ZOOPLANKTON IN UPWELLING AND COASTAL SYSTEMS

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Pucón, Chile

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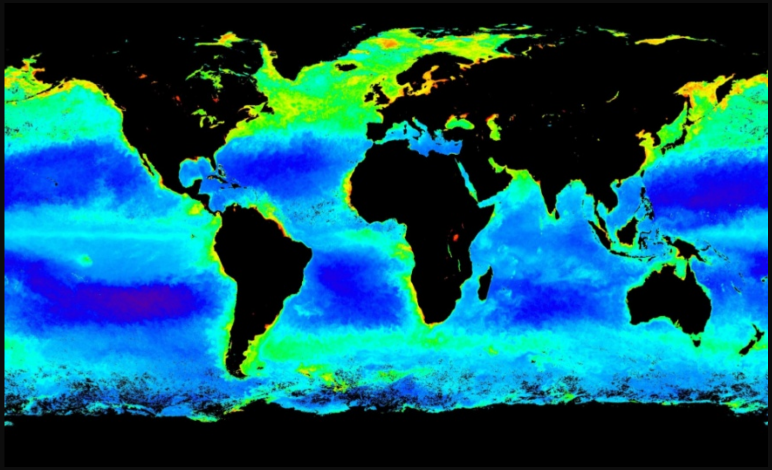
Outline

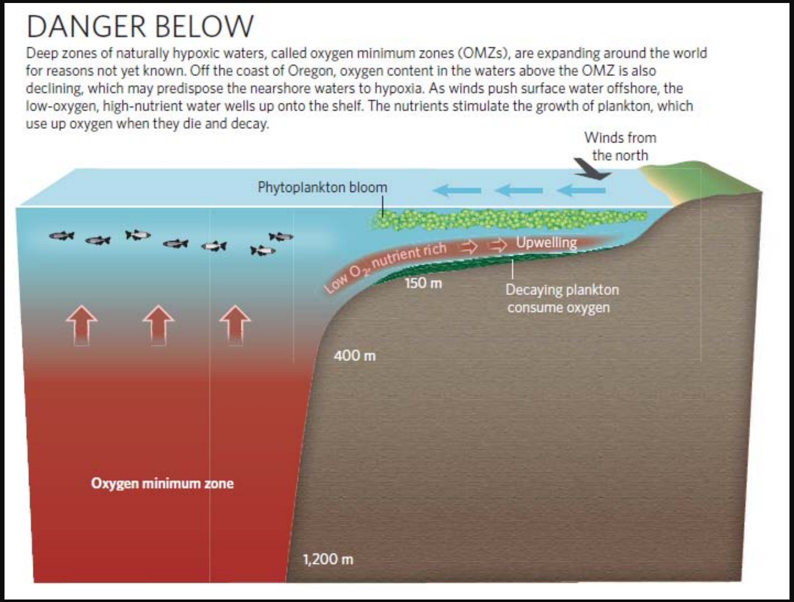
1. The importance of coastal and coastal upwelling systems
2. Role of zooplankton in coastal/upwelling systems
3. What are we currently learning on zooplankton from these systems
4. What are some key pending or future issues
5. Summary and conclusions

1. Coastal upwelling systems

- They cover about 7% of surface ocean, but account for 15-30% of ocean PP (Bozec et al. 2005).
- Highly energetic zone: everything goes fast, or changes occur rapidly compared to oceanic regions. This may imply rapid responses to perturbations
- Biological processes all become greatly enhanced
- They are regions of convergence: land, ocean, humans, marine life
- Key processes take place: upwelling, rising of OMZ systems, increased cycling of C, N, enhanced harvesting and fishing, pollution
- They have been historically the main target areas for research: sampling, field observations and experimental work.

1. Coastal/upwelling systems





Gewin, 2010 Nature

FACTS:

❖Coastal systems are heavily exploited by us and no doubt they are suffering dramatic changes since the human era.

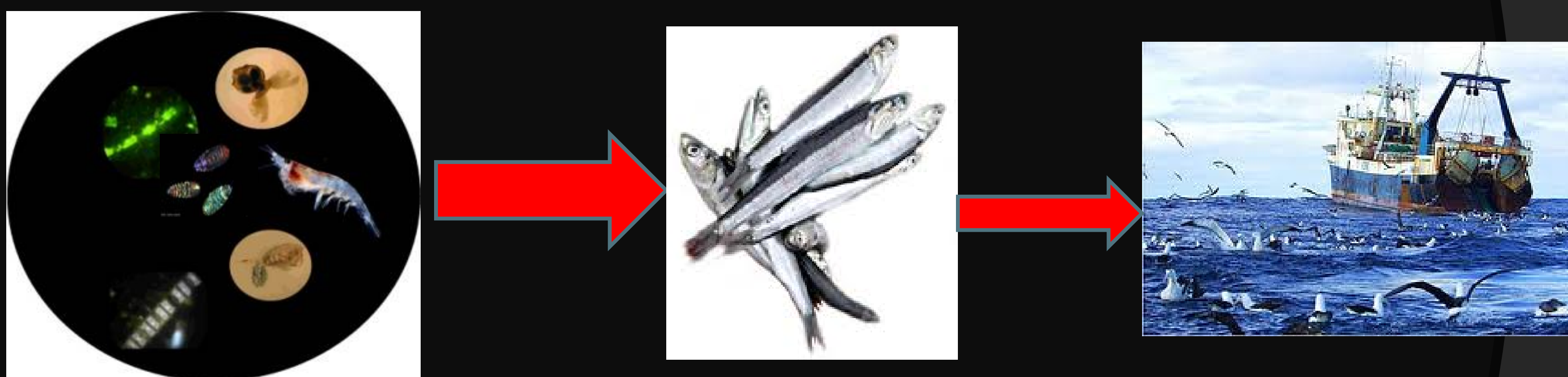
❖Despite being the most investigated regions of the ocean, we are still unable to sufficiently understand the key biogeochemical processes for suitable management and predict their responses to natural or anthropogenic perturbations.

❖Climate change may drastically modify coastal systems by expanding suboxic/anoxic zones, increase stratification, reduce nutrient input , reduce biological production and change communities.

❖Biological oceanography faces a huge challenge as to be able of providing good science and knowledge to advice policy makers and public for taking actions for maintaining environmentally healthy coastal systems

2. Role of zooplankton in coastal/upwelling systems

Zooplankton is the main prey for fishes…Key role regulating fish recruitment and production of fish biomass. Many country economies are highly dependent on fish production



2. **¡But not only fish!**

Feeding top predators

2. Also feeding the rich coastal benthic system

Passive sinking

(Dead animals, Faecal pellets)

Active migration (Respiration, excretion, defecation mortality at depth)

BENTHIC SYSTEM

2. Strong Impact on the C budget of coastal regions

CAPTURE

RETENTION

CHANNELING

How do we know that?

