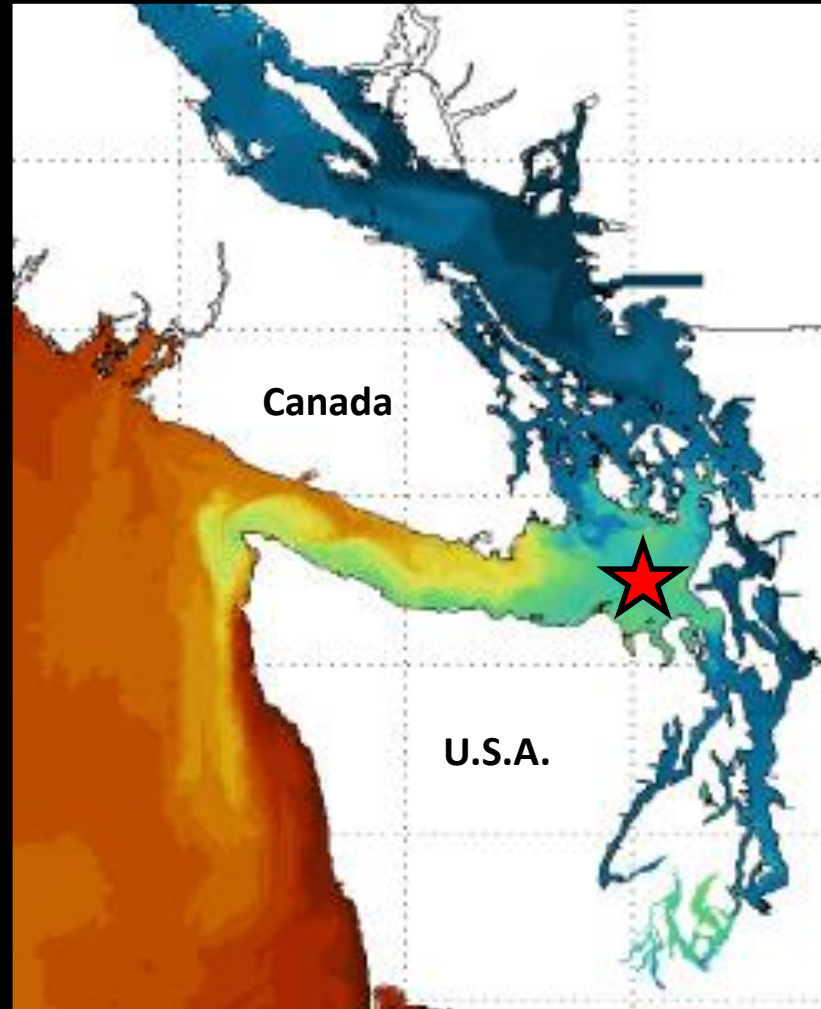### Hydrographic and plankton time series, since 1999 (2003 for zooplankton)

140 m water depth

Region of complex circulation:

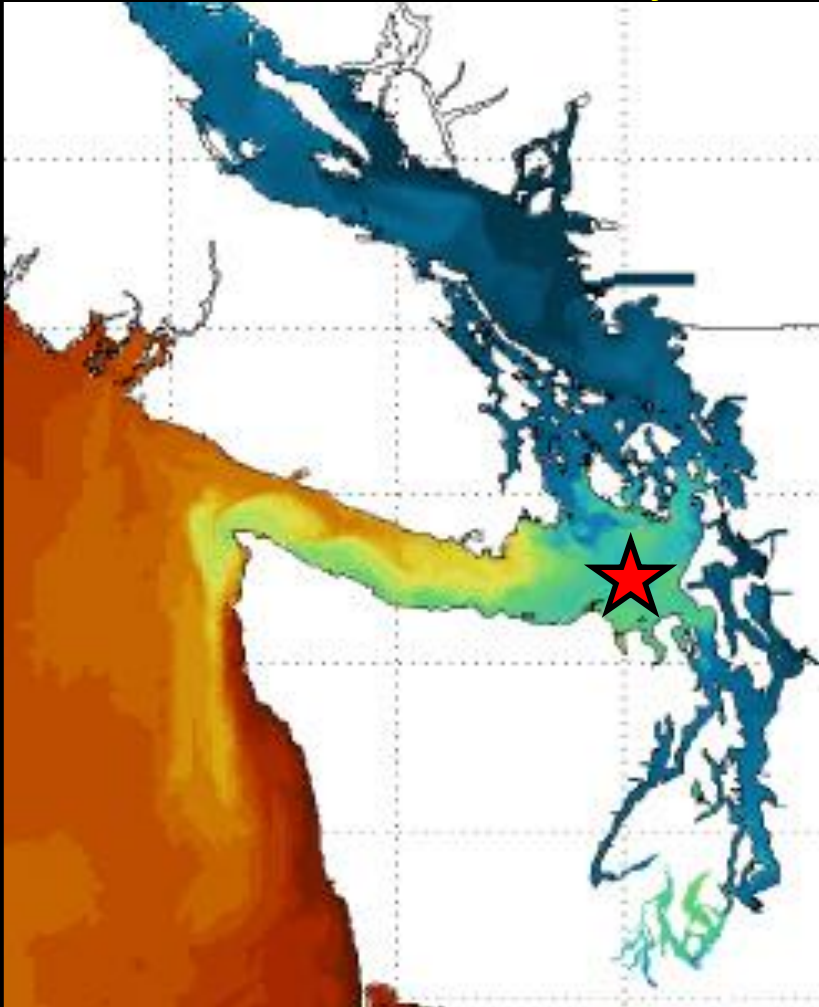**Modeled sea surface salinity**

Canada

U.S.A.

MacCready: MOSSEA Model

Questions:

Does the zooplankton species composition reflect large-scale environmental variability (and how)?

Can the time series be an effective index of the local ecosystem or fish populations?

JEMS Sampling

Modeled sea surface salinity

MacCready: MOSSEA Model

- Monthly sampling (with many gaps)

- CTD casts (T, S, D, DO)

