WG-23 and COVE

Prepared by Bill Peterson with some thoughts from Se-Jong Ju

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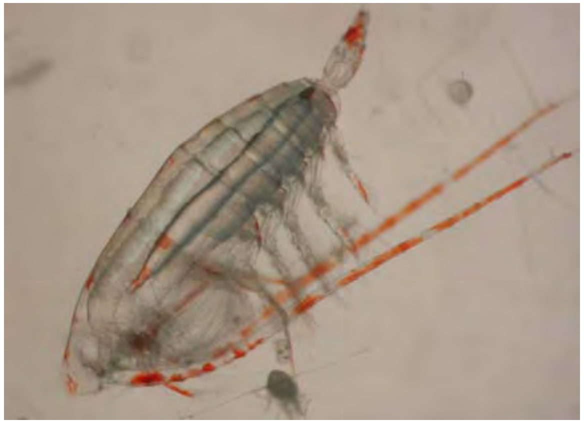


FUTURE and Climate Change: how does one study climate change?

- By modeling, using Global Climate Models, ROMS and coupled ROMS-Ecosystem models and GCM-Ecosystem Models

- By measuring and studying trends in physical and biological variables measured in long-term observations programs

- Through experiments on response of organisms to decreased pH (ocean acidification) and decreased oxygen (hypoxia)

COVE and WG 23

- The COVE Key Questions:
  - (1) What determines an ecosystem's intrinsic resilience and vulnerability to natural and anthropogenic forcing?
  - (2) How do ecosystems respond to natural and anthropogenic forcing, and how might they change in the future?

Size structure: *Euphausia pacifica*, large copepods (*Calanus*) and small copepods (*Pseudocalanus)*

COVE, Ecosystem Properties and Ecosystem Response

- COVE could take several approaches:
  - One approach is a focus on the ecosystem itself **(The holistic approach)**. In the past, through modelling, monitoring and retrospective analysis of data that already exists, groups within PICES have focused on how different *ecosystems* function (for example NEMURO, BASS and OECOS). Efforts like this could be continued but with a focus on <u>ecosystem response</u> to climate change. It would be really interesting to compare the Kuroshio with the California Current for example (project POBEX of DiLorenzo, Peterson, Chiba, Keister and others).
  - Another approach is to look at the species within the ecosystem **(The reductionist approach)** and focus on population response.

WG-23 Contributions

WG-23 ends in 2011. We are well-prepared to contribute ideas, data and new research to FUTURE on the following topics:

- **Population Dynamics**. How might climate change affect distribution, population dynamics and production of euphausiids (and other zooplankton)?

- **Modeling**: Krill (and copepods) in models is well developed

- **Trends:** trends in abundance of copepod and krill eggs, larval and/or adult abundance based on long term monitoring of eggs, larvae and adults as a function of changes in temperature, oxygen, pH, and transport pathways.

- **Response**: Experiments on the effects of reduced pH and Oxygen on development, growth and survival of krill eggs, larvae and adults

Modelling

- Much progress has been with modeling *Euphausia pacifica* and other zooplanklton in waters off N. Japan using NEMURO (Kishi and others)