FEEDING PROCESSES

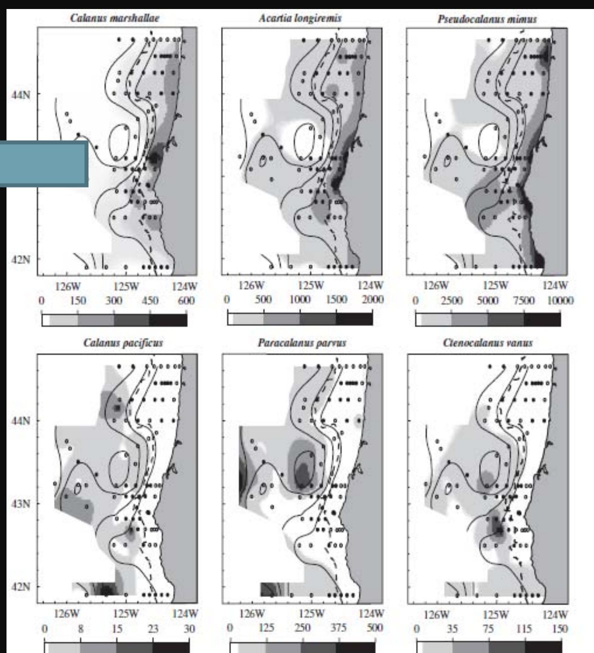
BIOMASS AND PRODUCTION

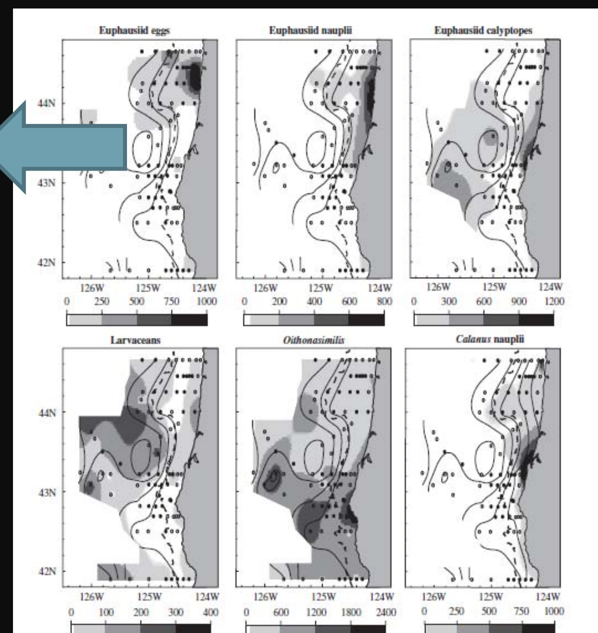
FOOD WEB AND C FLUXES

3. What are we currently learning on zooplankton from coastal/upwelling systems?

Key role for lateral transport: feeding the offshore oligotrophic regions

Cross-shelf transfer of C induced by upwelling
Northern California Current

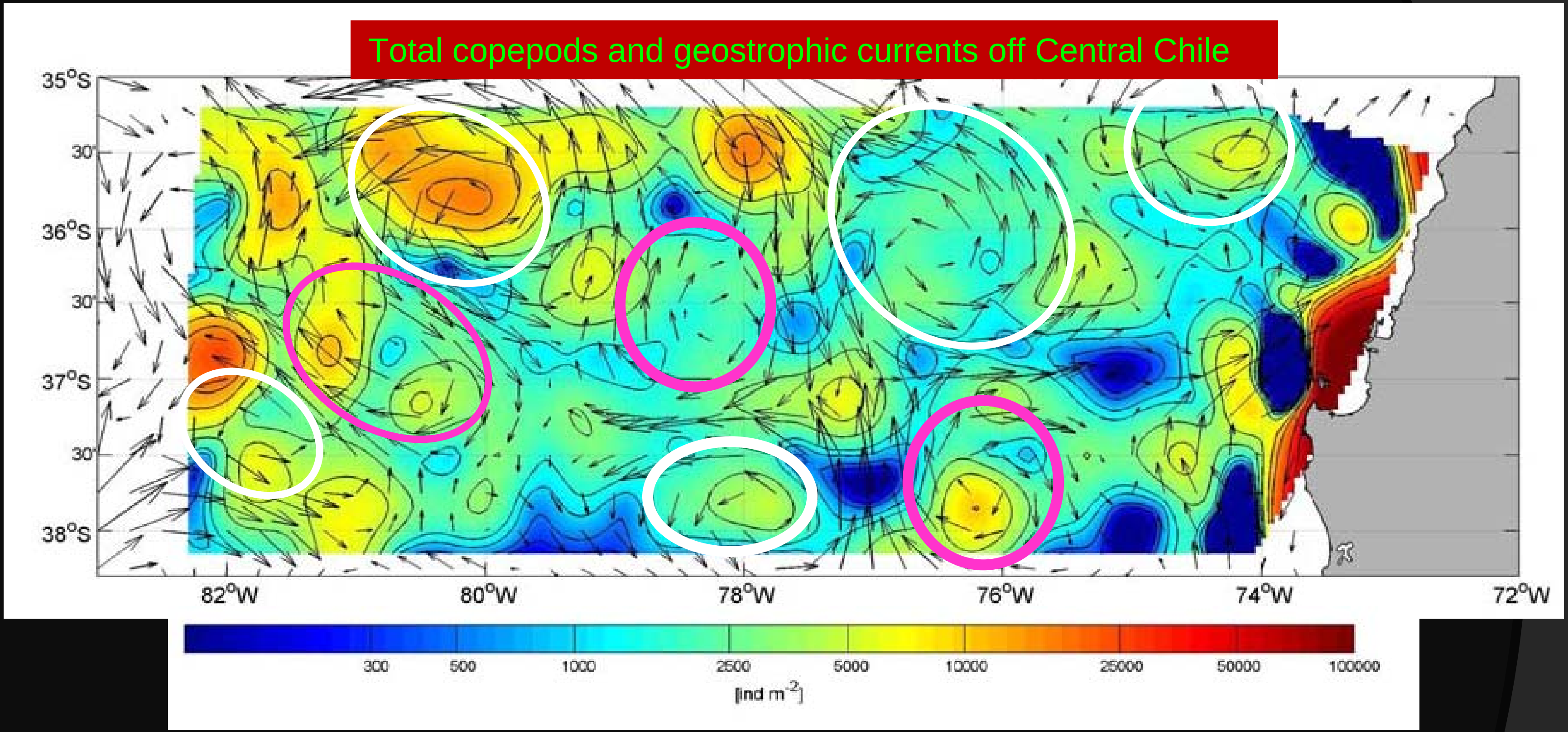




That flux equated to offshore transport of >900 metric tons of carbon each day, and 4–5 × 10^4 tons over the 6–8 week lifetime of the circulation feature. Thus, mesoscale circulation can create disparate regions in which zooplankton populations are retained over the shelf and biomass can accumulate or, alternatively, in which high biomass is advected offshore to the oligotrophic deep sea.