- Bottle chlorophyll, nutrients, oxygen

- Zooplankton net tows
  - 75-cm diameter closing net
  - 150-µm mesh
  - Surface (0-40 m) vertical net tows
  - **No flow meter until 2011
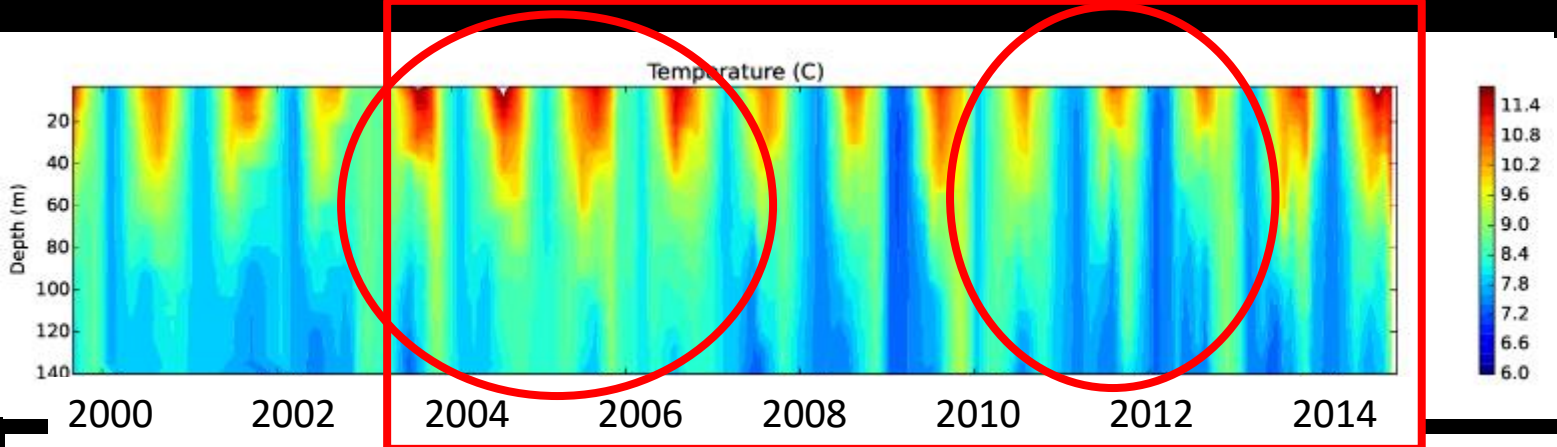
Analysis: NMS Ordination

Ordination data:

- Copepod species only

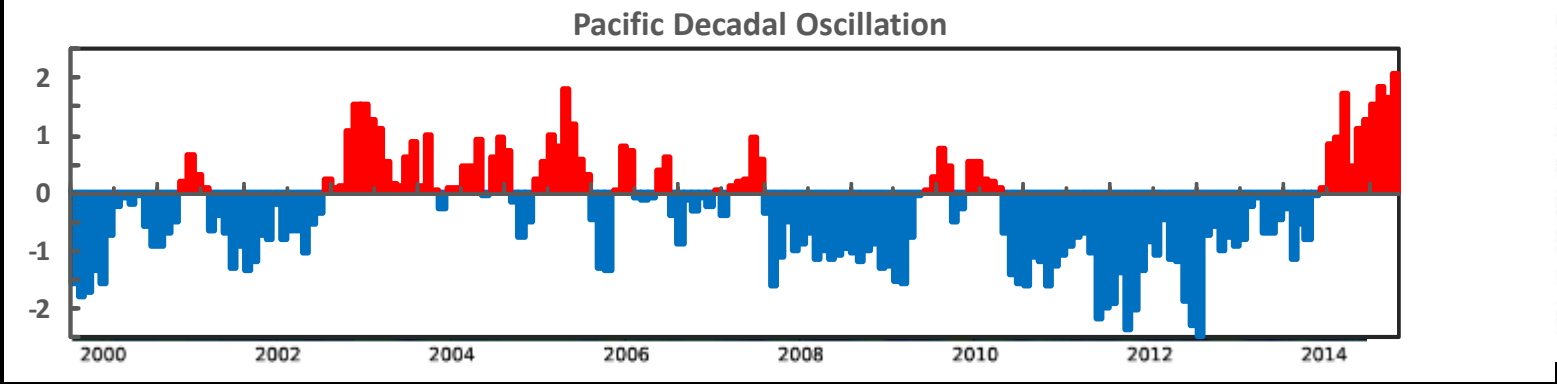- Transformed proportion of total numbers

Following analysis:

- Aligned Axis 1 to strongest environmental correlate (SST)

- Aligned Axis 2 to carry max. possible remaining variance in community structure
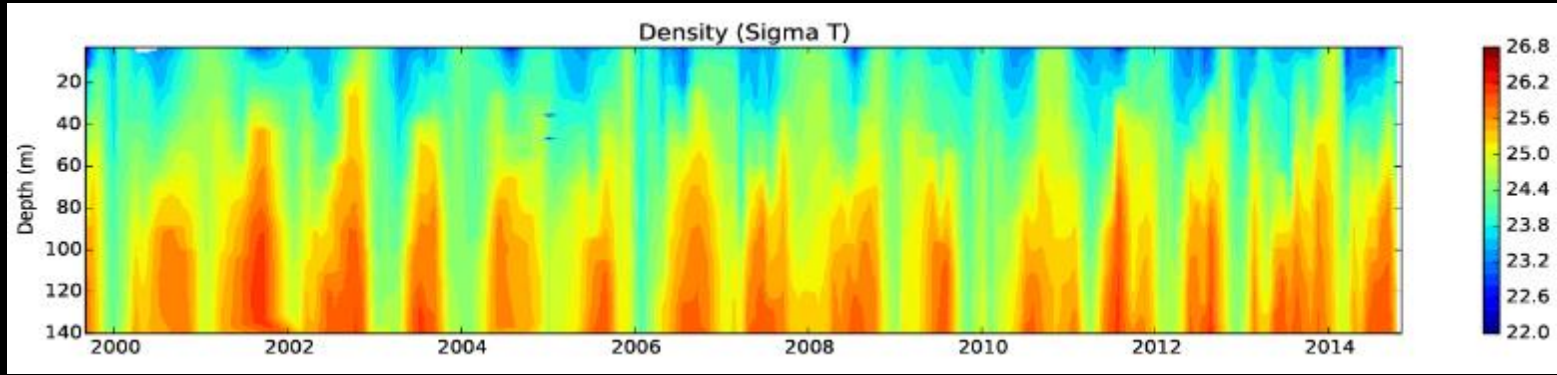
Physical variability at JEMS site:
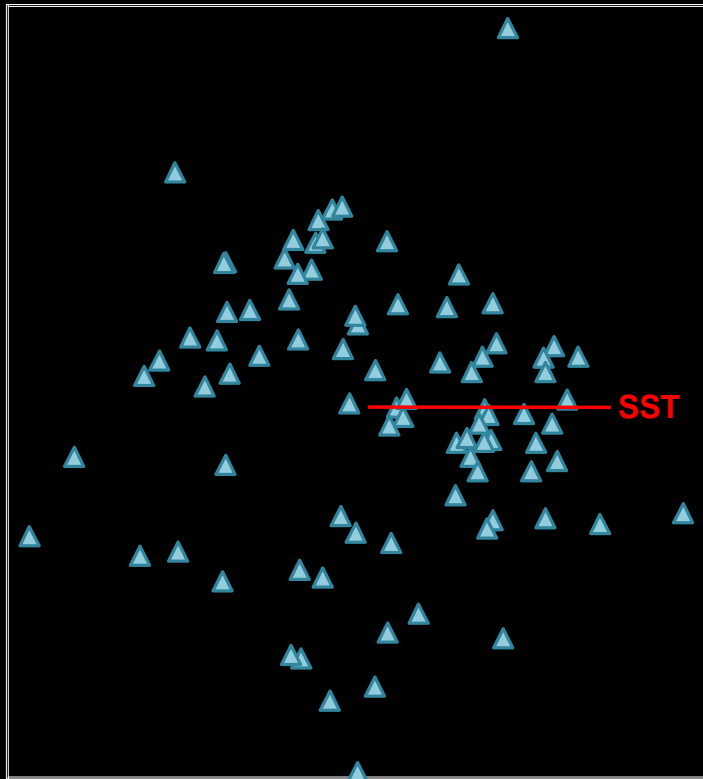
Temperature - seasonal cycle removed

