PERÚ Ministerio de la Producción
Instituto del Mar del Perú

Asia-Pacific Economic Cooperation

Productivity and sustainable management of the Humboldt Current Large Marine Ecosystem under climate change

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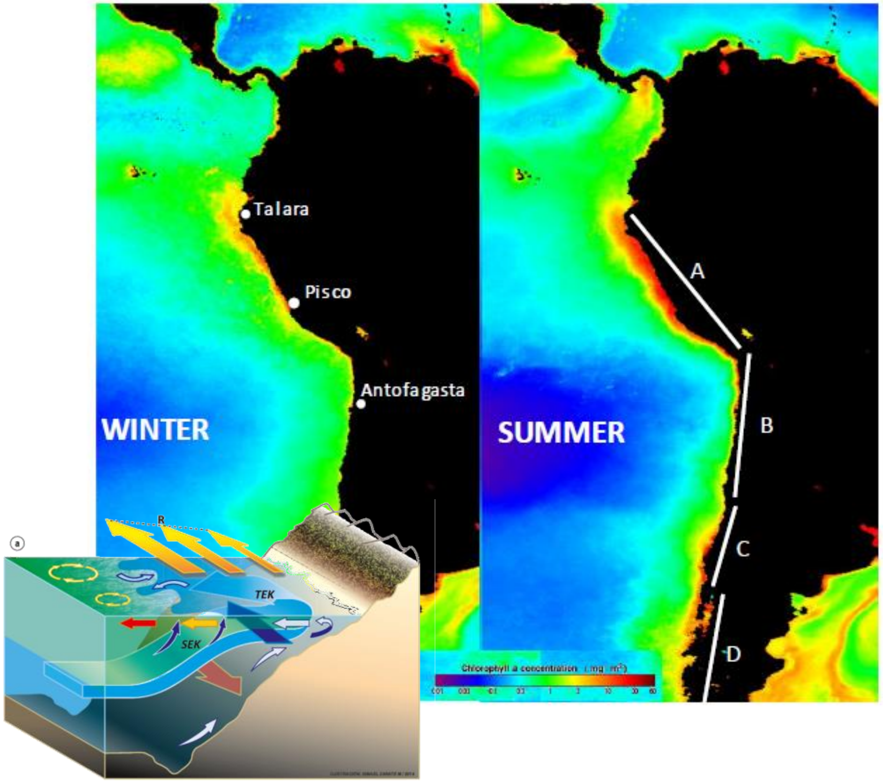
Background tips of HCLME



- The most productive Eastern Boundary Upwelling System of the world in terms of fishing yields. A large part of yields is directed to fish meal and fish oil production and export (Peruvian anchovy)
- 135,000 artisanal fishers and 39,000 fishing vessels exist in both countries
- In Peru only, over 200,000 people is employed directly or indirectly, related to fishery activities
- Over 50 million people live in Peru and Chile, from which more than 70% of the population of both countries live near or at the coast.
- Larger cities and industries are located next to the coast

Table 5
Total Economic Value of the HCLME services 2015.

Humboldt Current Large Marine Ecosystem and Humboldt Current System Total Economic Value 2015				
Values in millions of USD	**Total Peru**	**Total: Chile**	**Total: HCLME (3–58° south)**	**Total: HCS (4–40° south)**
Total: provision services*	4115.40	6747.28	10,862.68	7,683.35
Total: cultural services**	3179.75	3268.00	6447.75	5141.50
Total: regulation services***	880.29	1268.00	2148.29	2145.60
Combined total	**8175.44**	**11,283.28**	**19,458.72**	**14,970.45**

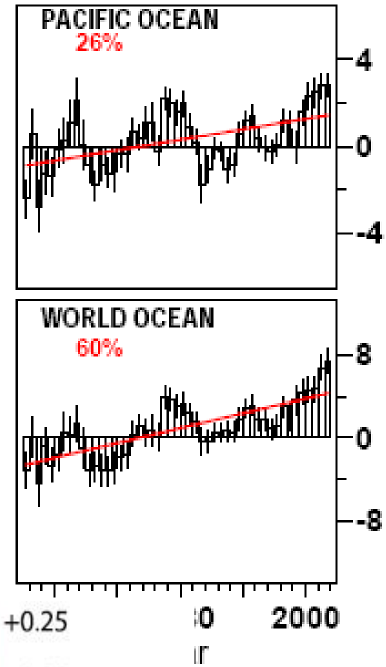
* Food from Fisheries and Aquaculture; Salt; Guano; Fishmeal & oil; Algae; water; energy; transport.
** Tourism; Recreation; Water Sports; Archeology; Scientific Research; Sense of Place & Wellbeing.
**** Climate regulation; Waste recycling.

Gutiérrez, D., Akester, M. & Naranjo, 2016.

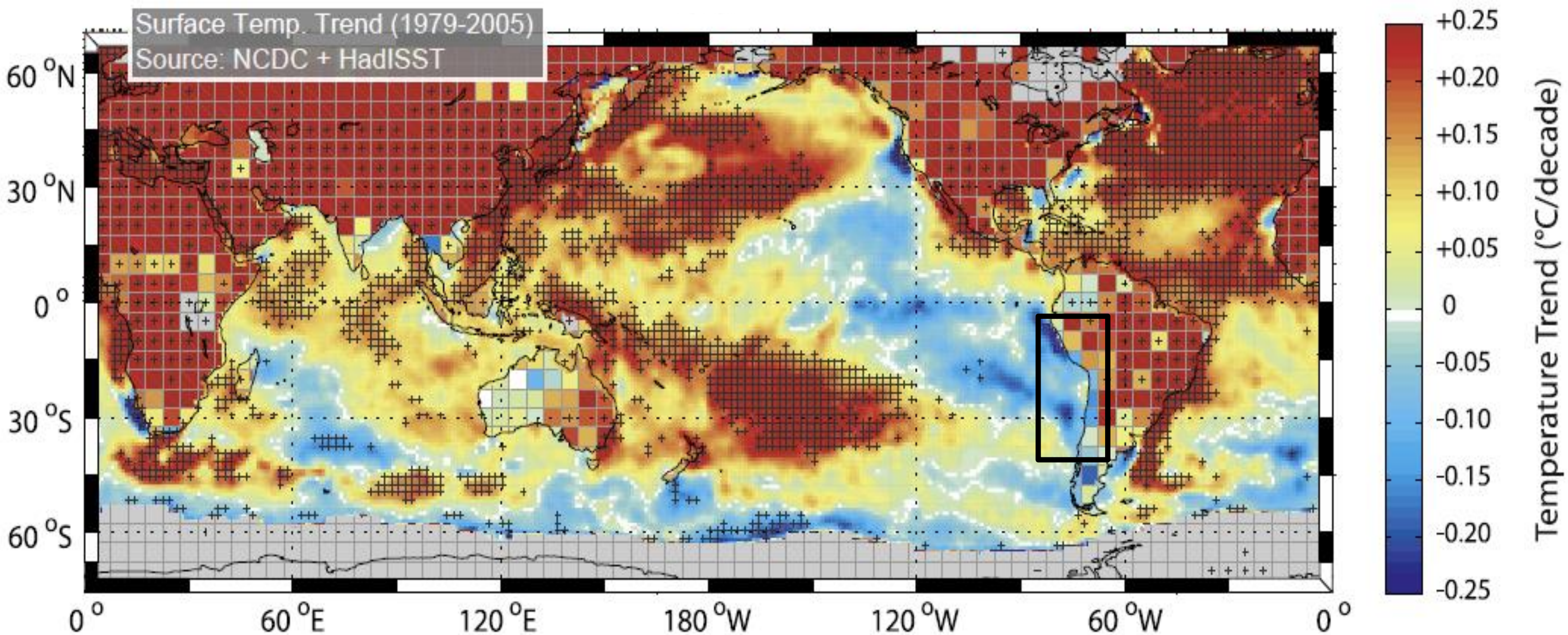
1. Climate Change in the South Eastern Pacific

SST trends in the Pacific Basin

1) Stronger decadal and interannual variability than in other basins;
2) Negative trends in the Eq. Eastern Pacific and the 'Cold tongue'