Keister et al. 2009 DSR-I

3. Exporting not just C, but also diversity to oceanic regions



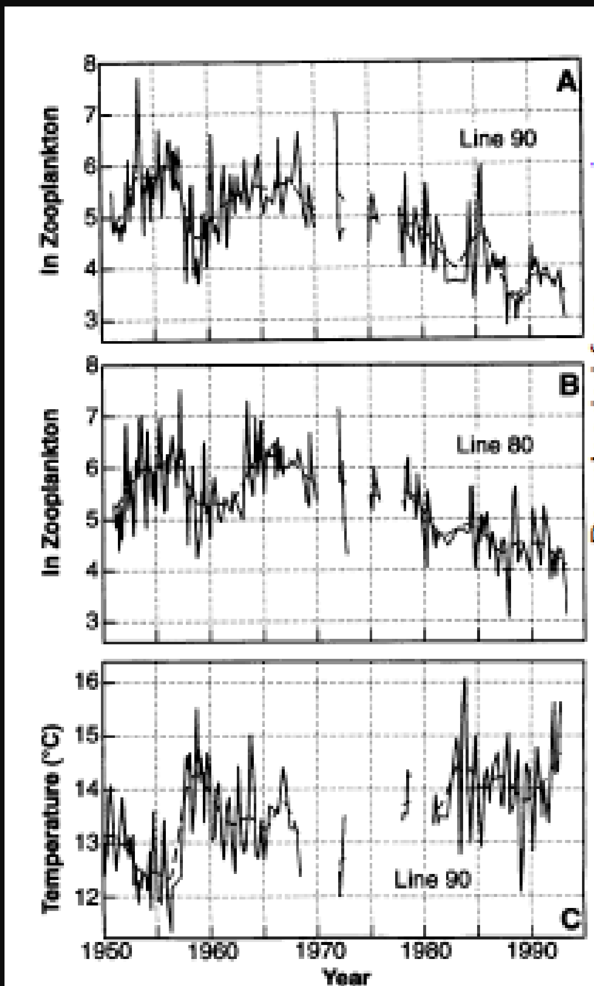
Anticyclonic eddy

Cyclonic eddy

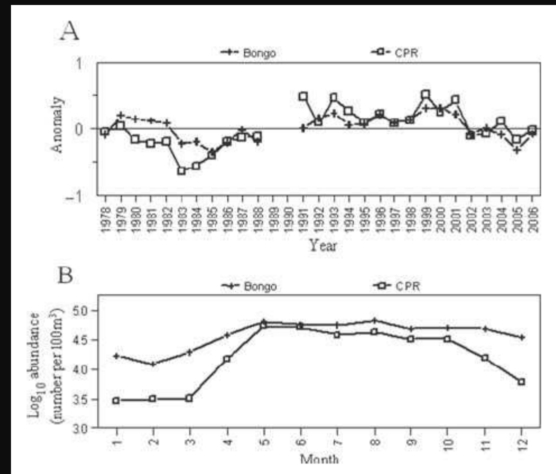
Morales et al. (2010) PIO

3. Zooplankton react to climate change, both in abundance and structure

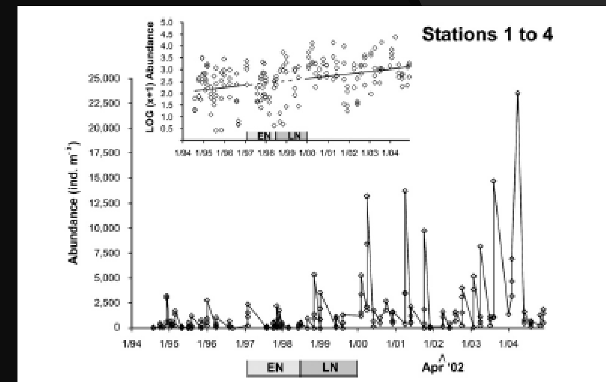
Zooplankton decline



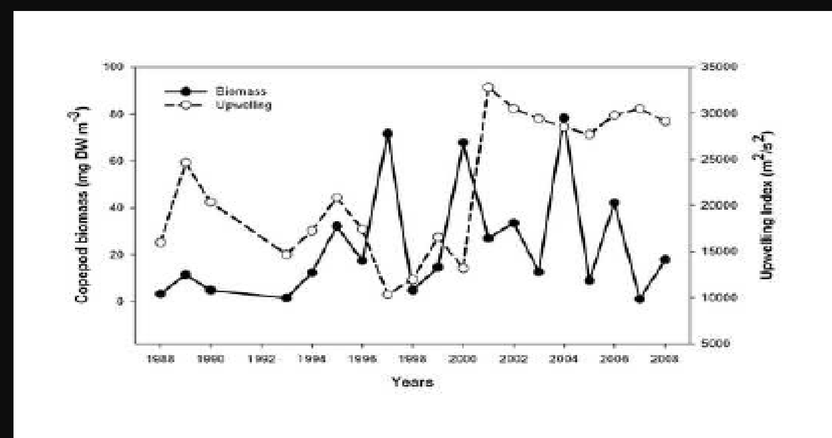
Roemmich & McGowan 1995 Science



Gulf of Maine: Kane, 2009 JPR



Northern Peru: Arones et al., 2009 JMS



Off Chile: Escribano et al. (under review PIO)

Changing but not clear trends!

THE IMPORTANCE OF TIME SERIES OBSERVATIONS

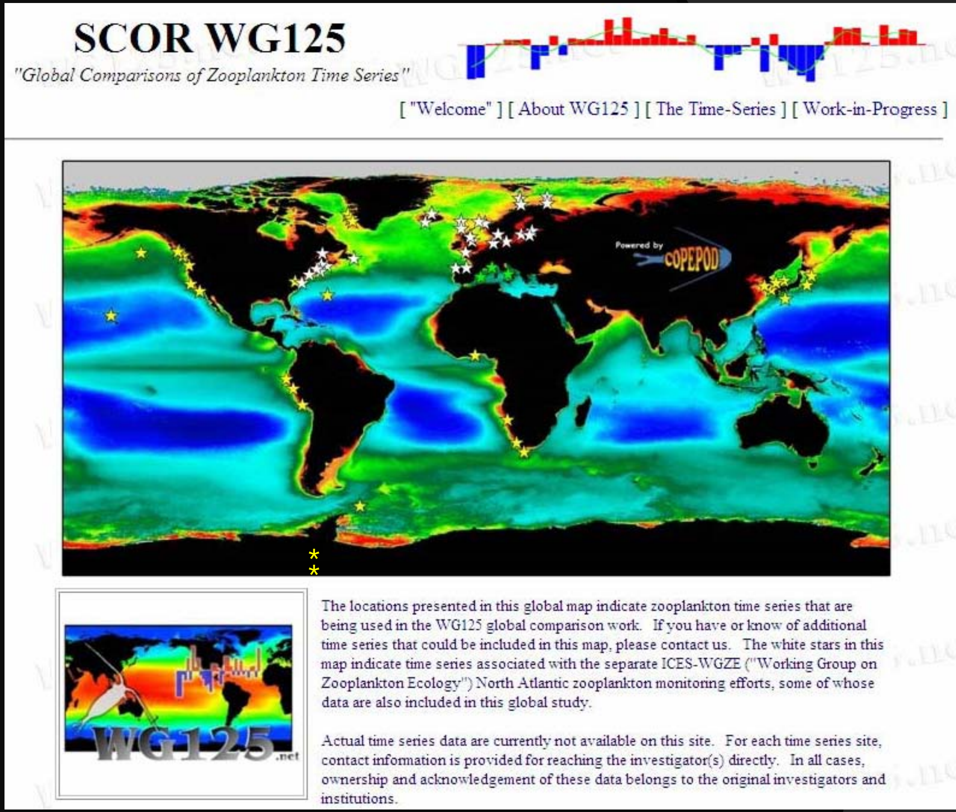
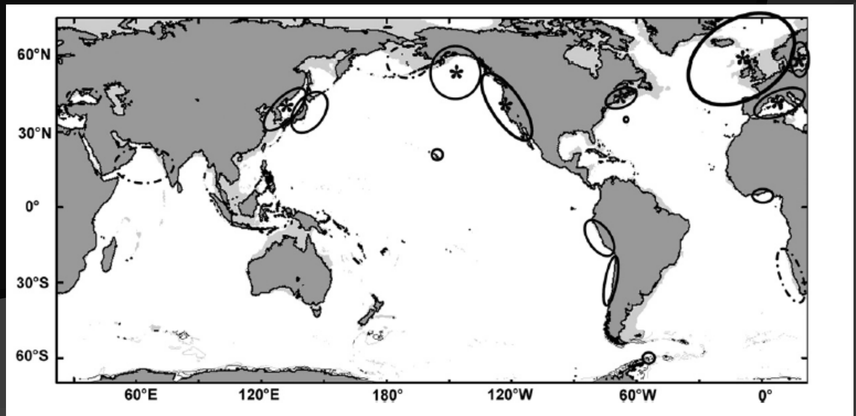


Table 1: Available *in situ* biological data sets

Data Set	Location/Resolution	Time	Properties
CalCOFI	Southern CCS; usually quarterly	1949 – pres. 1984–pres (chl)	Nutrients, chl, pp profiles; zoo biomass+ ichthy species
GLOBEC LTOP	Oregon shelf to 85 miles offshore; quarterly. Gulf of Alaska, along Seward Line.	1997 – 2005, 2007	CTD, nutrient and chl-a profiles, zooplankton species
Newport Line	Newport shelf and slope (quarterly) Newport shelf and slope; ~ monthly	1961-1972 1963-1967	Nansen bottles and reversing thermometers. Krill species
Newport Line	Oregon shelf and shelf break bi-weekly, 7 stations (1 to 25 miles from shore)	1969-1972; 1996– pres.	1969-72 SST only. 1996-present CTD, chl-a, nutrients, zoopl species
Newport Line	Oregon shelf, biweekly, summer	1973,78,83, 90-92	Zoopl only
Washington and Oregon shelf	6-7 stations along 7-8 transects between northern WA and central OR	2x/summer 1998-pres. 1981-1985.	CTD, chl-a and nutrients, zoop. species, trawls for pelagic fish & juv. salmon).
Stn PAPA	N. Pacific subarctic gyre, 3x/year	1956-pres.	Zoopl biomass
BC shelf	Vancouver Island southern shelf, quarterly	1985-pres.	CTD, chl, nutes, zoo species
Odate	Western N. Pacific, Kuroshio Oyashio, transition regions, monthly	1951-pres.	CTD, chl, zoopl species
Hokkaido University	Western / central subarctic Pacific, annual	1953-2001	Oshoro-Maru zooplankton Time series
Japan Nat. Fish. Res. Inst.	W. Subtrop. Pac., Kuroshio, 5-8 x per year	1971-pres.	Zoop, fish egg, larvae surveys
Hokkaido Nat. Fish. Res. Inst.	W. Subarctic Pac., Oyashio, 5-8x / year	1987-pres.	Line A monitoring, zoopl.
IMARPE	Peru upwelling region, seasonal	1964-pres.	zooplankton
IFOP	Northern Chile, cross-shelf surveys, seasonal	1985-pres. 1996-pres (chl)	Zooplankton, www.IFOP.cl
Antofagasta research	Northern Chile coastal, at least annually	1991-2003	zooplankton
COPAS	Central Chile, off Concepcion	2002-pres.	CTD, nutrients, chl-a, zoop