Salinity

Density

3-D ordination: total variance explained = 86.5%

Axis 1 vs. 2

Axis 1 vs. 3
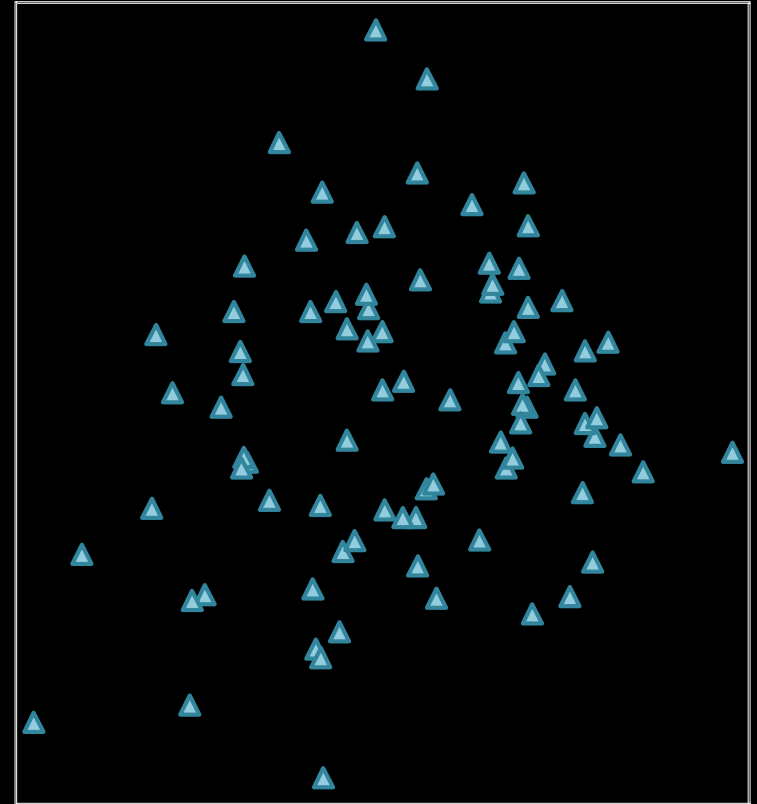
Axis 2 rotated to maximum remaining variance

Axis 2 (23%)

Axis 1   (43%)

SST

Axis 3 (20%)

Axis 1 (43%)

Axis 1 aligned to SST
(r = 0.70)
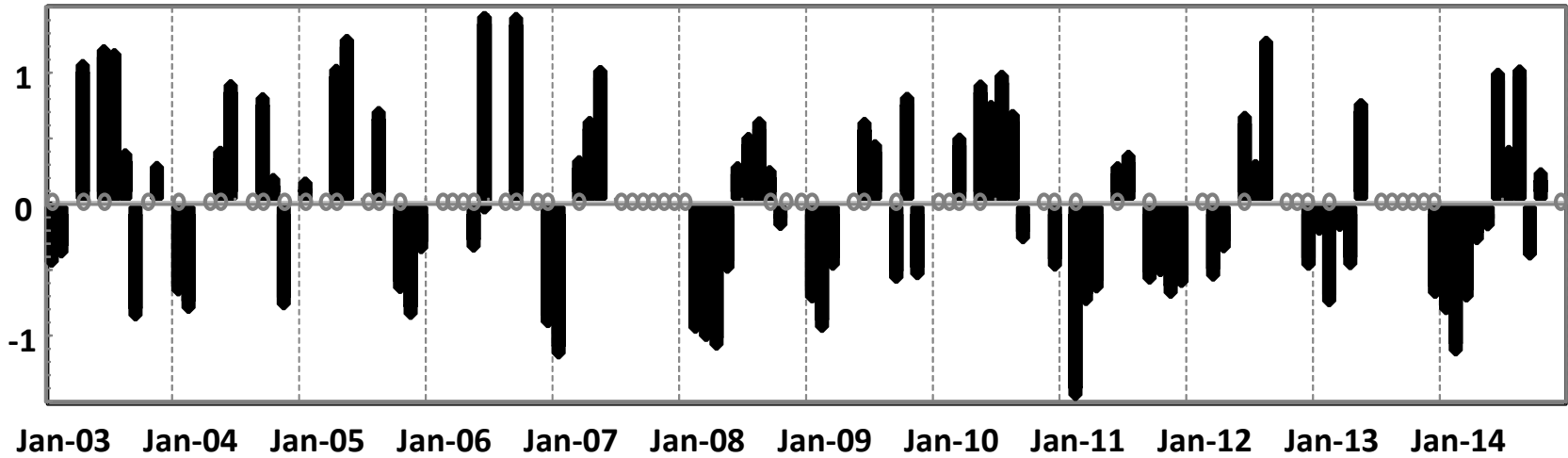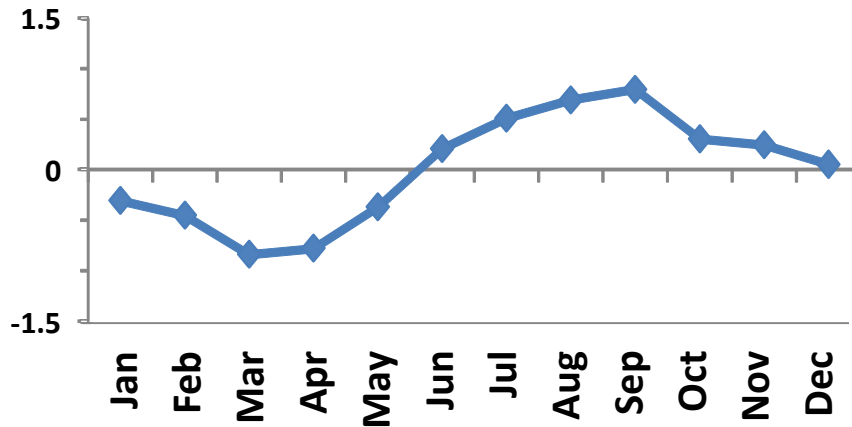
Time series of JEMS Axis 1 scores:

Axis 1 Ordination Scores

Axis 1 Seasonal Cycle

Axis 1 score anomalies:

Axis 1 Ordination Non-Seasonal Anomalies

Pacific Decadal Oscillation
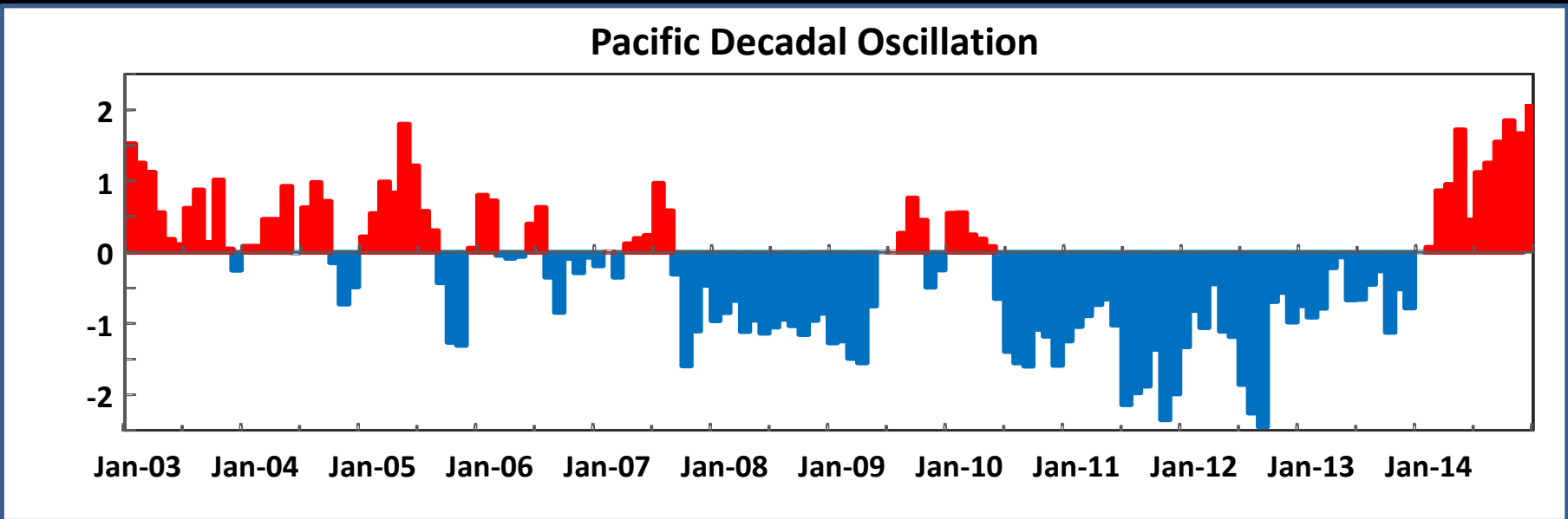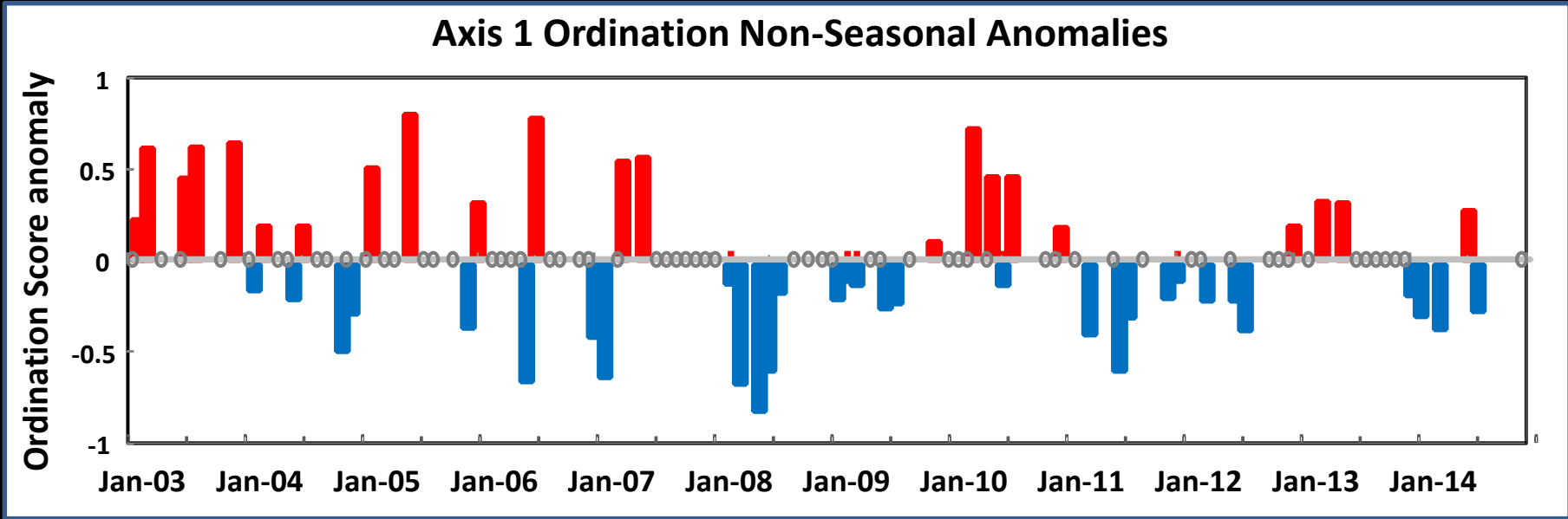
Correlates with PDO with ~2 month lag

Axis 1 score anomalies:

Axis 1 Ordination Non-Seasonal Anomalies

Axis 1 strongest species correlations (r > 0.5):
Copepod species: *Corycaeus anglicus* (r = 0.86) (inland waters)
Paracalanus spp. (r = 0.59)   (inland and oceanic)
Acartia longiremis (r = -0.50)   (oceanic)
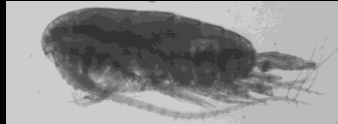*Pseudocalanus mimus* (r = -0.78) (oceanic)

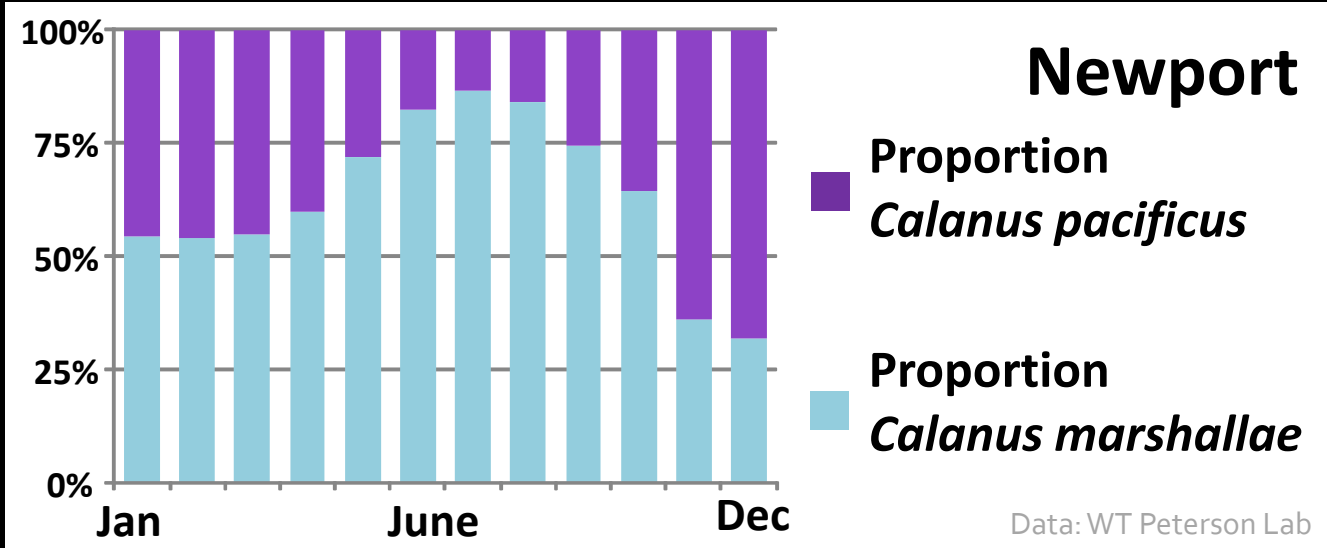**Strait of Juan de Fuca
(120 m station)**