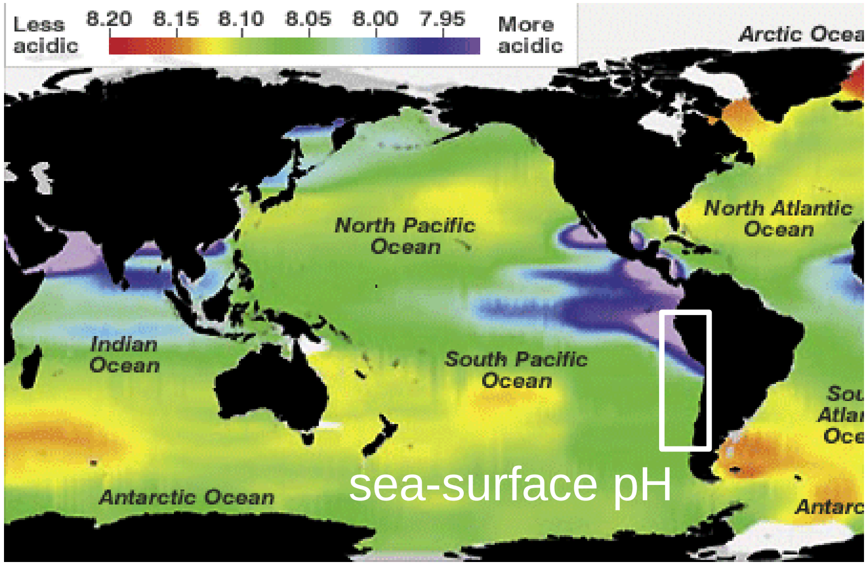


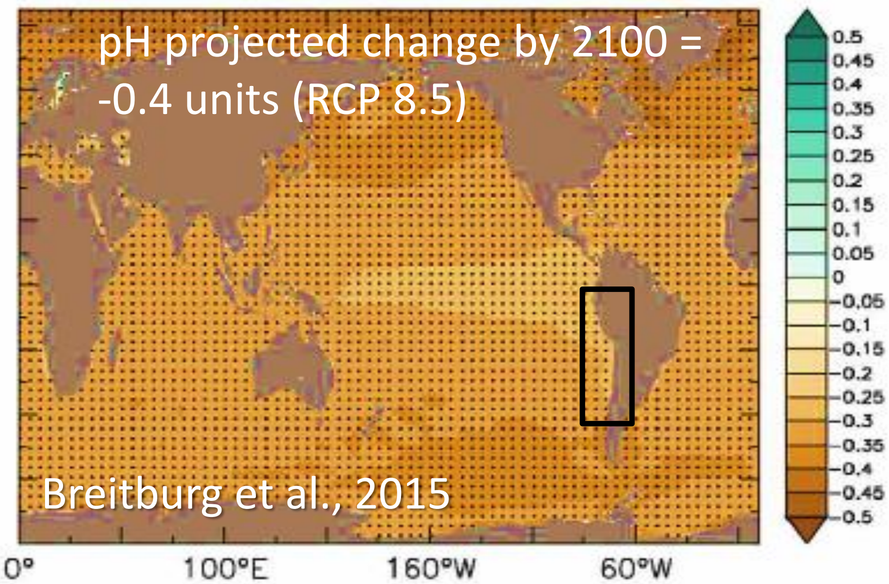
Levitus et al. (2008)

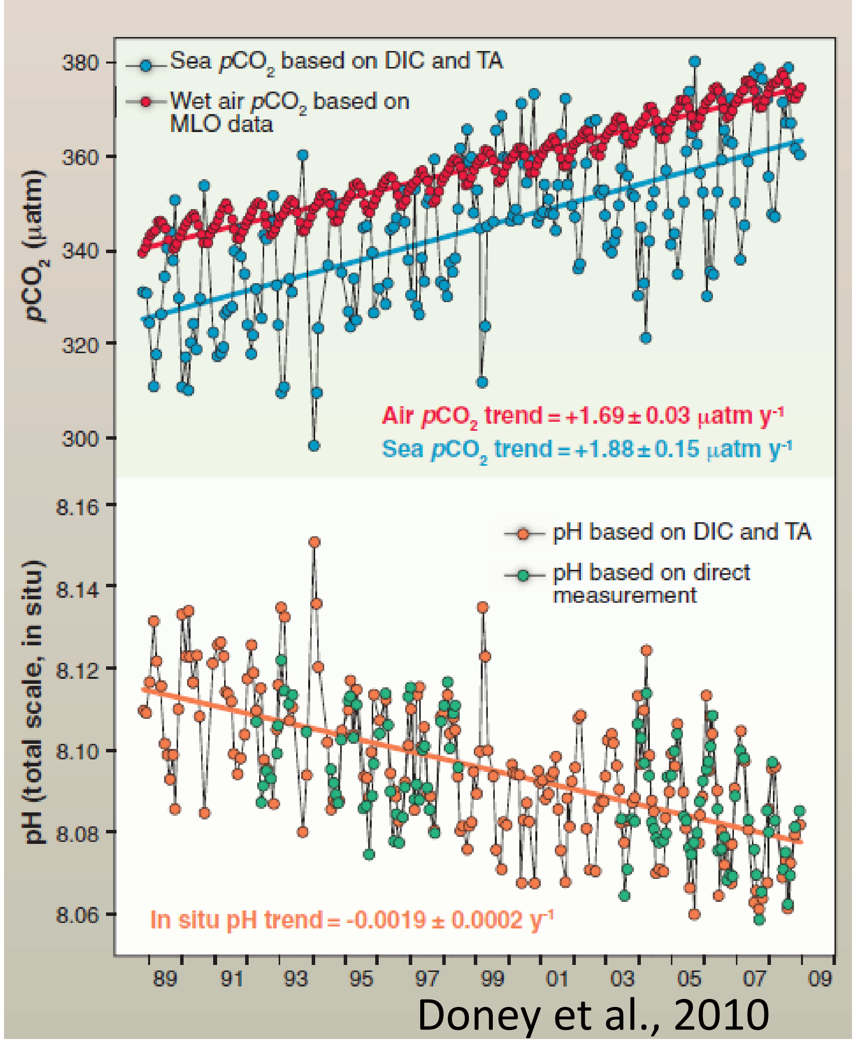


Falvey & Garreaud (2009)

Ocean acidification in the Pacific basin





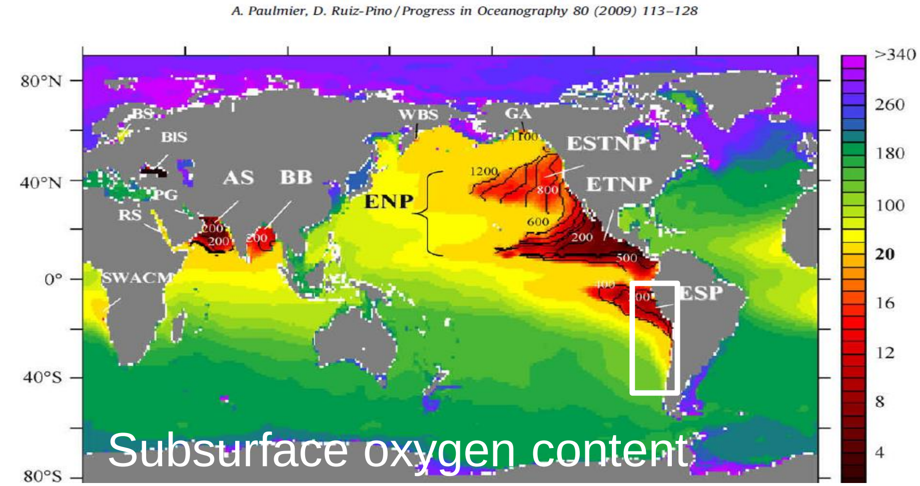


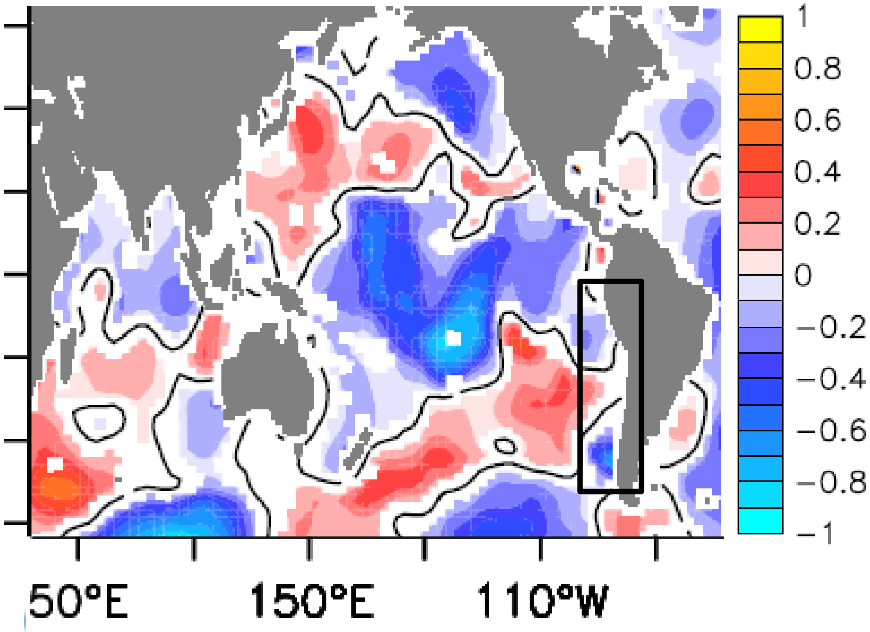
ΔpH = -0.05 units since 1989

Ocean desoxygenation in the Pacific basin

Global warming causes des-oxygenation due to:

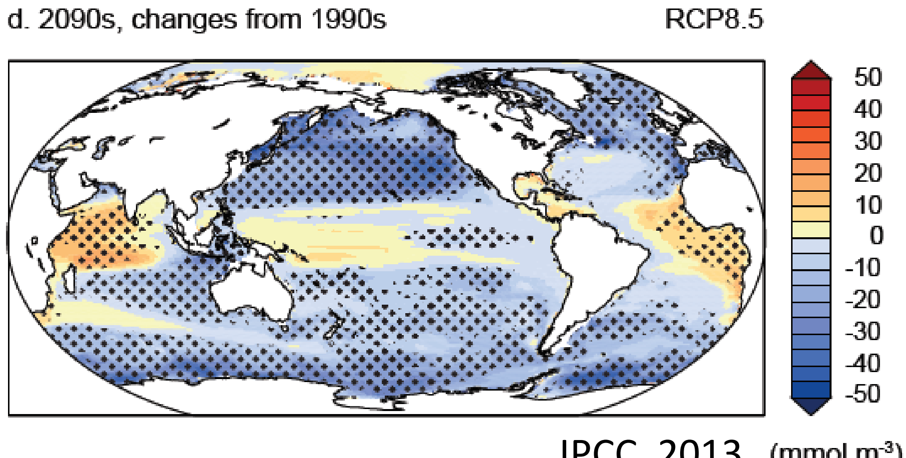
- Loss of solubility
- Reduced ventilation due to stratification





1960 – 2010, trend (mmol kg^{-1} DO y^{-1})

Stramma et al., 2012

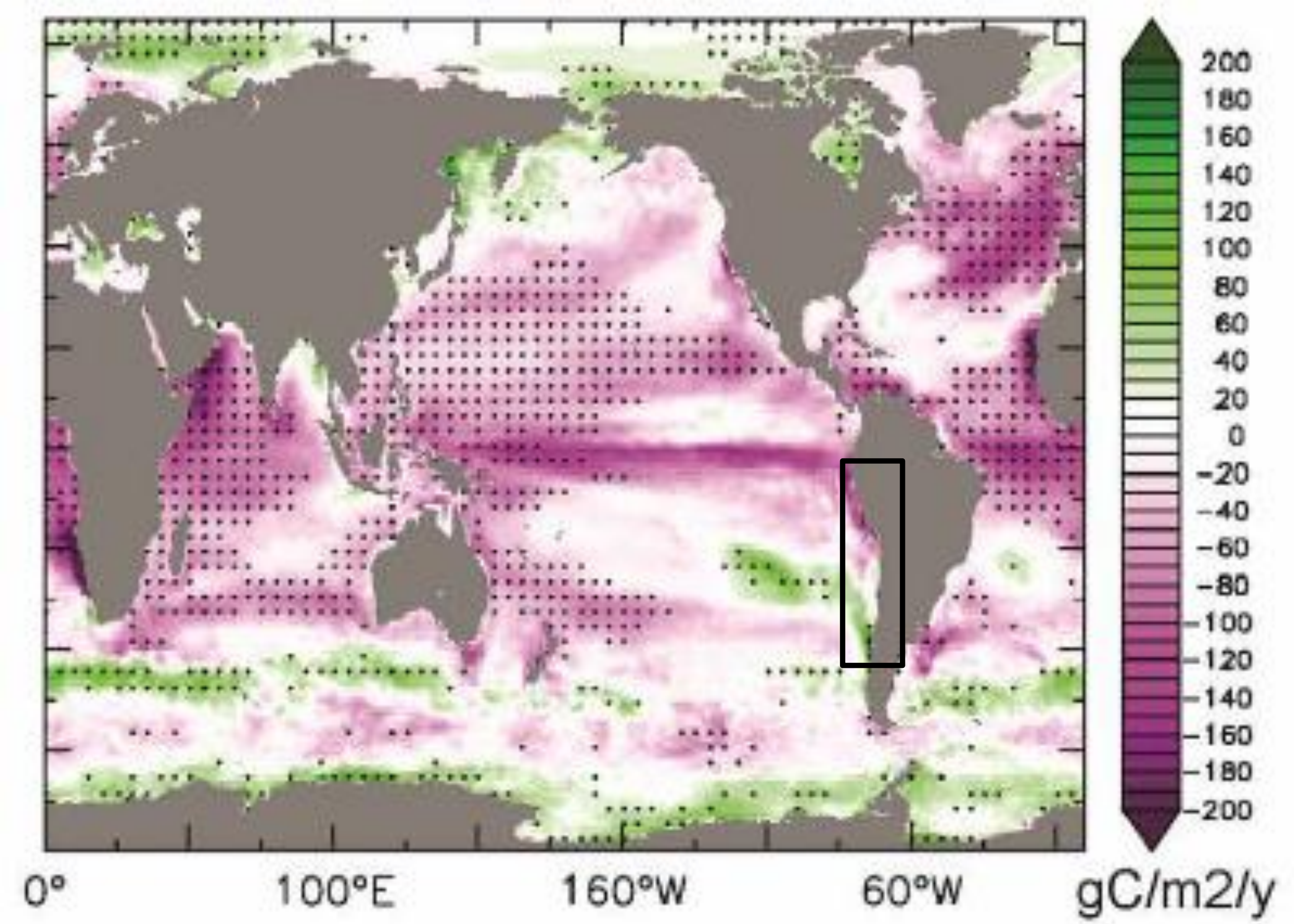


IPCC, 2013

- ➢ **But… models are unable to adecuately reproduce current OMZs nor trends in the Equatorial Pacific**
- ➢ Contrast NEP vs SEP

Projected net primary productivity change

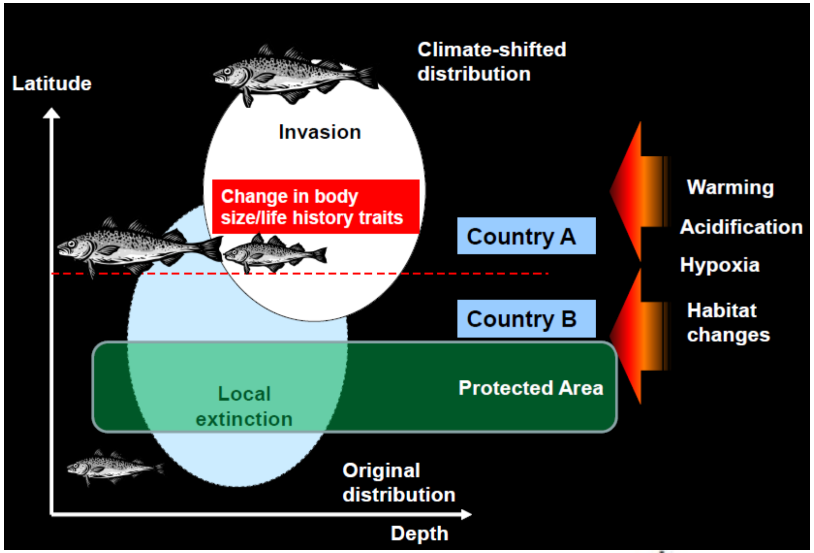
(2090 – 2099) – (1990 – 1999), RCP8.5



Stratification is the main driver (through nutrient input)