GLOBEC PAN Regional Collaborative Project

May be longer time series are needed and better coverage



Mackas & Beaugrand al., 2010

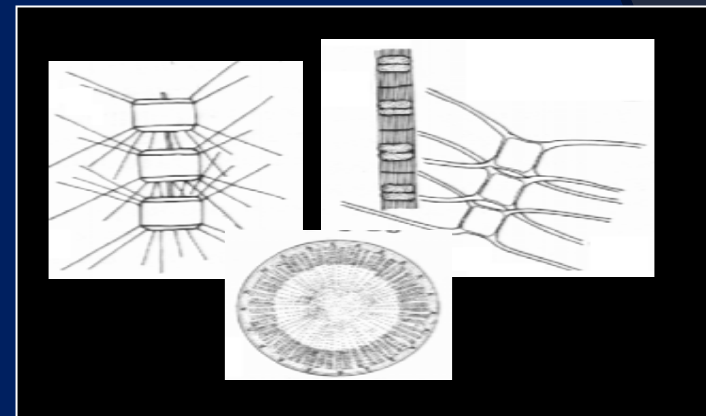
3. What are the pathways for C flux in the pelagic food web of coastal highly productive systems

¡not what we used to believe!

<5%

HERBIVORY

Classical



BACTERIA

MICROBIAL

>20%

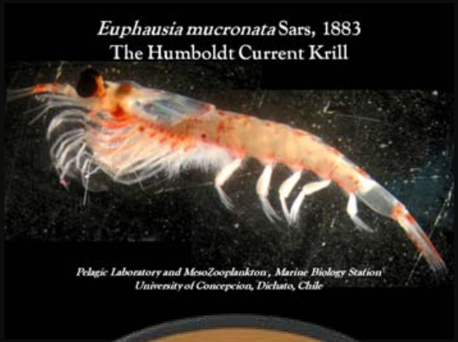
NANNO- MICROHETEROTROPHS

OMNIVORY

Vargas et al., 2007 L&O
Poulet et al., 2007 JEMBE
Aguilera et al., 2010 JMBR
Escribano & Perez, 2009 JMBA

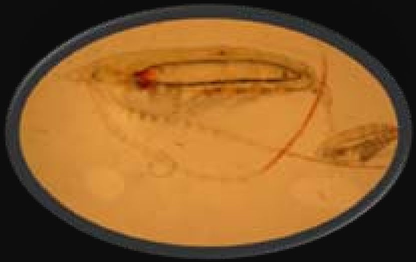
3. Small size vs large size zooplankton for controlling biomass and production

Size structure of zooplankton may have strong impact on biogeochemical processes and also affect the prey field for predators