Oregon shelf (60 m station)

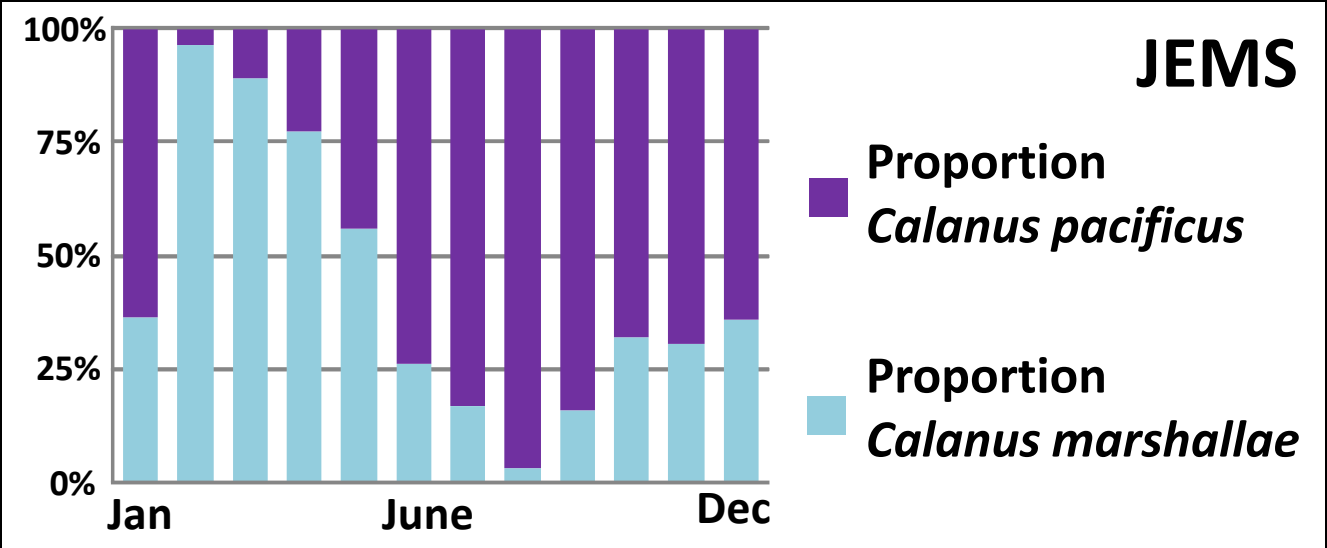*Calanus pacificus* = warm-water species (inland and warm oceanic)
Calanus marshallae = upwelling species

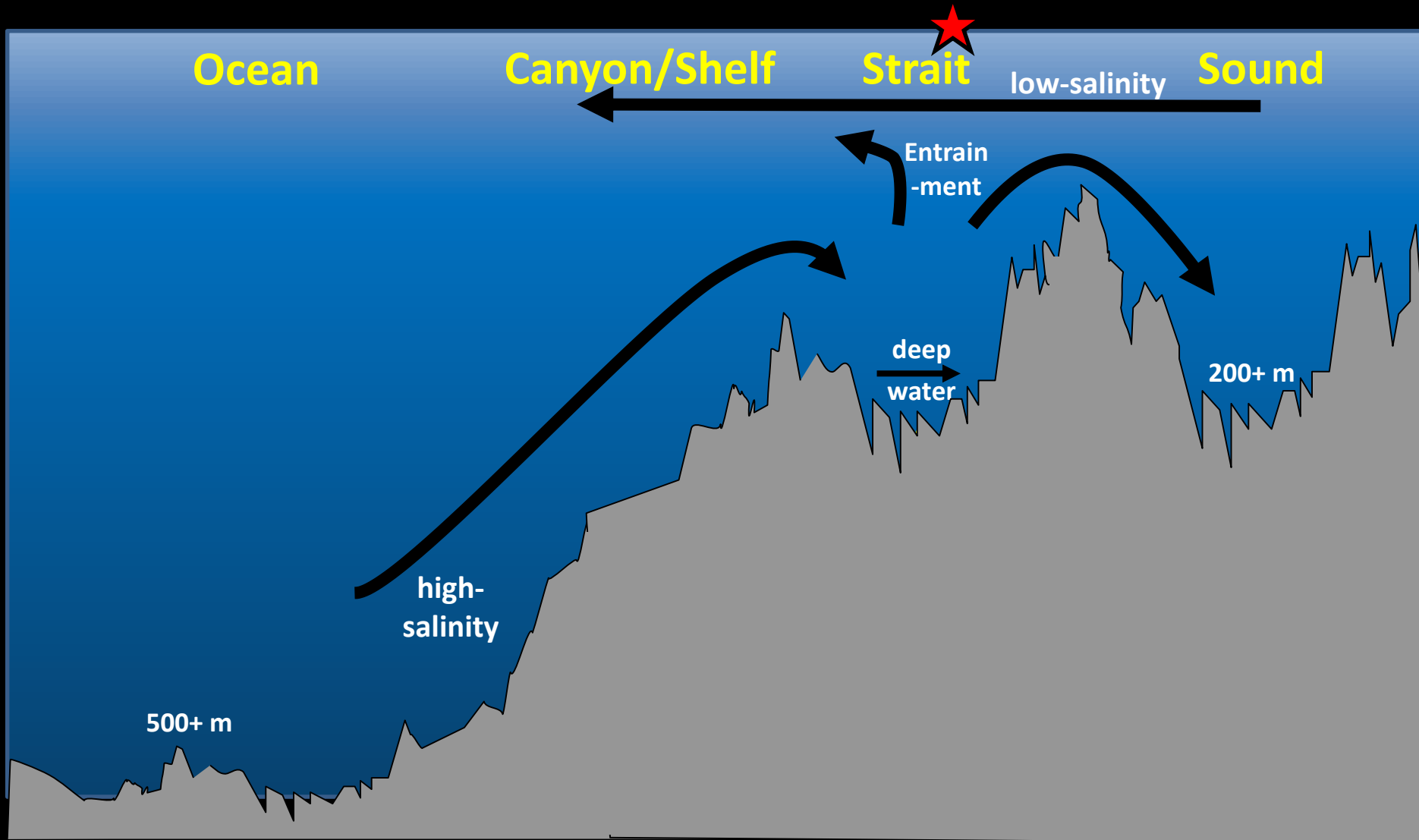**Northern California Current shelf (60 m station):**
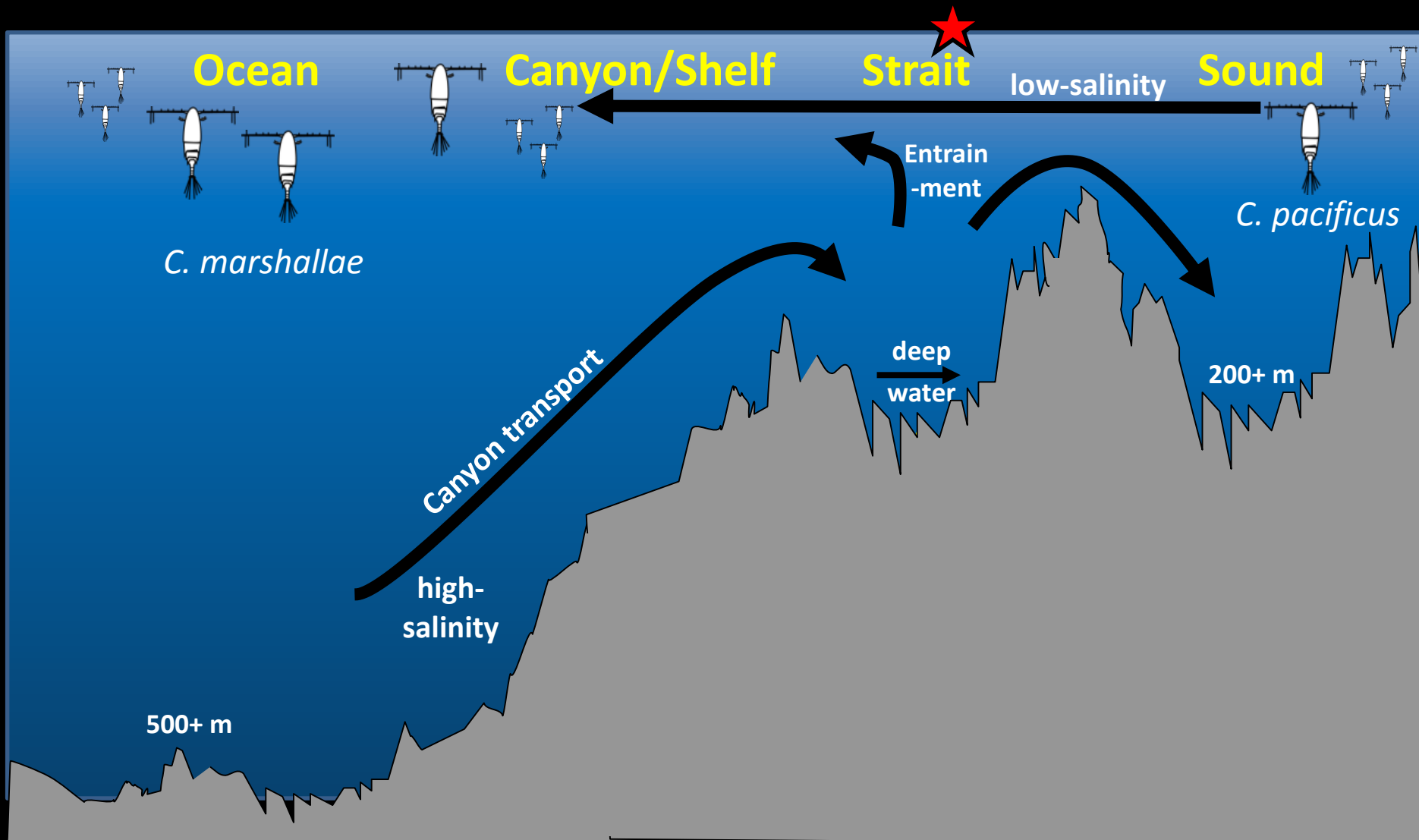
JEMS Strait of Juan de Fuca:

Newport

Proportion *Calanus pacificus*

Proportion *Calanus marshallae*

Data: WT Peterson Lab

JEMS

Proportion *Calanus pacificus*

Proportion *Calanus marshallae*

Consequences of copepod behavior?
Differential transport of species and life stages

Ocean   Canyon/Shelf   Strait   low-salinity   Sound

Entrain-ment

deep water

200+ m

high-salinity

500+ m

Summer: *C. pacificus* advected from Sound, *C. marshallae* remain offshore

Ocean   Canyon/Shelf   Strait   low-salinity   Sound

C. marshallae

C. pacificus

Entrain-ment

Canyon transport

deep water

200+ m

high-salinity

500+ m

Winter: Diapause→ *C. pacificus* retained in Sound
C. marshallae advected from ocean

Ocean   Canyon/Shelf   Strait   low-salinity   Sound
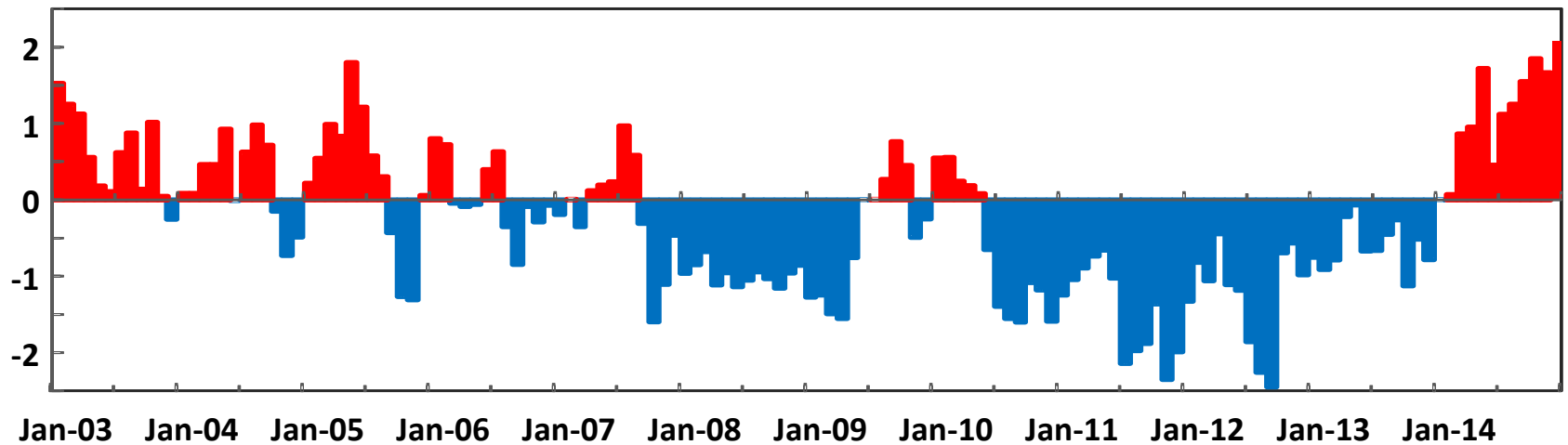
Entrain-ment