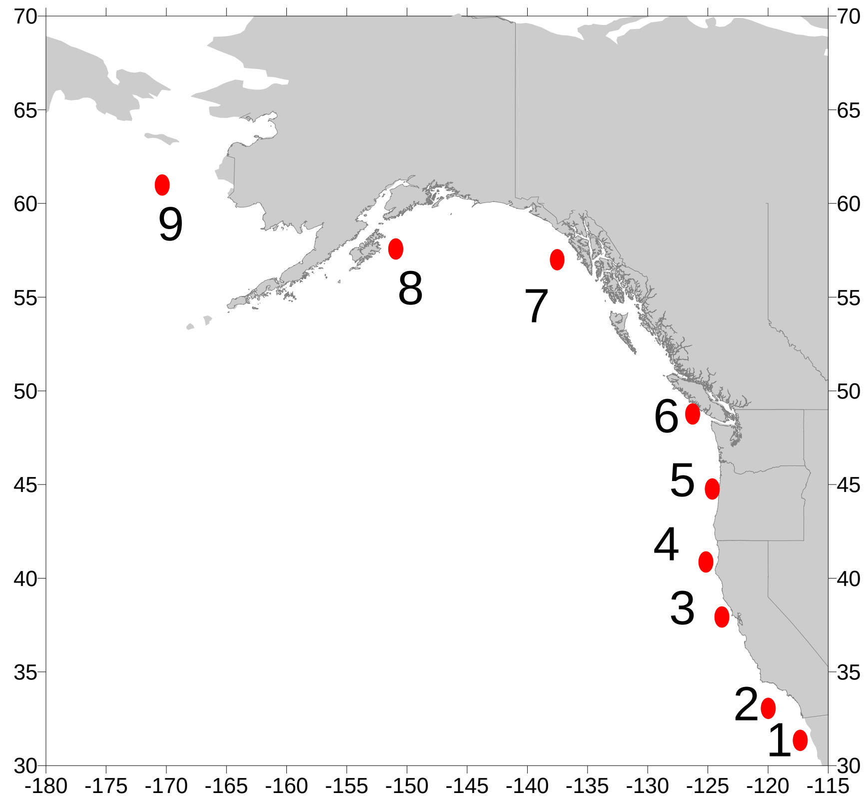
- The same is true for Oregon by Batchelder and students.

- In the U.S. the Geophysical Fluid Dynamnics lab in Princeton, has a simple coupled GCM-NPZ Ecosystem model (Rykaczewski and Dunne)

- I think work is being done to bring NEMURO into a GCM. Does anyone know the status of this effort?

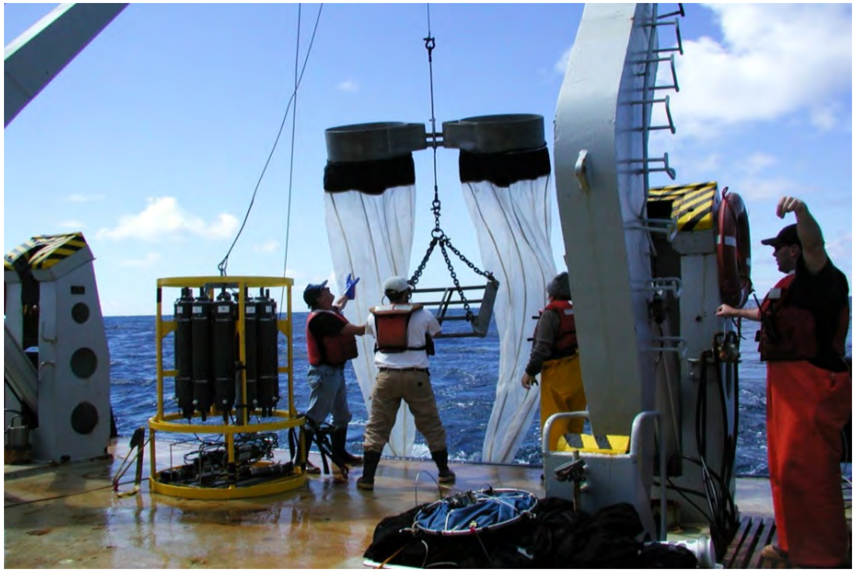
Trends (Time Series) of zooplankton sampling (including euphausiids) in the eastern Pacific

- 1. Baja Mexico: 14 years of sampling
- 2. CalCOFI: 60 years; data are available from May
- 3. Central California: Bodega Bay (two years); Gulf of the Farallones; Monterey Bay
- 4. Northern California: Trinidad (three years)
- 5. Newport Oregon (15 year time series)
- 6. Vancouver Island Canada (20+year time series)
- 7, 8. Gulf of Alaska (SE Alaska, 15 years; Seward Line 12 years)
- 9. Bering Sea. Not sure



Trends: Time series of zooplankton in the western Pacific

- Perhaps members of the audience can help make a list here:
  - A-Line
  - NE Japan (near Shiogama)
  - Southern Kuroshio
  - Japan/East Sea
  - Yellow Sea
  - Russian Coastal waters?
  - Sea of Okhotsk?