Euphausiids

Calanidae



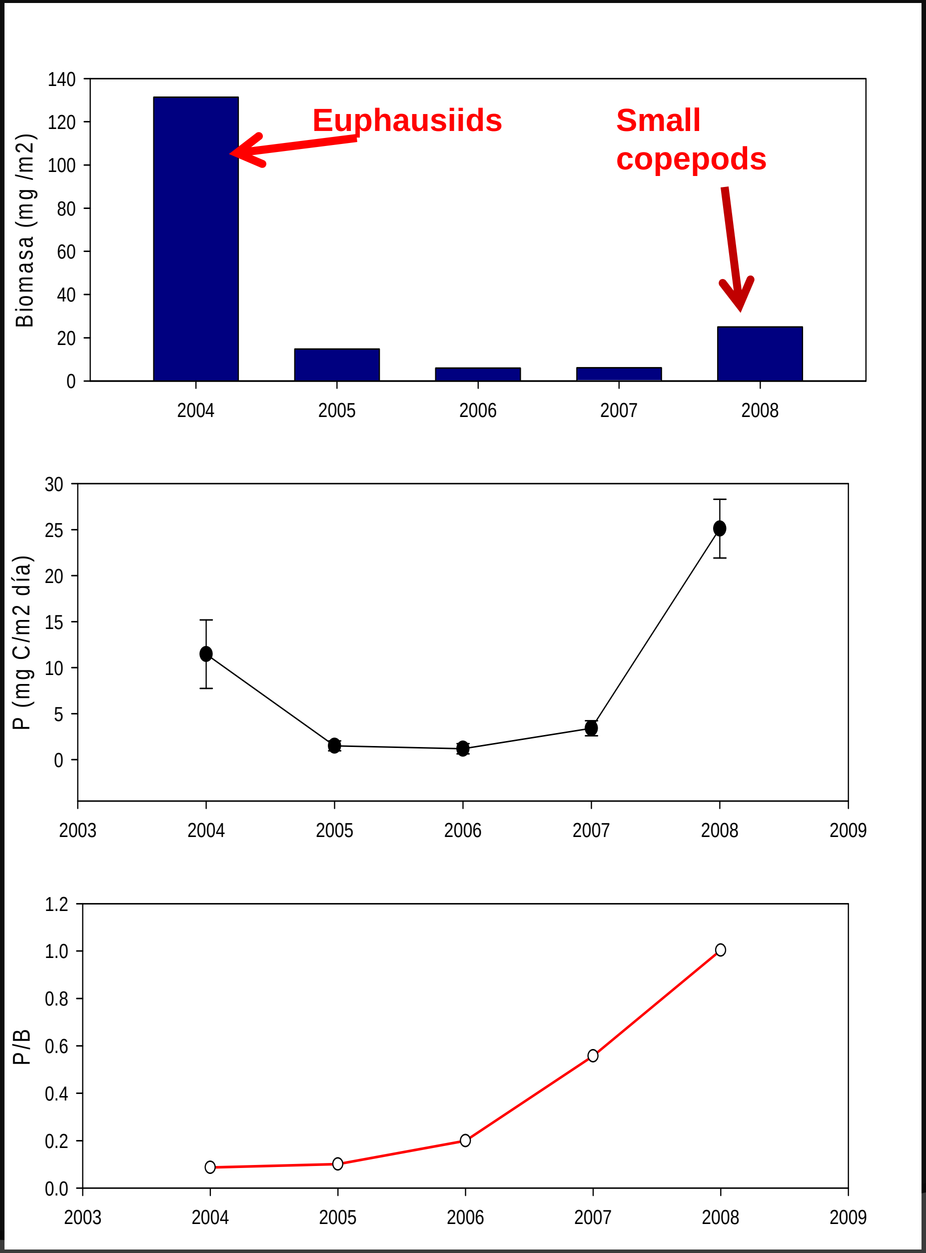
Eucalanidae

Acartidade

Paracalanidae

Oithonidae

Zooplankton production in the upwelling zone off Chile



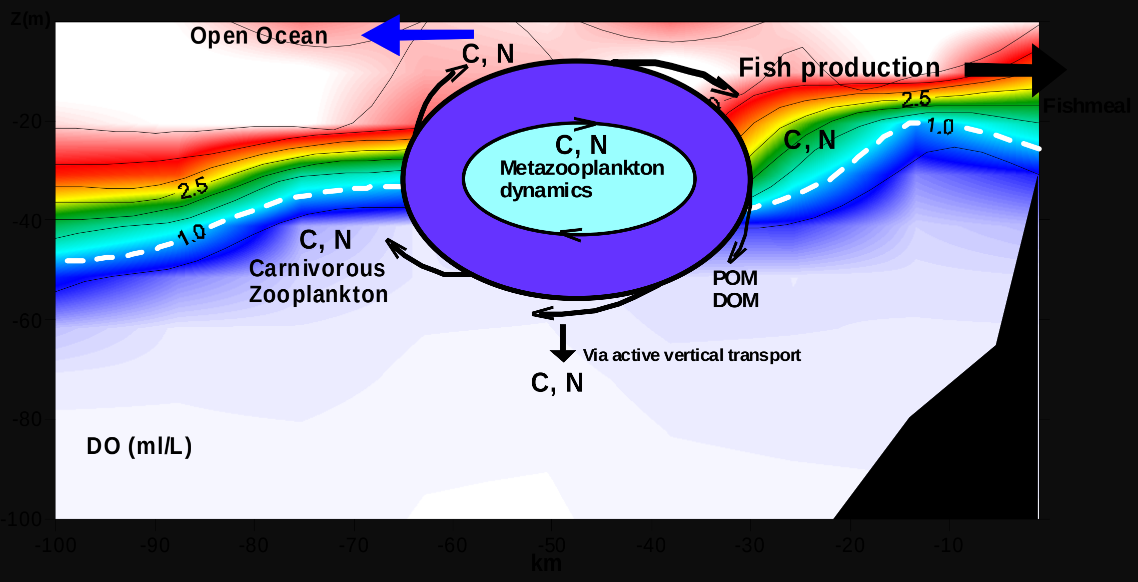
Interannual variation and the importance of the size-community structure

Small copepods account for most production of biomass

Size structure has a strong impact on zooplankton production

Escribano et al. (In prep.)

3. The impact and role of OMZ systems on zooplankton in the coastal zone



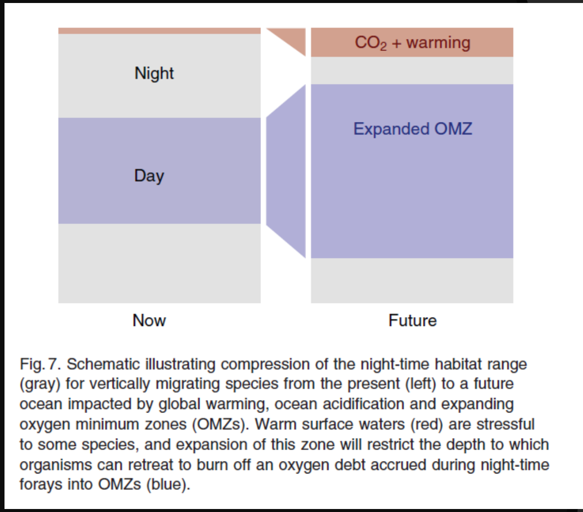
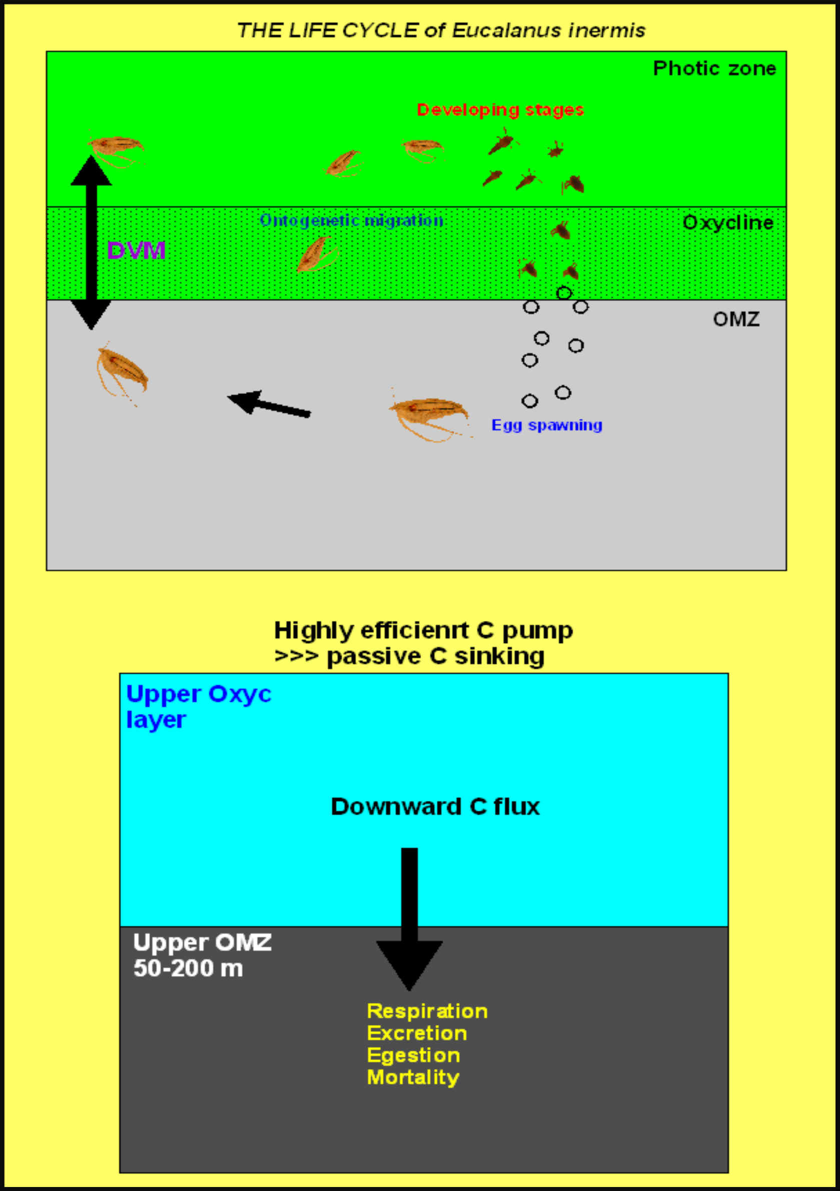


Fig. 7. Schematic illustrating compression of the night-time habitat range (gray) for vertically migrating species from the present (left) to a future ocean impacted by global warming, ocean acidification and expanding oxygen minimum zones (OMZs). Warm surface waters (red) are stressful to some species, and expansion of this zone will restrict the depth to which organisms can retreat to burn off an oxygen debt accrued during night-time forays into OMZs (blue).

Seibel 2011

- **Most zooplankton inhabits the upper highly oxygenated layer**
- **Habitat compression upon OMZ ascent may imply more aggregation in the mixed layer and so enhancement of C flux, because of increased trophic interactions (Manriquez et al. 2009 JPR)**
- **Expansion of the OMZ may constraint habitat of epipeplagic zooplankton, but also increase biological interactions?**

Other species may use the OMZ system (avoiding predation?)



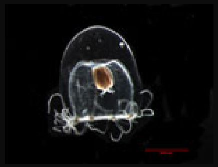
Hidalgo & Escribano, 2007

Ontogenetic migration into the OMZ

Late stages (C4, C5 and Adults) perform DVM

This behavior may provide an efficient mechanism for downward flux of C (if copepods are metabolically active in the OMZ)

4. Pending or future issues



In coastal zones zooplankton is changing upon climate change

Zooplankton may also be shifting towards small-sized organisms?

¡HONEY WE SHRUNK THE PLANKTON!