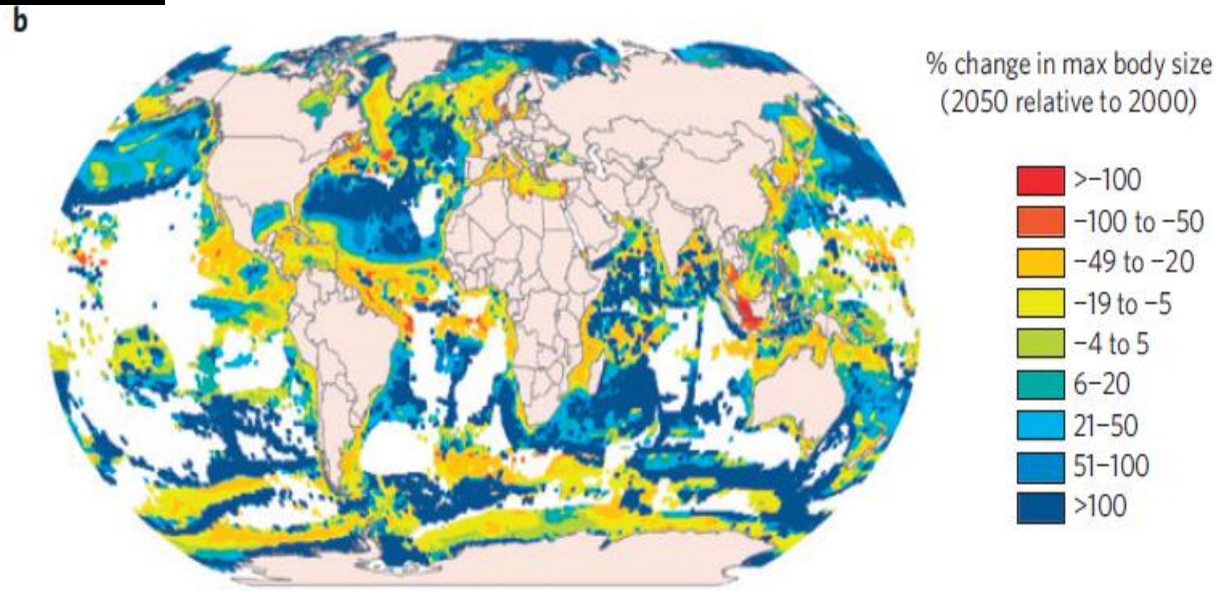
Breitburg et al., 2015

Impacts on Fisheries (global scale)

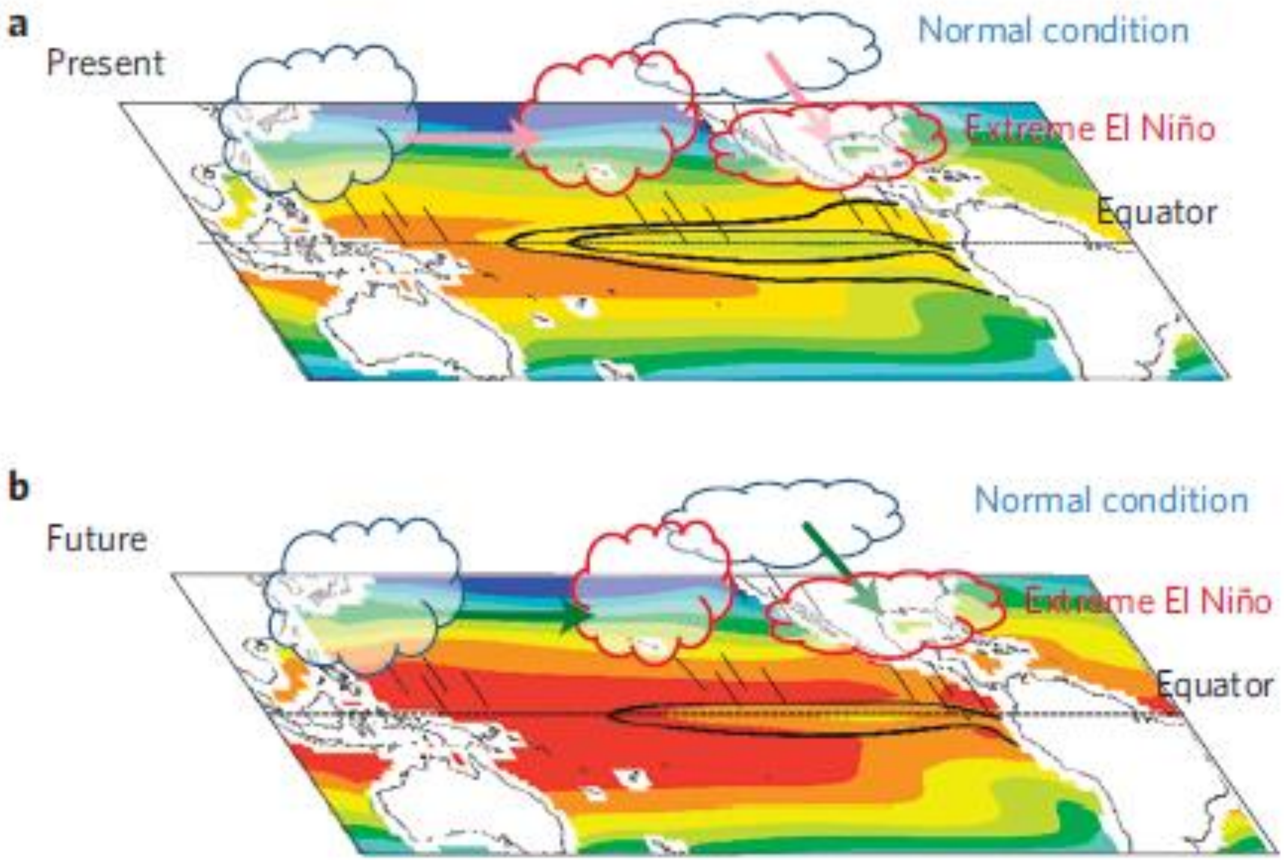


In terms of distribution, most vulnerable areas are the Equatorial region (higher risk of local extinctions) and polar regions (higher risk of species turnover).

Impacts are exacerbated by ecxpected decrease of body size (higher T and lower O cause higher energy use for maintenance, and lower for growth) - Cheung et al., 2012



ENSO and extreme events (El Niño) under Climate Change

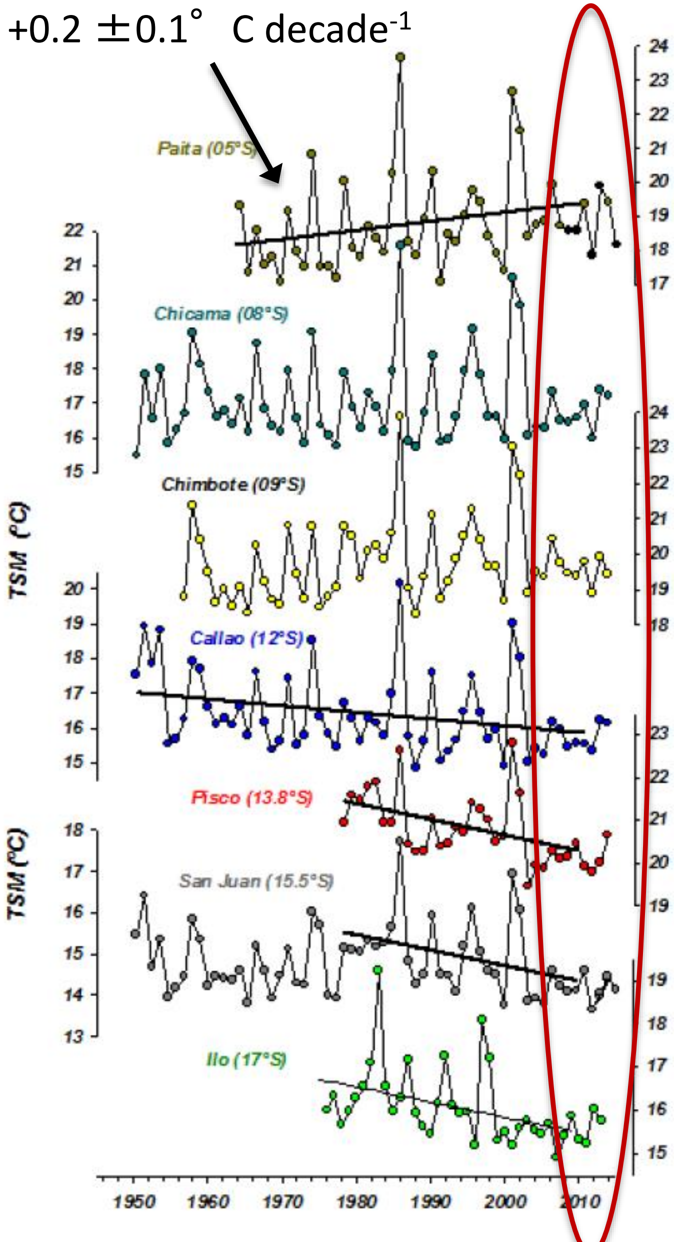


- A higher frequency of **extreme El Niños** is expected according to CMIP5/CMIP3 model simulations under climate change (Cai et al., 2014). Increased frequency arises from a projected surface warming over the EEP, facilitating more occurrences of atmospheric convection in the eastern equatorial region.
- Extreme EN events impacts are longer-lasting for marine ecosystems and resources to recovery.