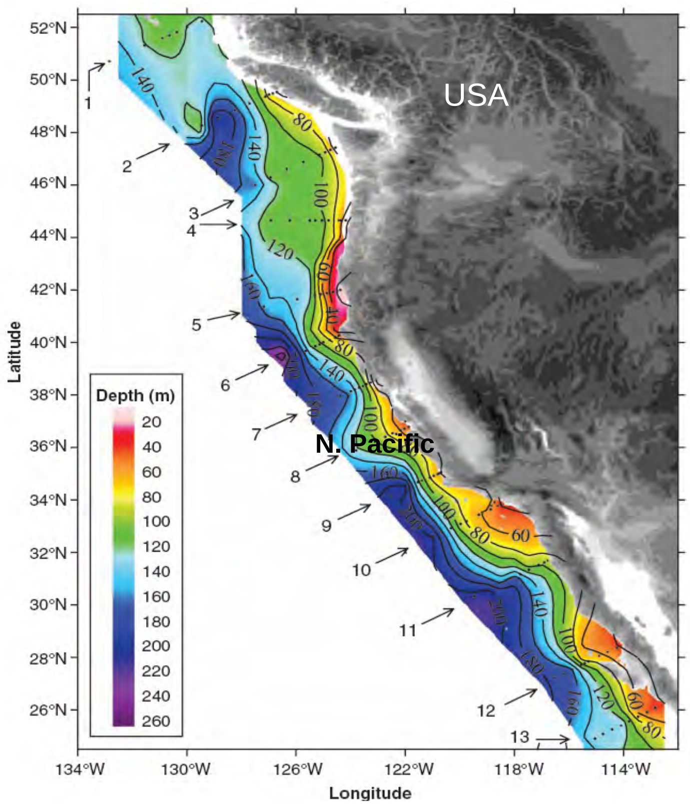


Research focused on hypoxia and ocean acidification

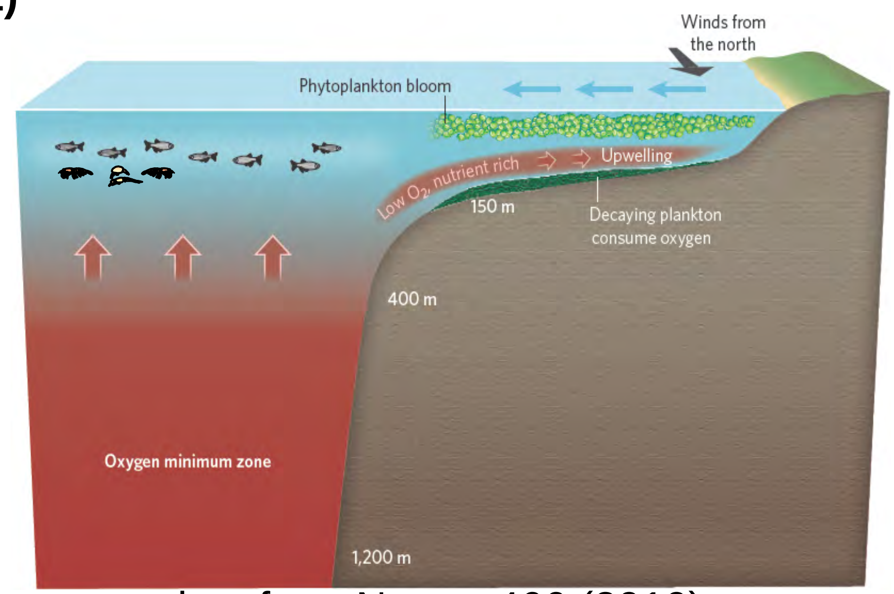
- California Current (two examples)
- Yellow Sea (one example)