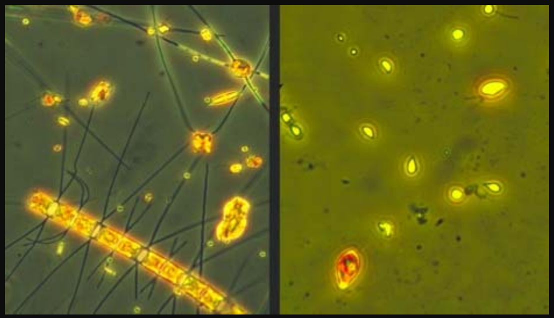
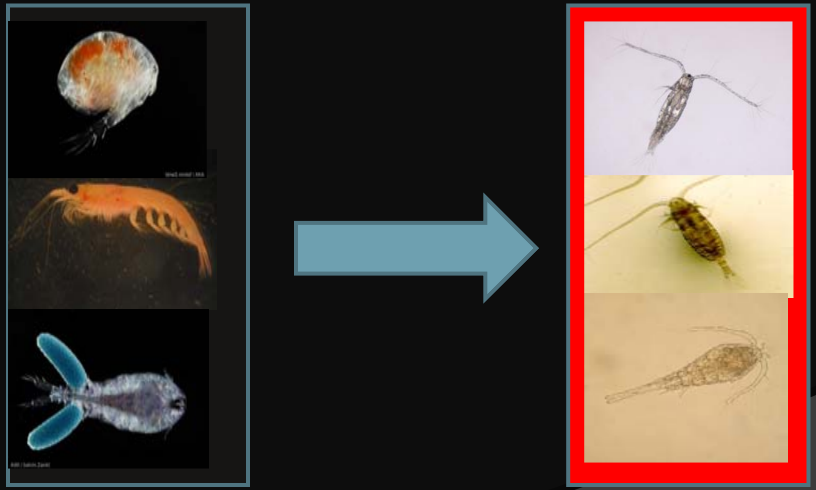


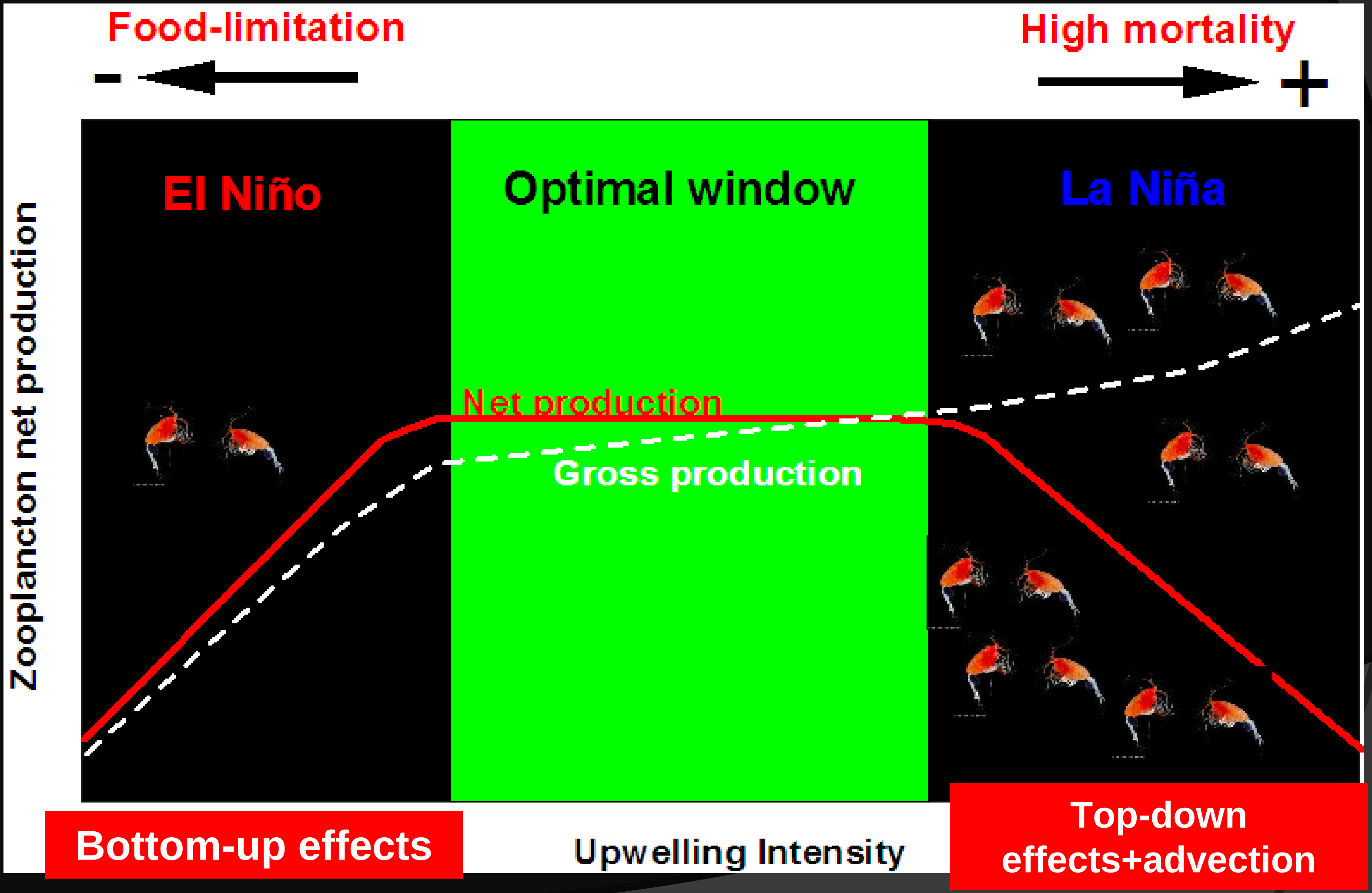
Image credit:IFM-GEOMAR, via PhysOrg.com



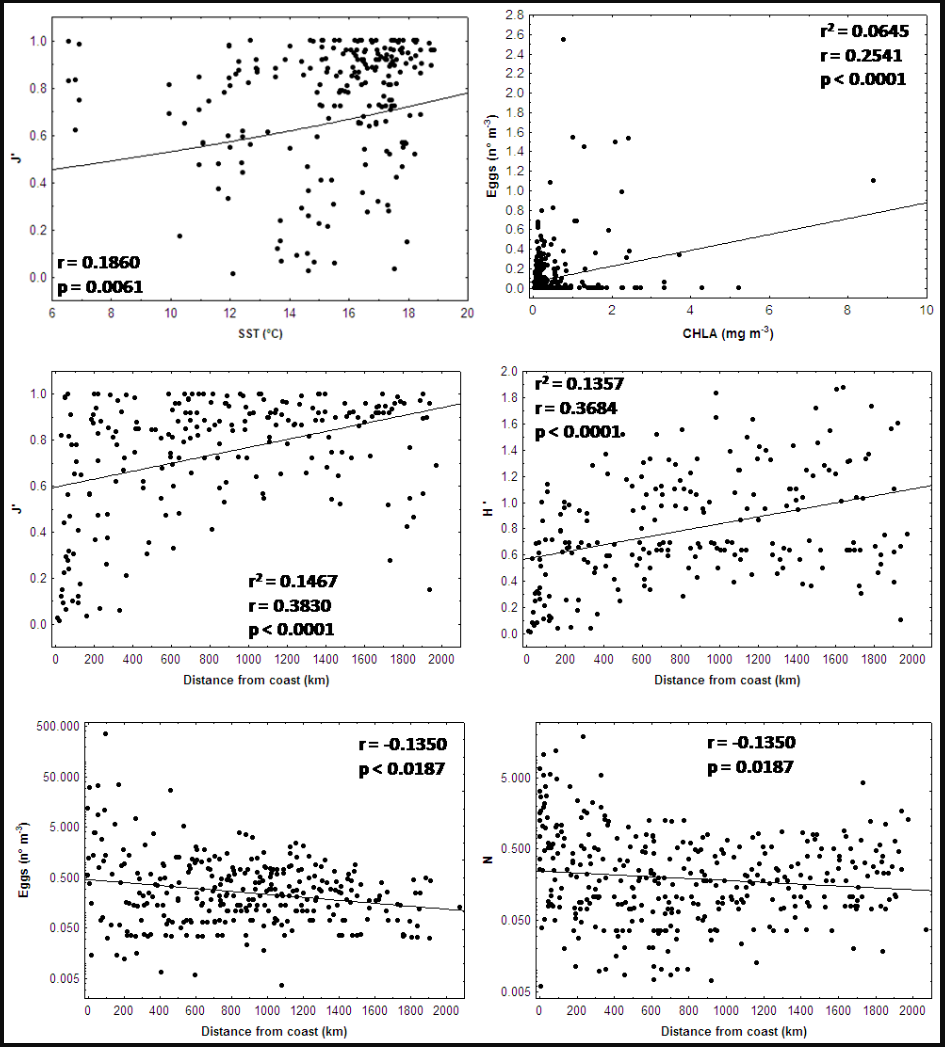
Or maybe individual body size is responding to altered temperature regimes?