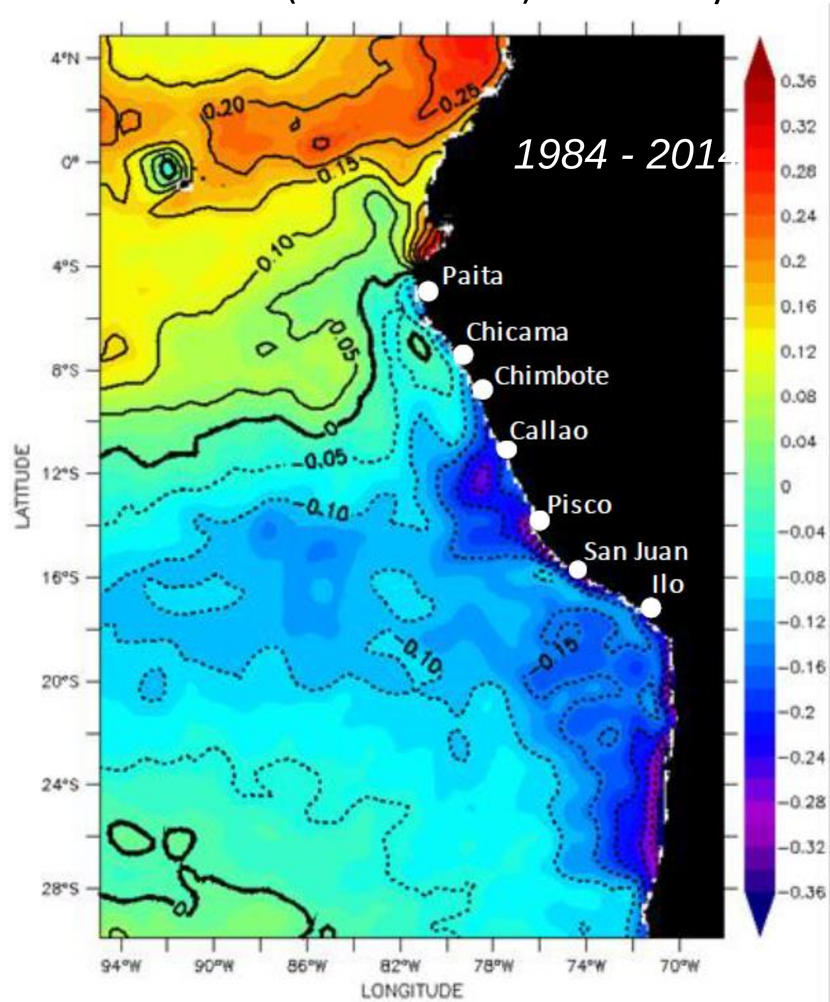
2. Vulnerability of the HCLME resources to climate change

SST trends in the South Eastern Pacific

+0.2 ±0.1° C decade^{-1}

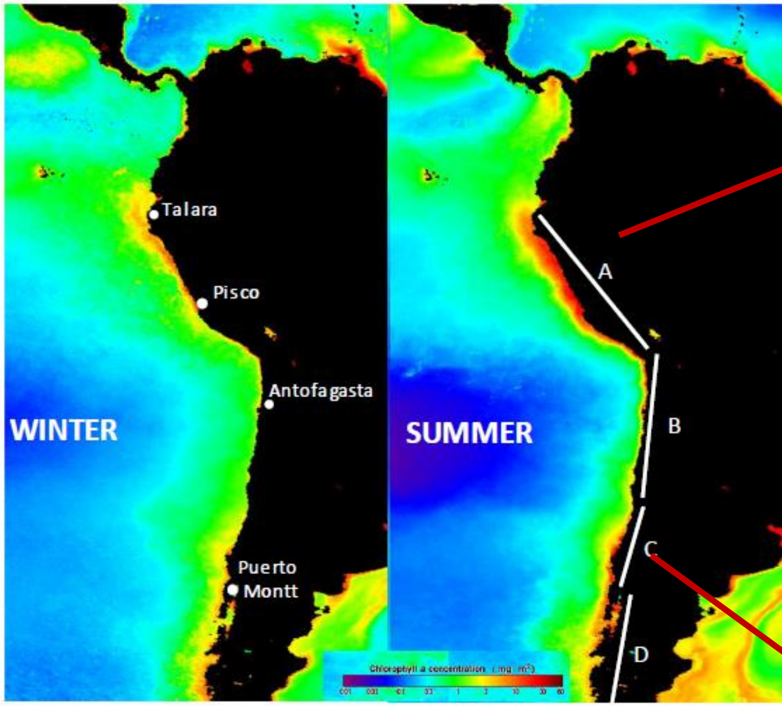


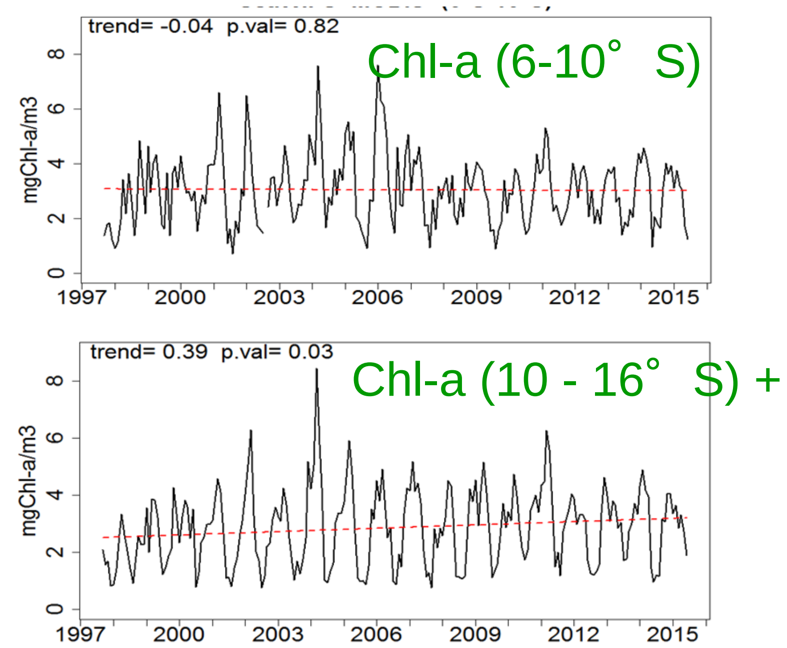
SST trends (° C decade^{-1}) on the Reynolds database



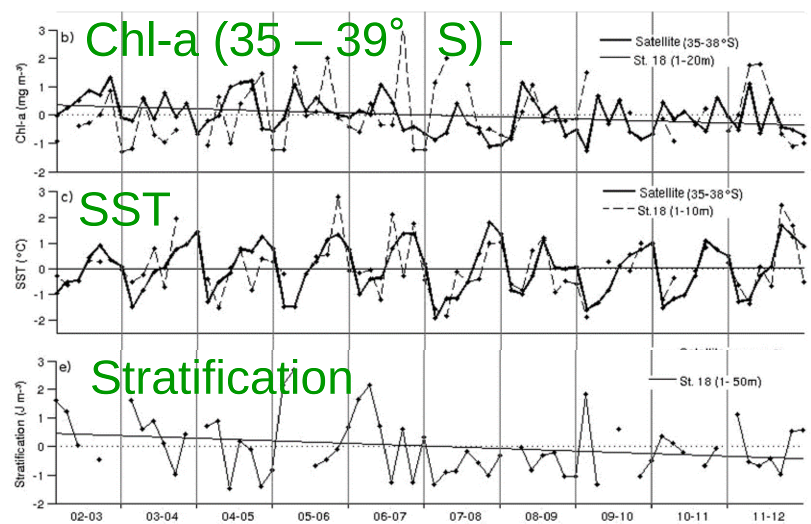
Left: pier records; significant linear fits are over-imposed on the time-series; negative SST trends until 2010 are **-0.3±0.1 C decade^{-1}**. Trends are mostly explained by springs, attributed to coastal upwelling intensification (Gutiérrez et al., 2016).