Synergistic effects (Hypoxia + Acidification) in the California current region (Oregon coast) as considered as Natural laboratory (upwelling regions are more acidified and the OMZ (oxygen minimum layer is expanding)

Depth scale: where pH<7.75 (or Ωarg <1)



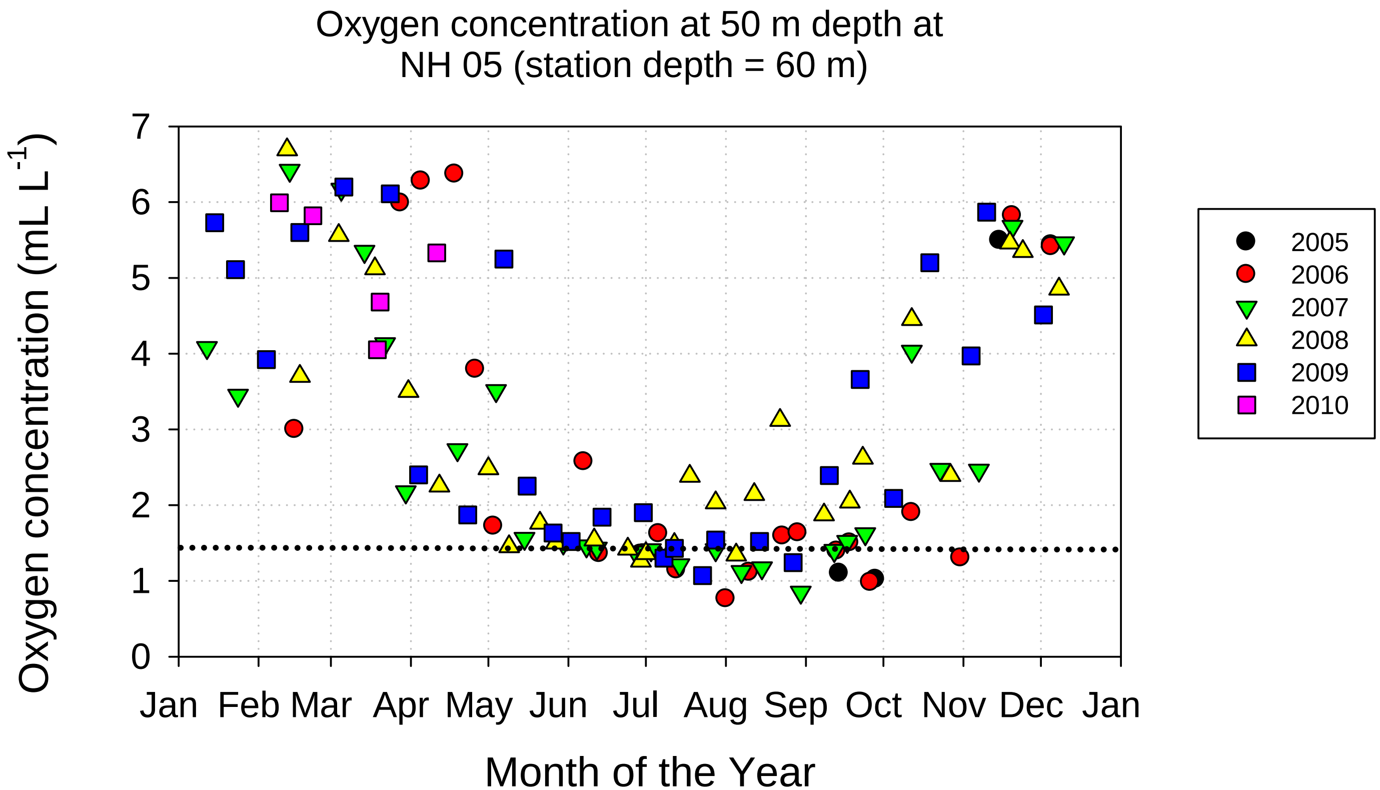
taken from Science 320 (Freely et al., 2008)



taken from Nature 466 (2010)