Canyon transport

deep water
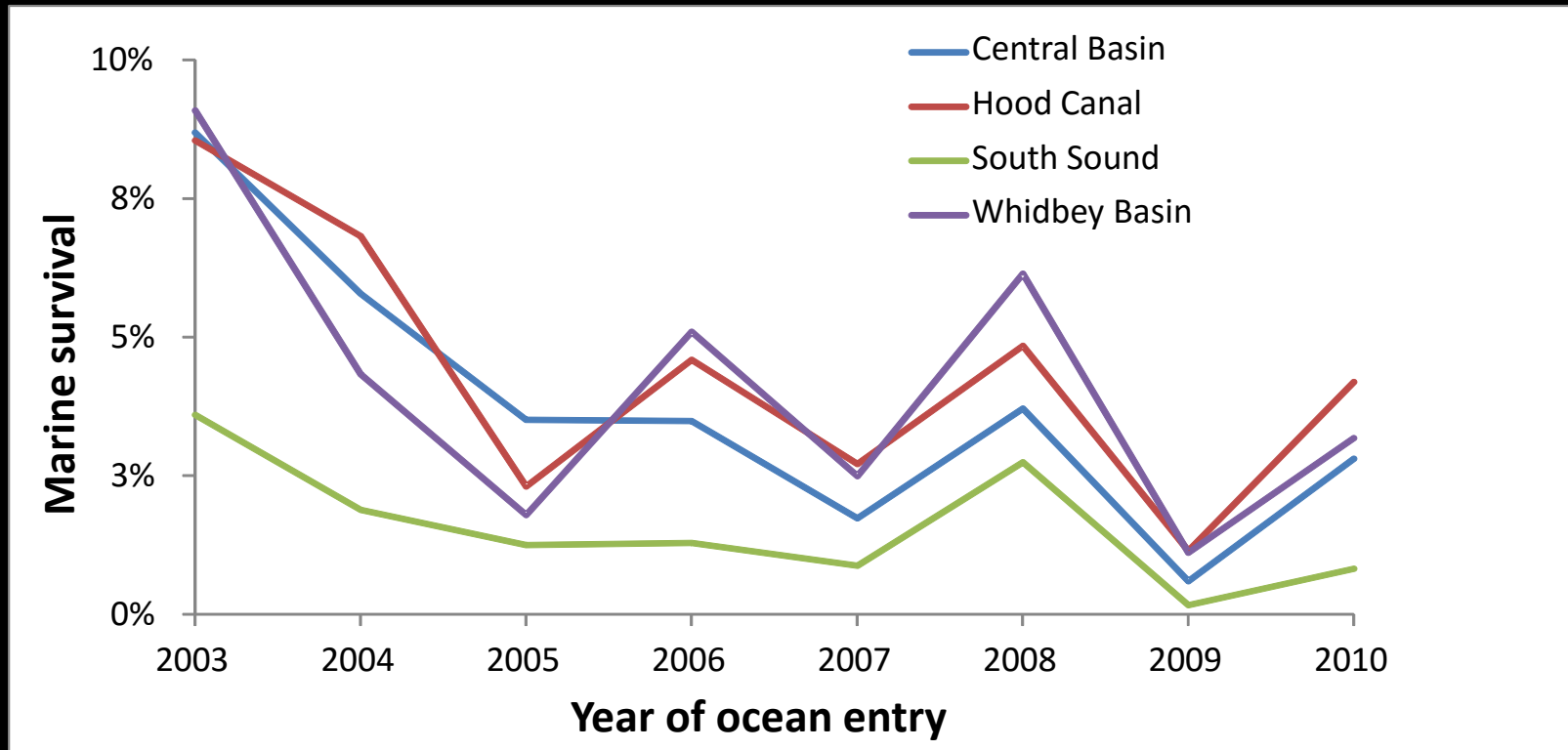
high-salinity
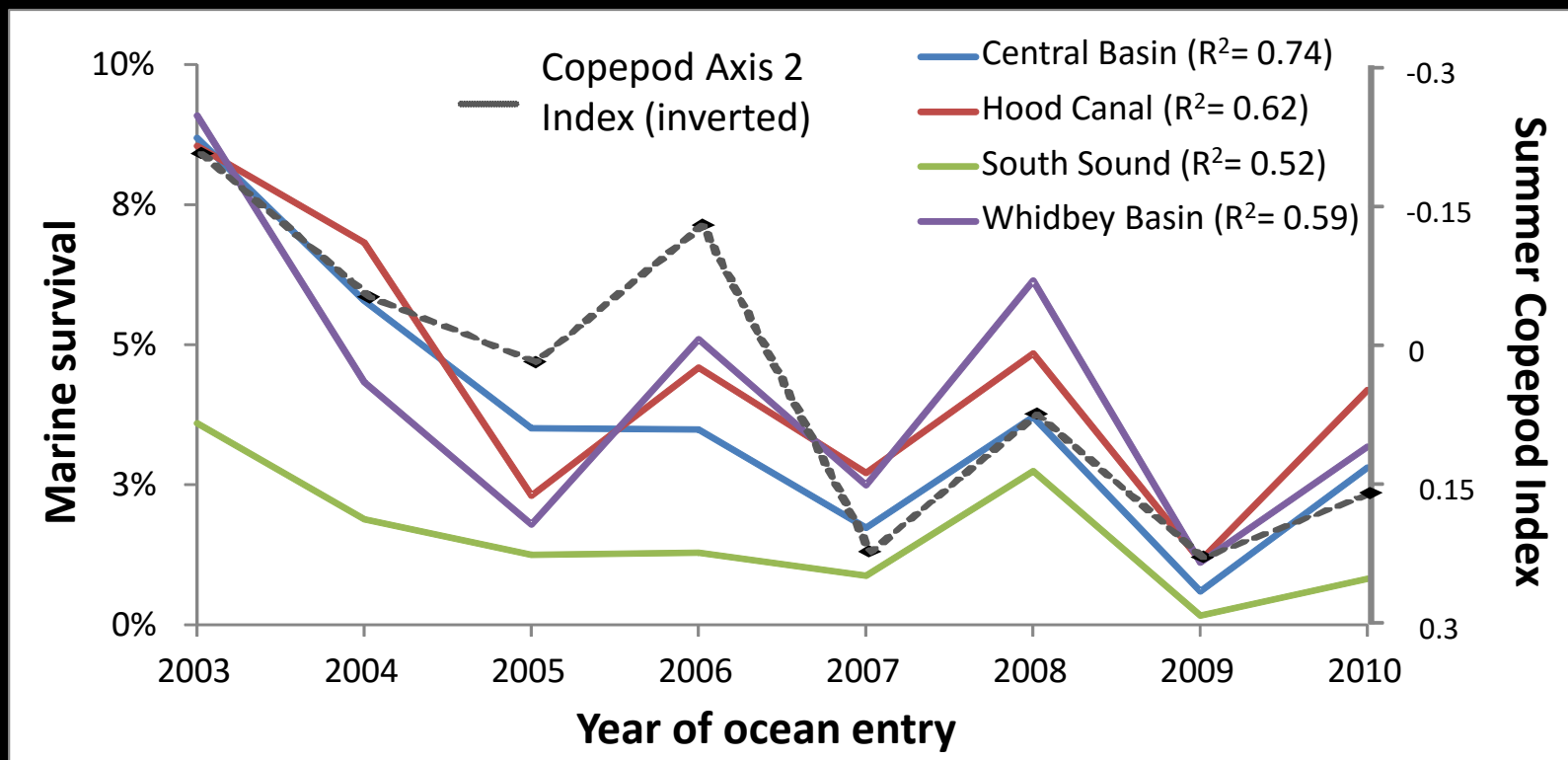
500+ m
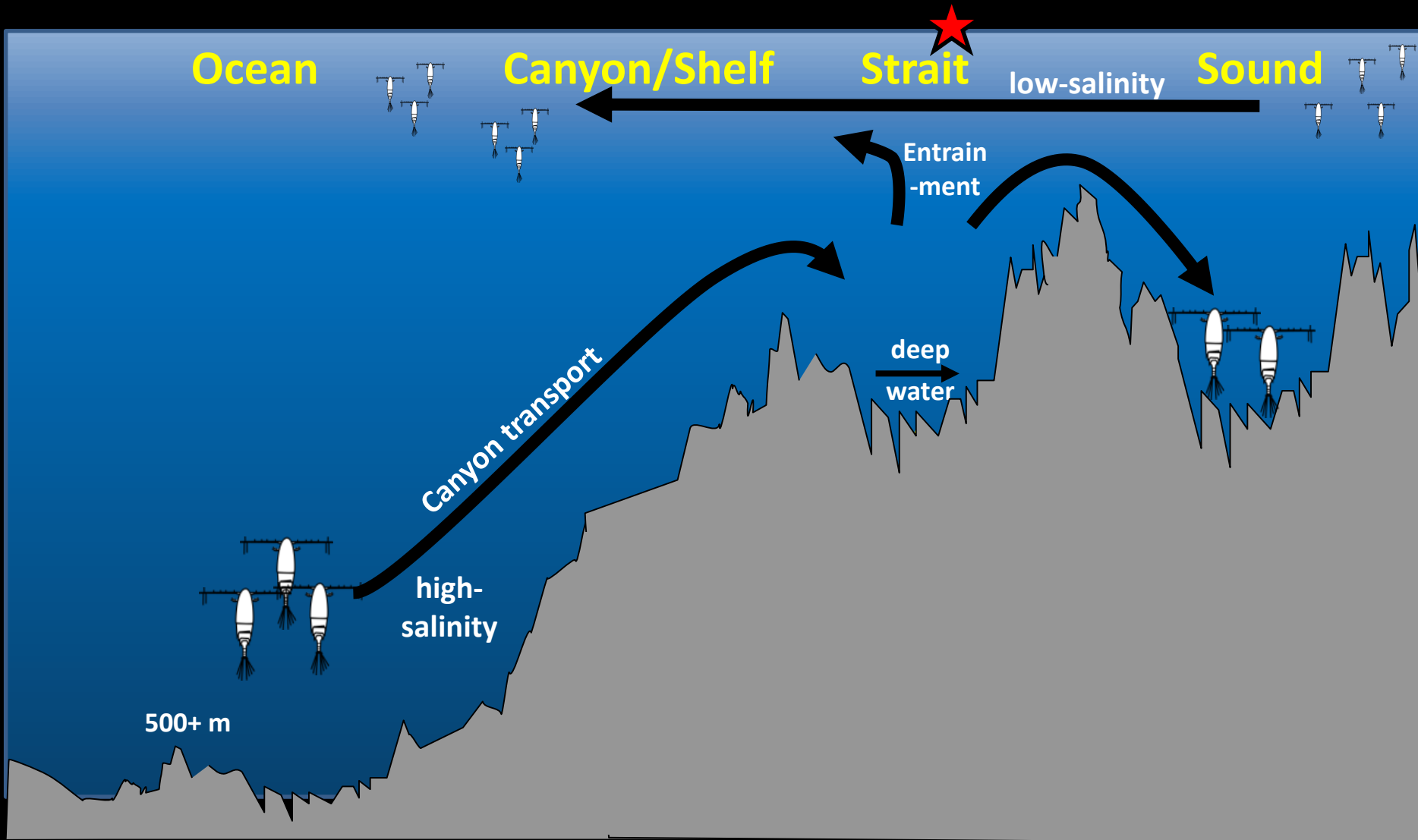
Axis 2 copepod community anomalies:
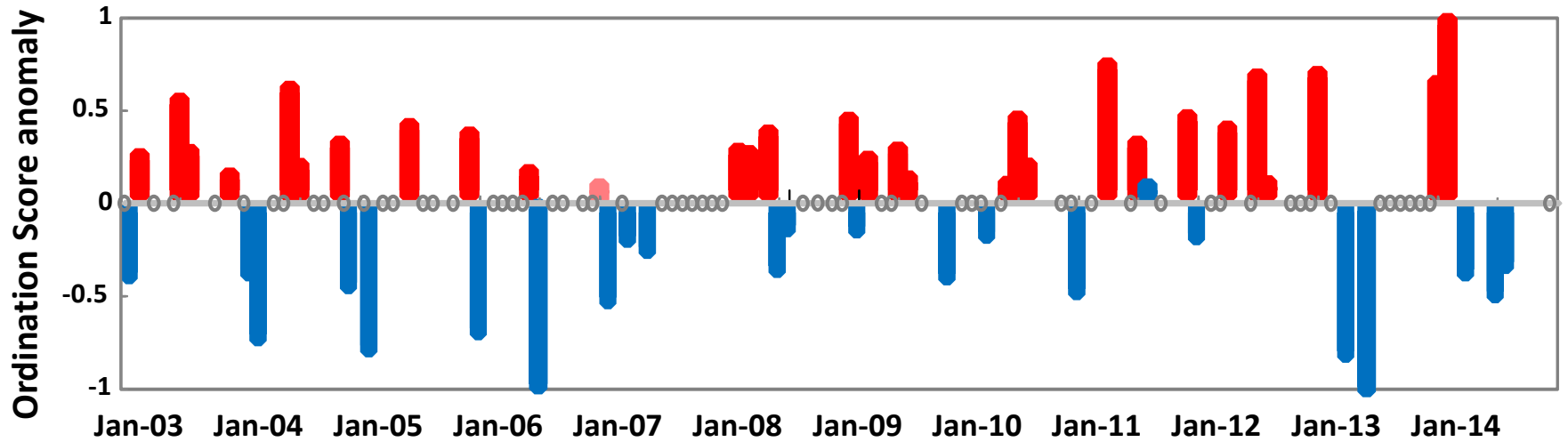
Coho salmon smolt-to-adult survival by marine entry year:

Zimmerman et al. 2015

Coho salmon smolt-to-adult survival by marine entry year:

Zimmerman et al. 2015

JEMS time series

- Correlates with climate indices

- Shows evidence of seasonal and interannual shifts in ocean-sound exchange

- Relates to salmon survival (good index?)

- Mechanisms of variability – still under study, but copepod behavior important!

Partnerships:

Thanks to:

- Friday Harbor Laboratories and the Shannon Point Marine Center for sampling
- WA Department of Ecology for funding the sampling
- Olga Kalata for conducting the taxonomy
- The University of Washington and the Salish Sea Marine Survival Program for funding the sample analysis