Surface Chl-a trends





Gutiérrez et al., in prep.

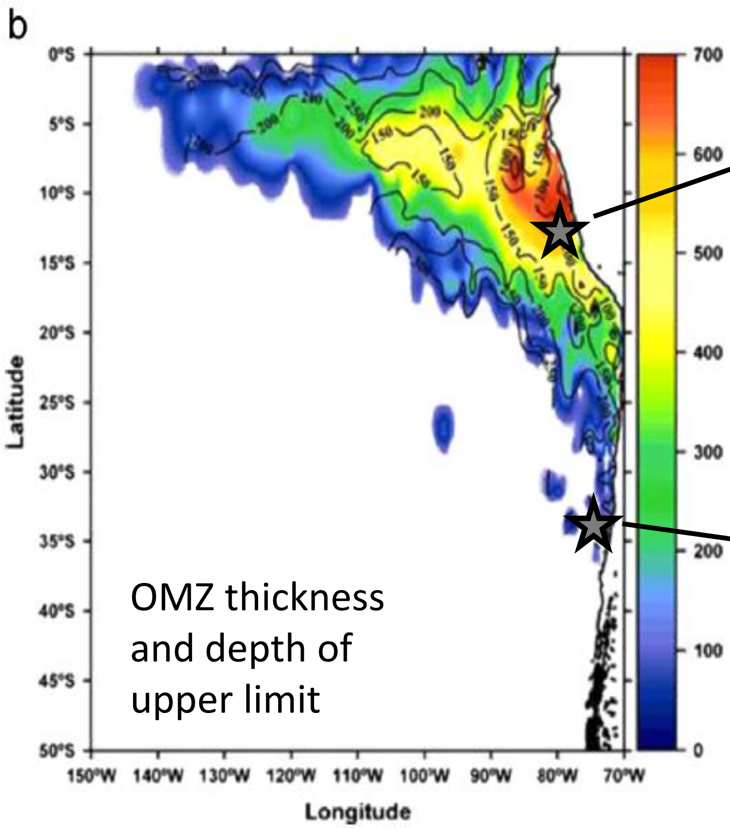


Corredor-Acosta et al., 2015

- Regional (latitudinal) differences in the Chl-a trends. No trend in the north coincides with SST warming, while positive trend in southern Peru goes along with cooling.
- Negative trend in Central/Southern Chile related with lower stratification (deeper wind mixing/turbulence?)

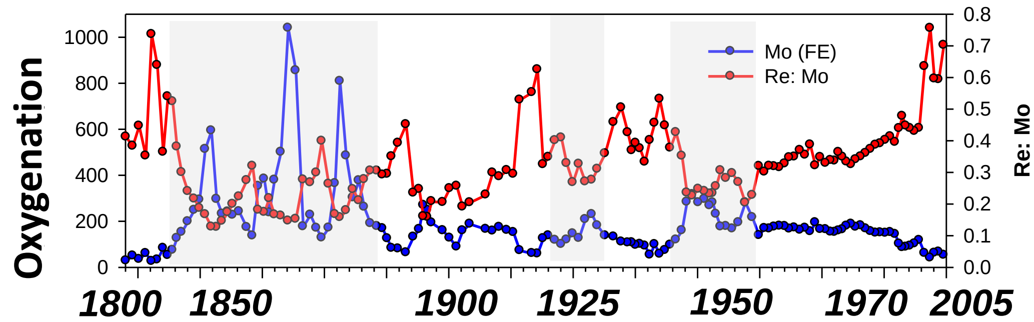
Subsurface oxygenation: more or less?

Stars: sediment cores

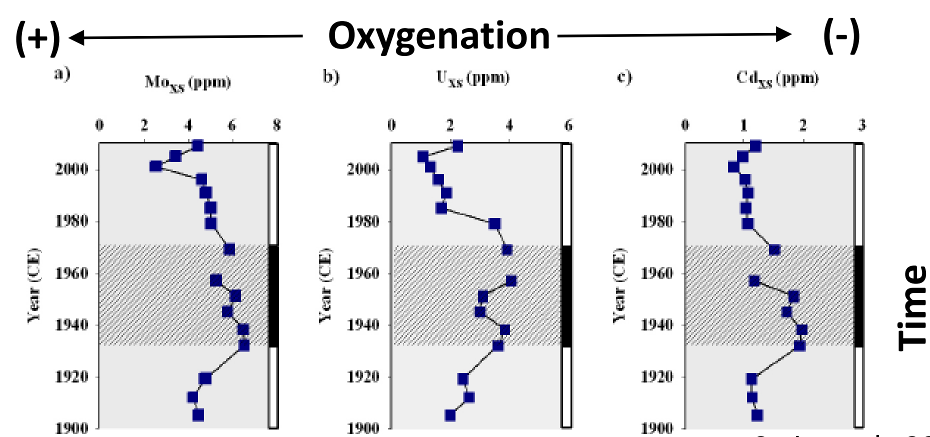


Fuenzalida et al., 2009

Callao: enhanced oxygen depletion in the XIX century, decadal fluctuations between 1920 and 1960's. More oxygenation in recent decades.



Salvatteci, Sifeddine, Gutiérrez, unpub. data



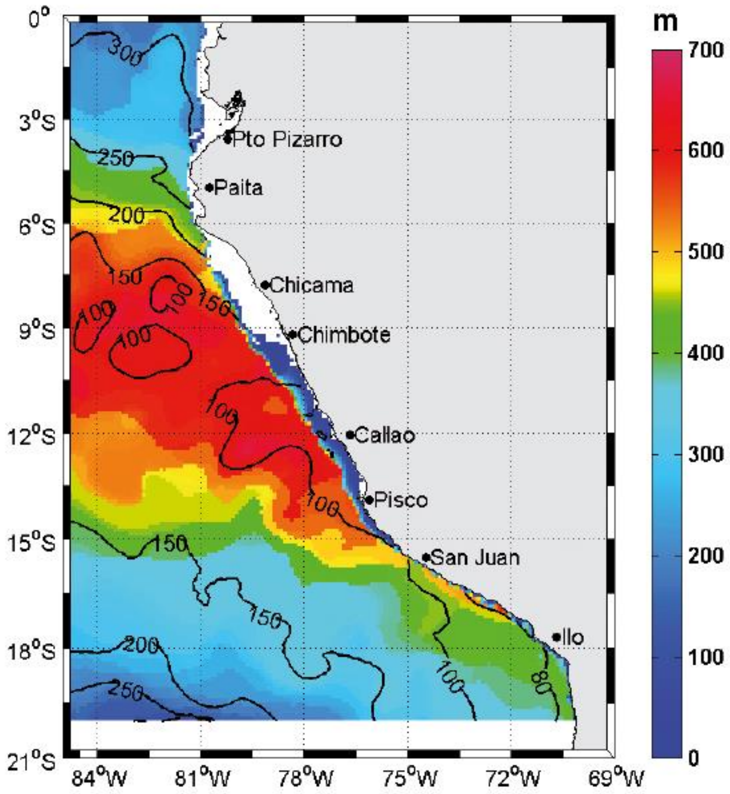
Srain et al., 2015

Concepcion: enhanced oxygen depletion from 1935 and 1970, lower oxygen depletion from 1970 to 2000.

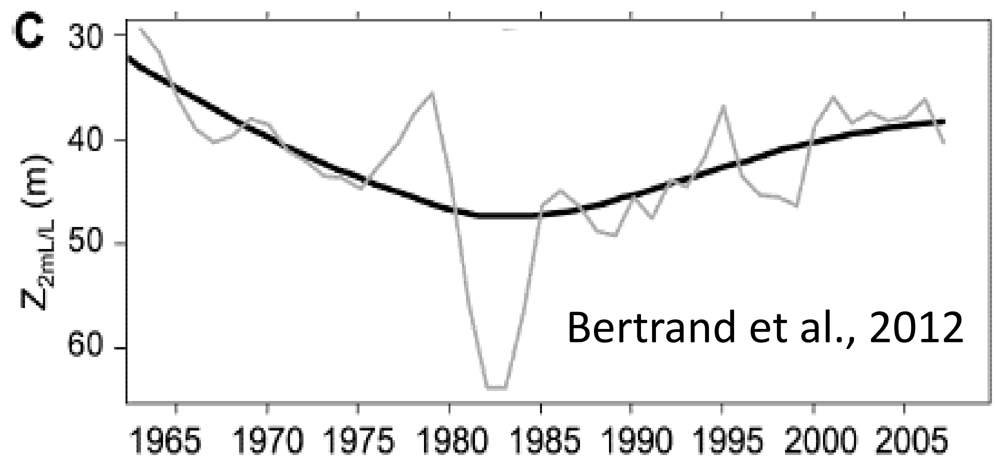
Subsurface oxygenation: more or less?