Courtesy: Se-Jong Ju

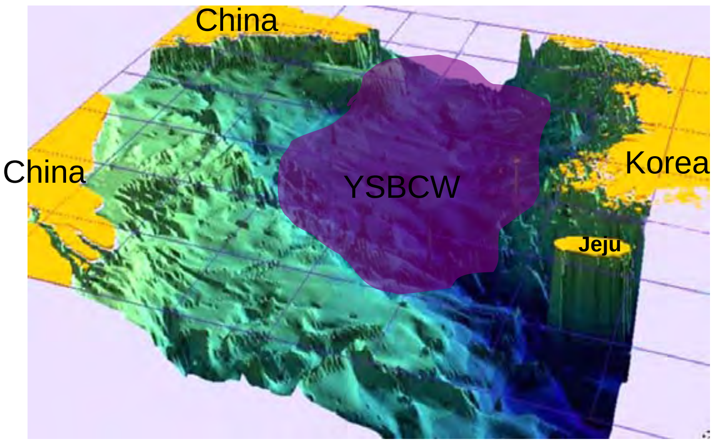
Seasonal cycle of Oxygen off Newport Oregon, a region with coastal upwelling



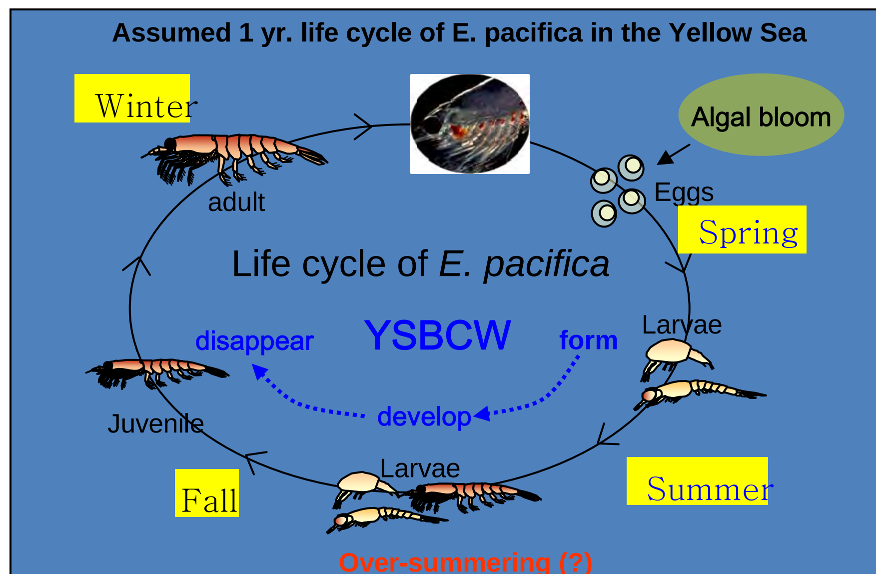
A double problem: during the summer upwelling season, upwelled waters have very low oxygen (often < 2 ml L^{-1}) and upwelled waters can have a pH of 7.8 units. Thus upwelling has a "dark side" (waters are hypoxic and relatively acidic). How will the ecosystem respond?

Current project (KORDI) - **Understanding the role of the Yellow Sea Bottom Cold Water (≤10°C) for *Euphausia pacifica* (distribution, population dynamics) in the Yellow Sea**

- How will interannual or decadal variation (reduction and/or enlargement) of the size of YSBCWM likely due to global warming affect the krill population in the Yellow Sea ?