4. Pending or future issues

Zooplankton and upwelling intensity



4. What is the impact of increased upwelling on diversity?



Euphausiids off Central/southern Chile

1) Weak but significant correlation with upwelling variables

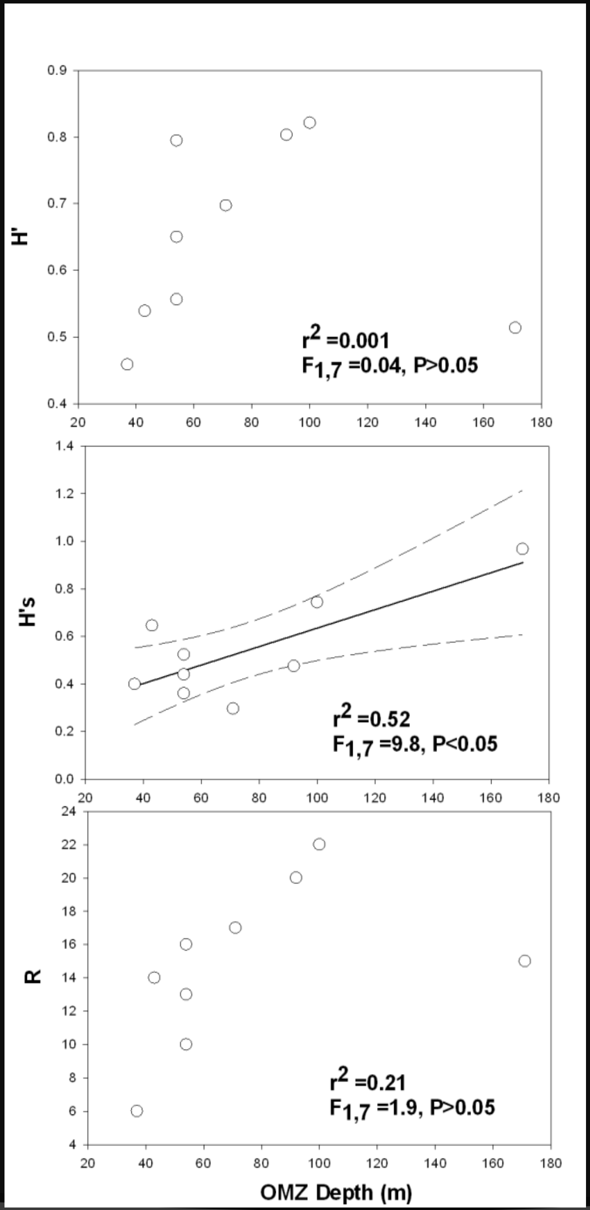
2) Diversity higher towards offshore, then negative correlation between diversity and abundance

3) > Abundance in the coastal zone

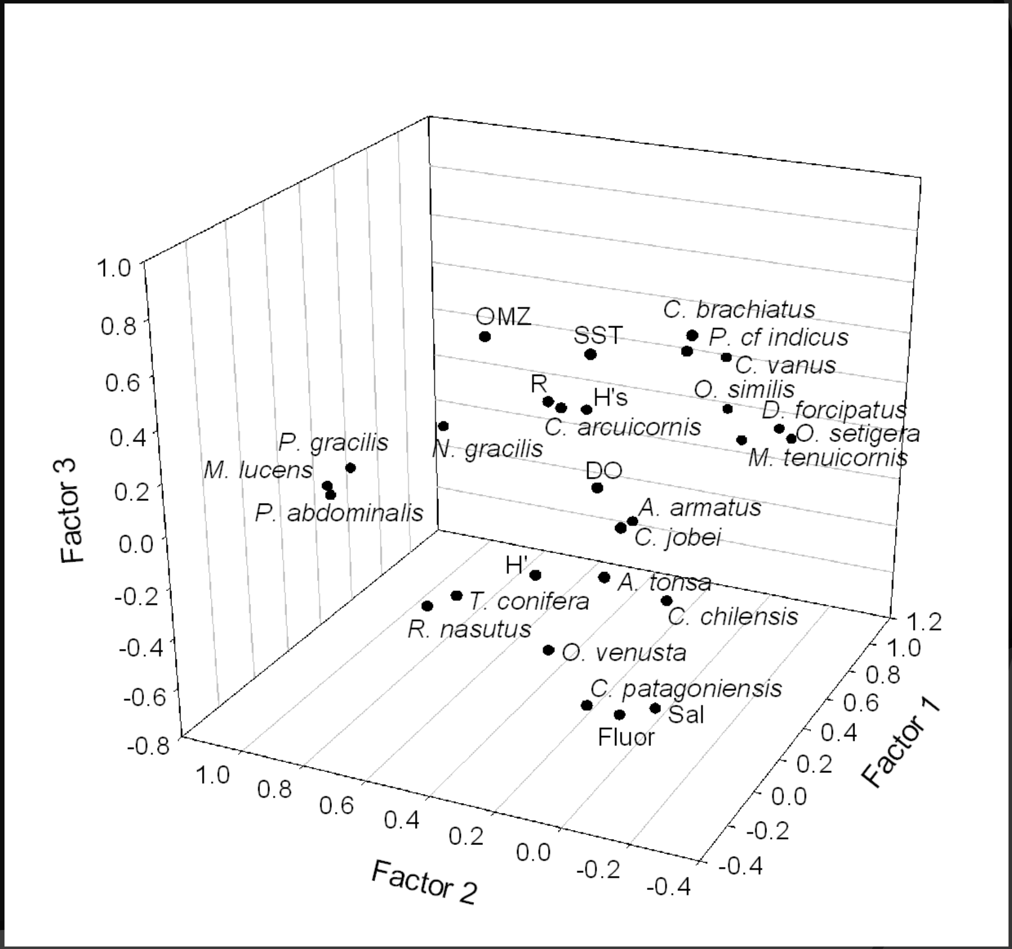
Riquelme-Bugueño et al. (accepted PIO)

THE COPEPOD COMMUNITY IN CENTRAL/SOUTHERN CHILE

UPWELLING DRIVEN VARIABLES MAY IMPACT DIVERSITY



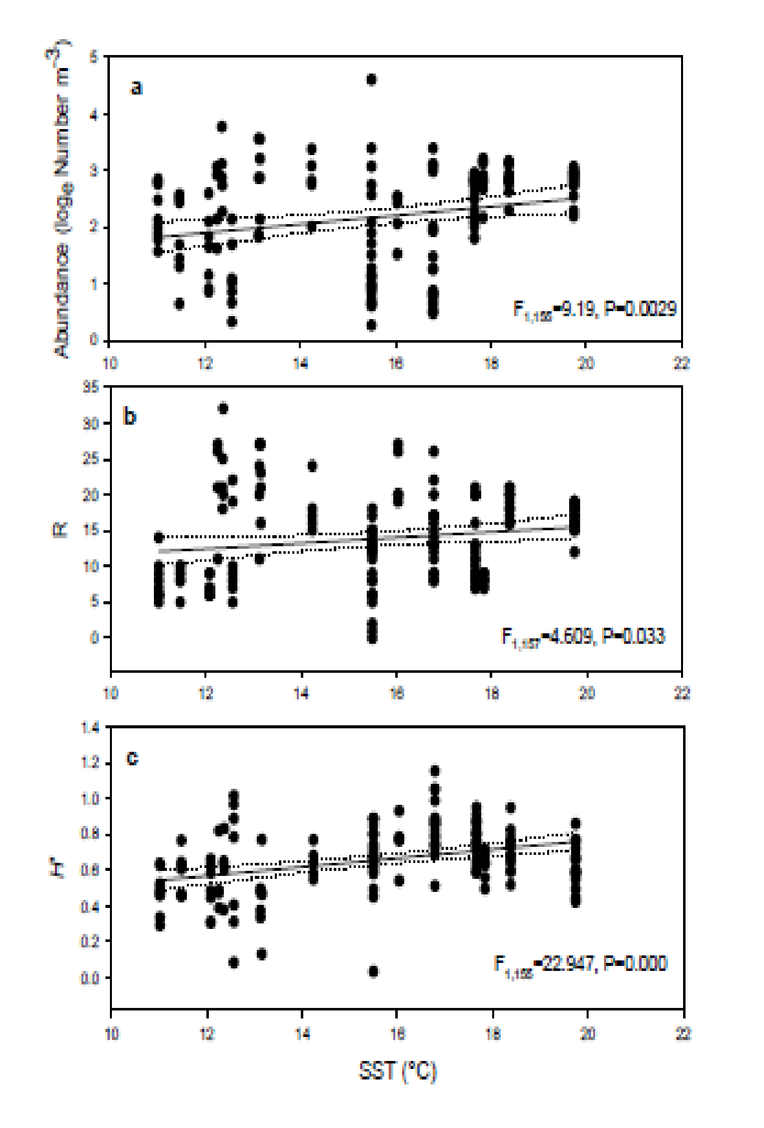
Size-weighed biodiversity index correlates to depth of the OMZ (Forced by upwelling)