Depth of upper limit of oxycline (2 mL L^{-1})

➢ 7-18 S, 0 – 200 nm

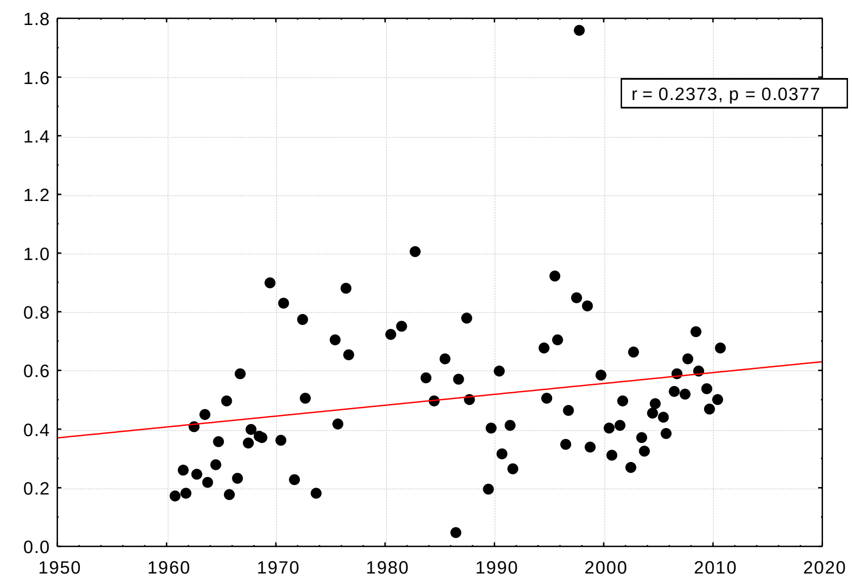


Gutiérrez et al., 2014



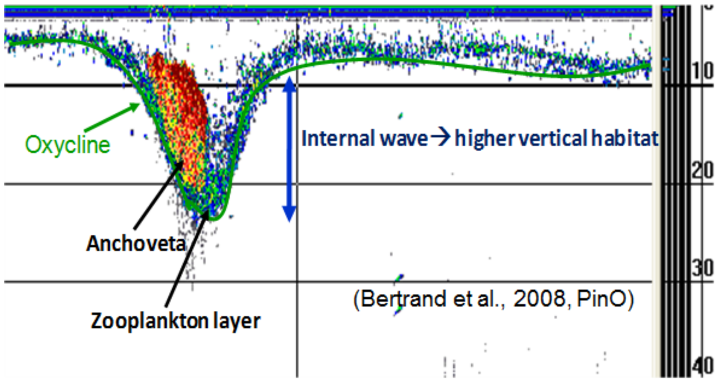
Oxygen concentration at 100 m

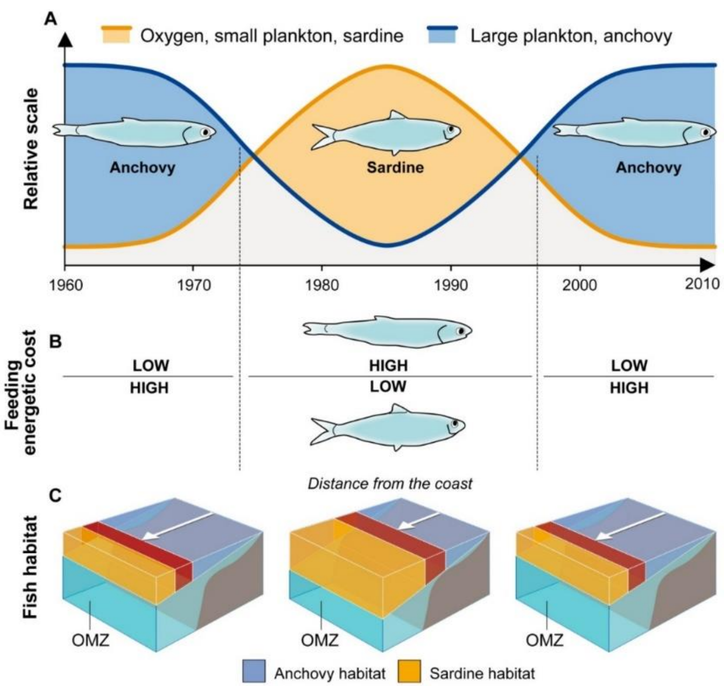
➢ 11 – 15 S, 30 – 100 nm



Source: IMARPE

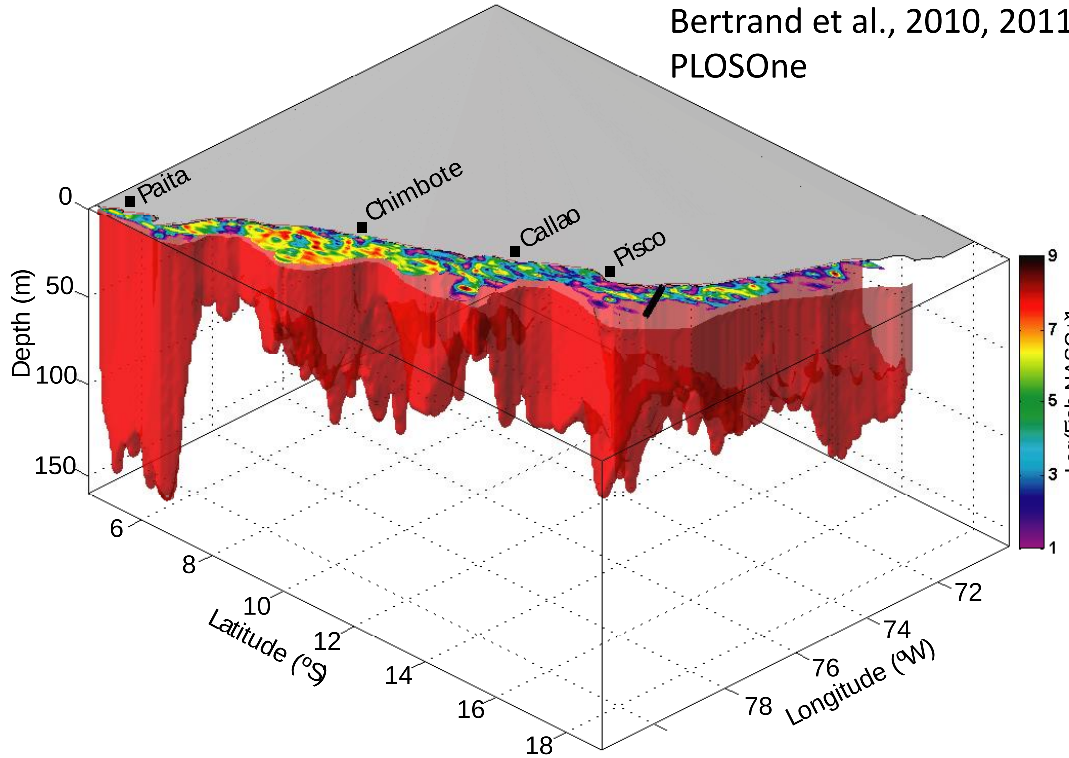
Oxygen as a key factor structuring the pelagic habitat in the HCLME