The Yellow Sea Bottom Cold Water (YSBCW: ≤10°C) is a unique physical feature of the Yellow Sea. It forms through winter cooling and mixing and it is persistently observed in the deep central region during summer. Although the important role of YSBCM on physical and biological processes in Yellow Sea has been recognized, few studies have been conducted to understand its role on ecosystem. Particularly, it provides a refuge (i.e. over-summering sites) for some organisms (i.e. *Euphausia pacifica*) to survive through the hot summer (>20°C in surface).

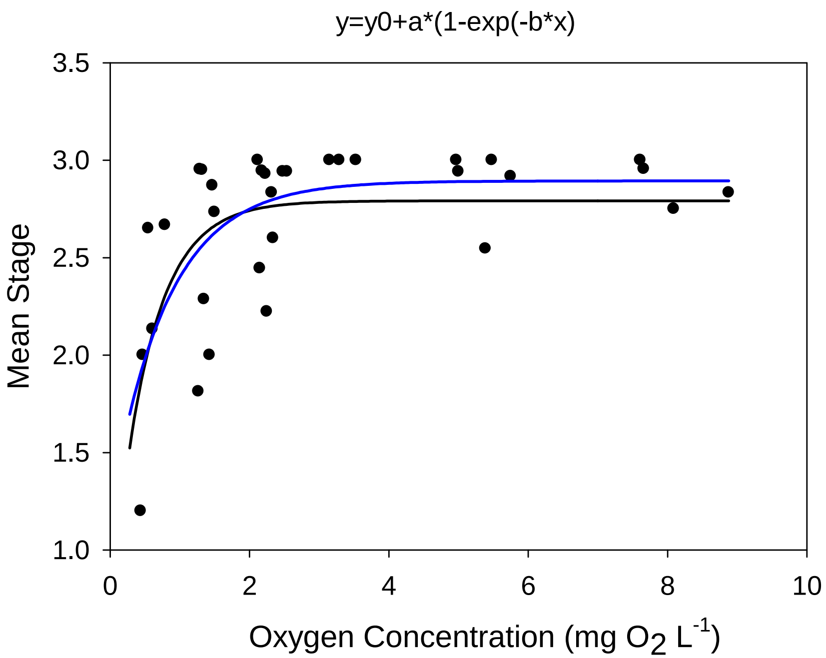


Courtesy: Se-Jong Ju

Examples from two simple experiments on effects of hypoxia and reduced pH on development of copepod and euphausiid larvae, carried out in the Peterson lab recently

Response (experiments on hypoxia)

Mean stage of *Calanus marshallae* nauplii vs. oxygen concentration



- Animals were maintained in waters of different oxygen concentrations for 7 days.
- At high oxygen concentrations, development is normal, with most nauplii reaching third nauplius
- At low oxygen concentrations (< 2 ml L^{-1}), development slows and at the very lowest concentrations (0.4 ml L^{-1}), most nauplii do not leave the first nauplius stage

Response – experiments on reduced pH

- Experiments were done this summer in the Peterson lab on effects of low pH on development of eggs & nauplii of *Calanus marshallae, Calanus pacificus* and on the eggs and early larvae of *Euphausia pacifica.* Range of pH was 7.2 to 8.2.
- Results are just now being worked up (we don't have any graphs yet) but we found that in every case development was slowed only very slightly (quite different from the hypoxia experiments) but we did find that some of the copepod nauplii and the euphausiid calyptopis stages were deformed. This suggests that although development rates are not affected, there is an effect on the developmental process at the cellular level.

Conclusion

- These are exciting times because climate change as caused by global warming is upon us, and as a result provides many natural experiments;
- Now we must work hard on this problem to understand how marine ecosystems might change in the future.
- We must keep in mind that the future is now!
- And remember that FUTURE is also now!