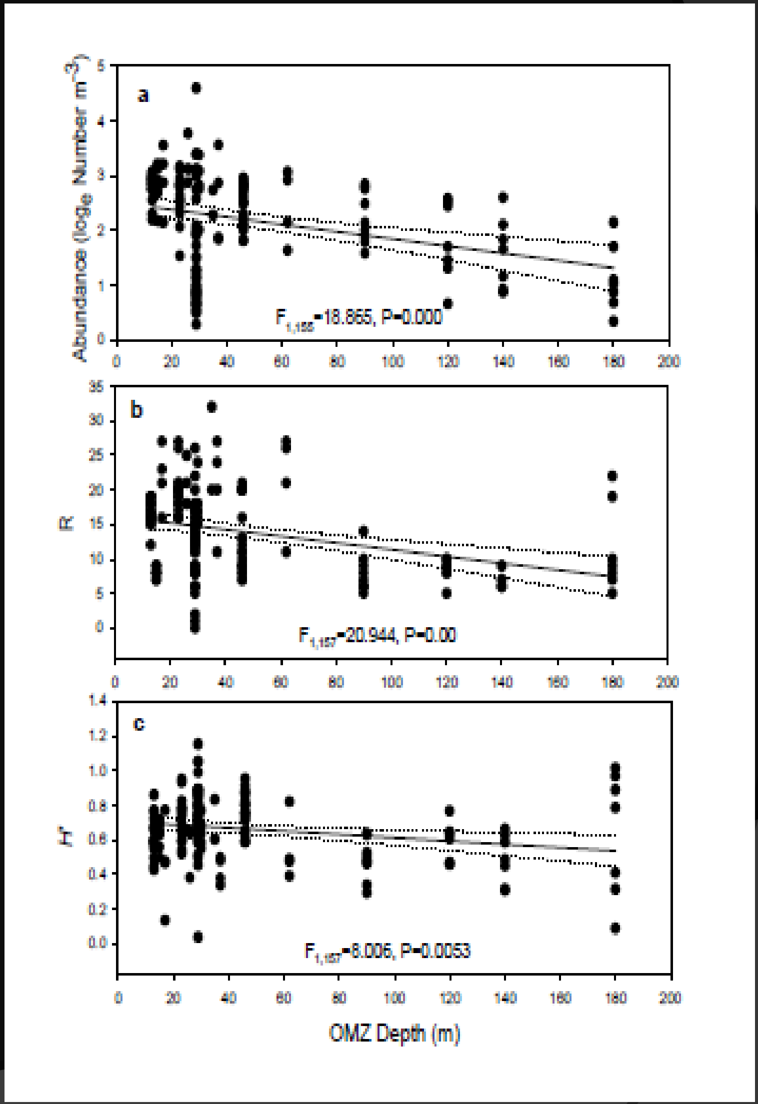


Hidalgo et al. (accepted PIO)

COPEPOD DIVERSITY OVER A LARGER SPATIAL SCALE

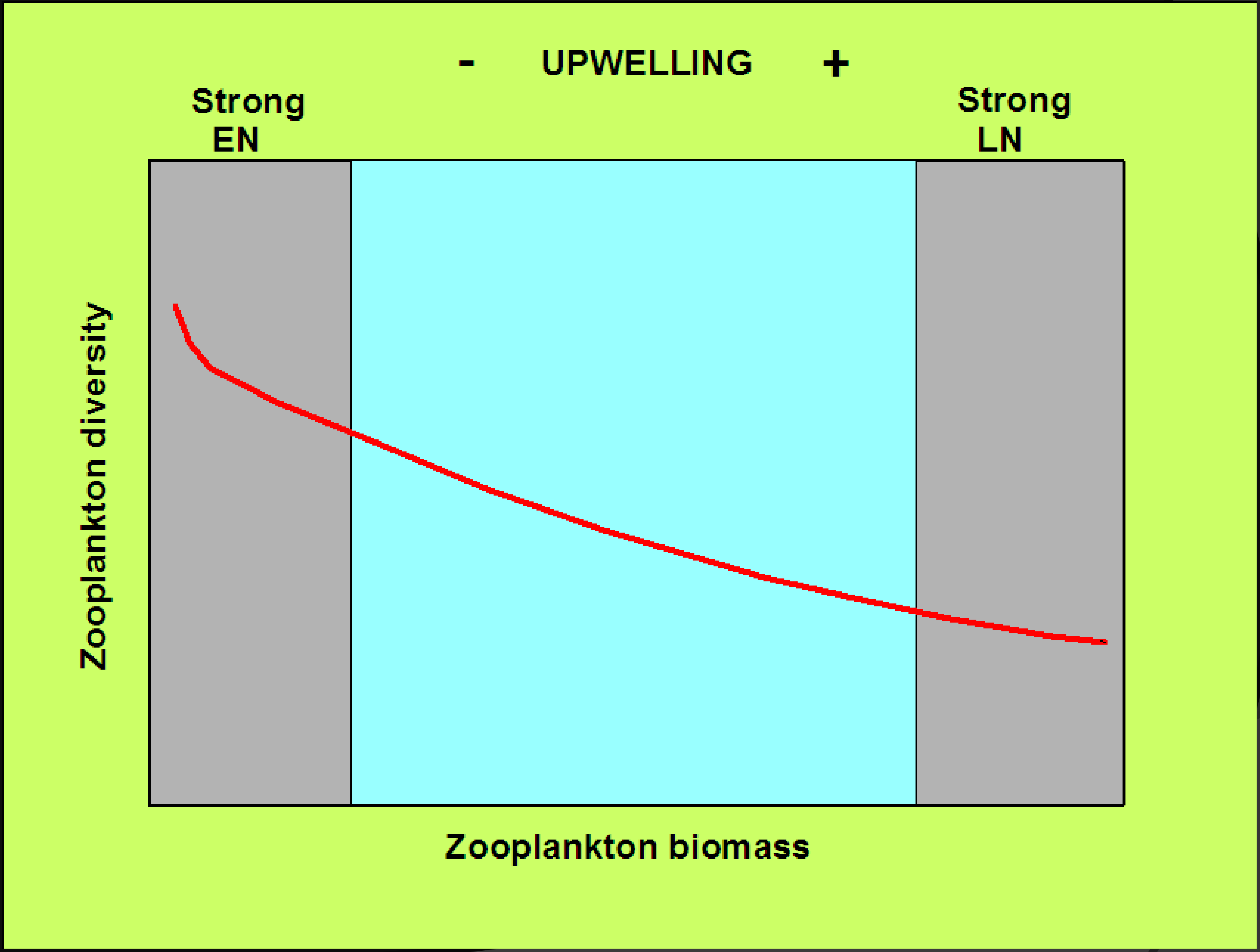
Correlations to upwelling-driven variables become weaker, but still significant





Hidalgo et al.. 2010 DSR II

SOME PREDICTIONS: ZOOPLANKTON DIVERSITY



SUMMARY AND CONCLUSIONS

- **Coastal upwelling seems to be the key process governing dynamics and diversity of zooplankton in highly productive coastal systems**
- **Small-sized copepods are key components for zooplankton dynamics and secondary production**
- **Global warming can greatly impact upwelling and productivity of coastal zones and then zooplankton**
- **Changes in species abundances, phenology, species composition and richness may occur.**
- **Time-series observations must keep going to assess changes and predictions**
- **Basic research in marine biology (e.g. phenology, drivers of diversity) is the right direction for understanding ecosystem changes and define suitable indicators of ecosystem health upon ongoing global warming**

FINALLY!

Climate change provides a great opportunity for doing zooplankton research upon an ongoing experiment in the coastal/upwelling zone

¡Muchas gracias!