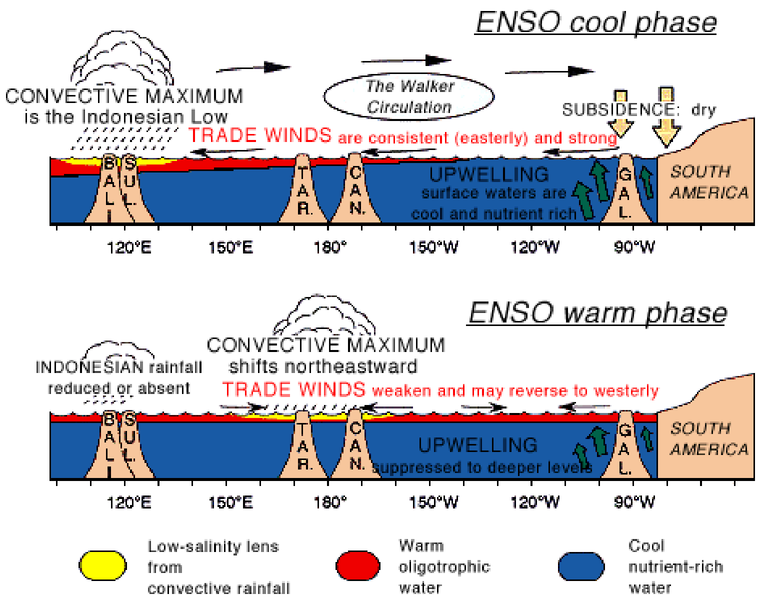
Bertrand et al., 2011. PLOSOne

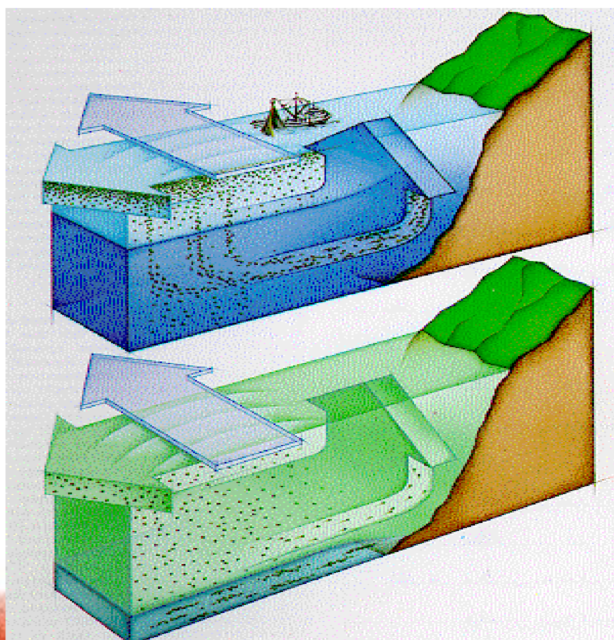
Bertrand et al., 2010, 2011. PLOSOne

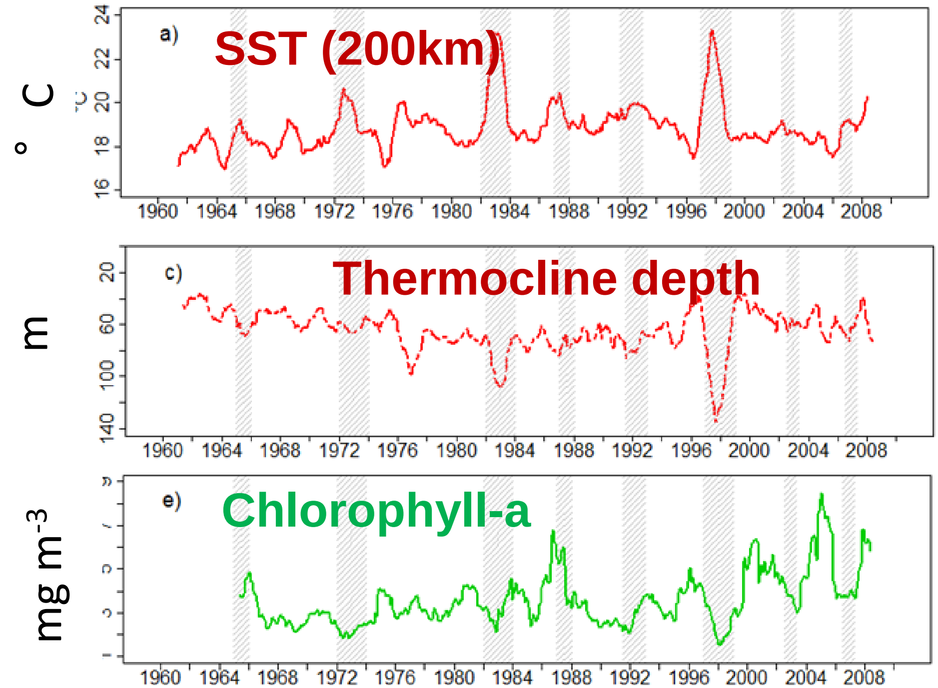


- ➢ Habitat compression for pelagics
- ➢ 3-D habitat of anchovy can be reproduced given its preference to wáter mass and oxygen tolerance
- ➢ Anchovy: better tolerance to low-oxygen (near coast); Sardine has lower tolerance and stays offshore

ENSO variability and oceanographic impacts



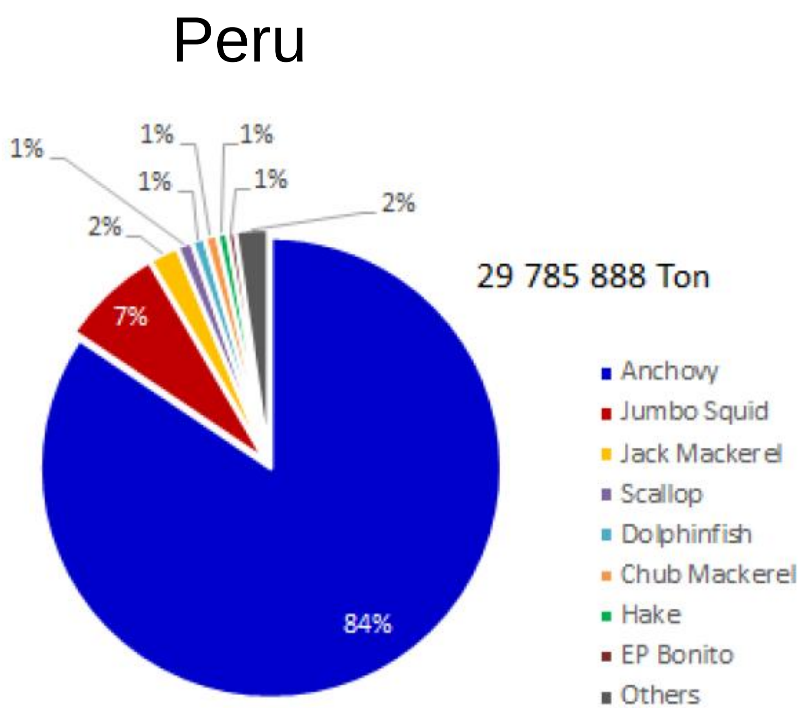


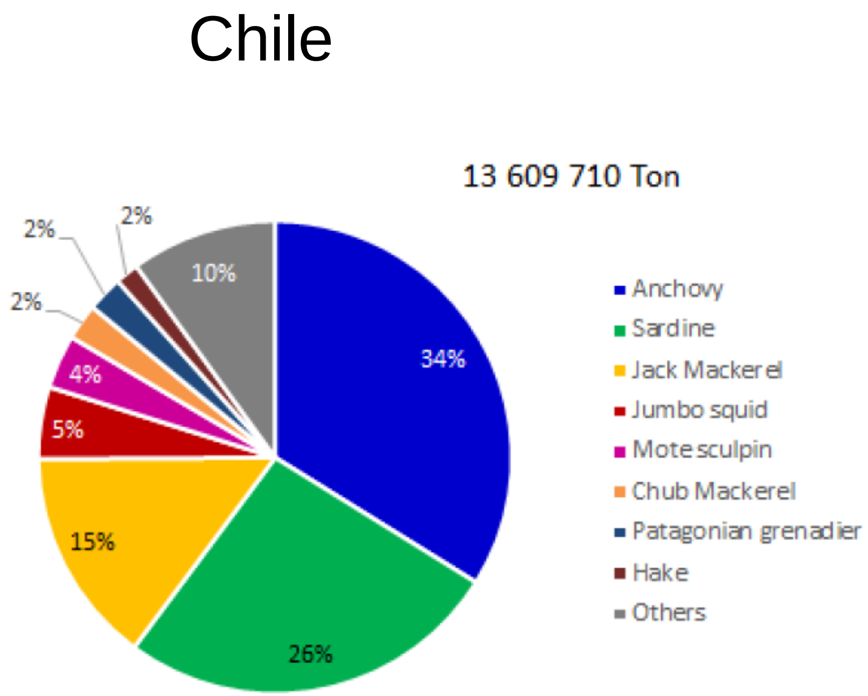


Source: IMARPE

- Large-scale and KW activity alter the coastal upwelling hábitat in the SEP
- El Niño years characterized by warming, deeper thermocline, lesser nutrients advected to the surface and lower primary productivty (Peru and Northern Chile)

Fish landings composition in the HCLME (2009 – 2013)

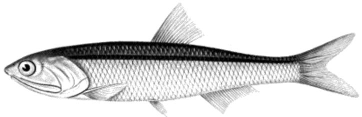


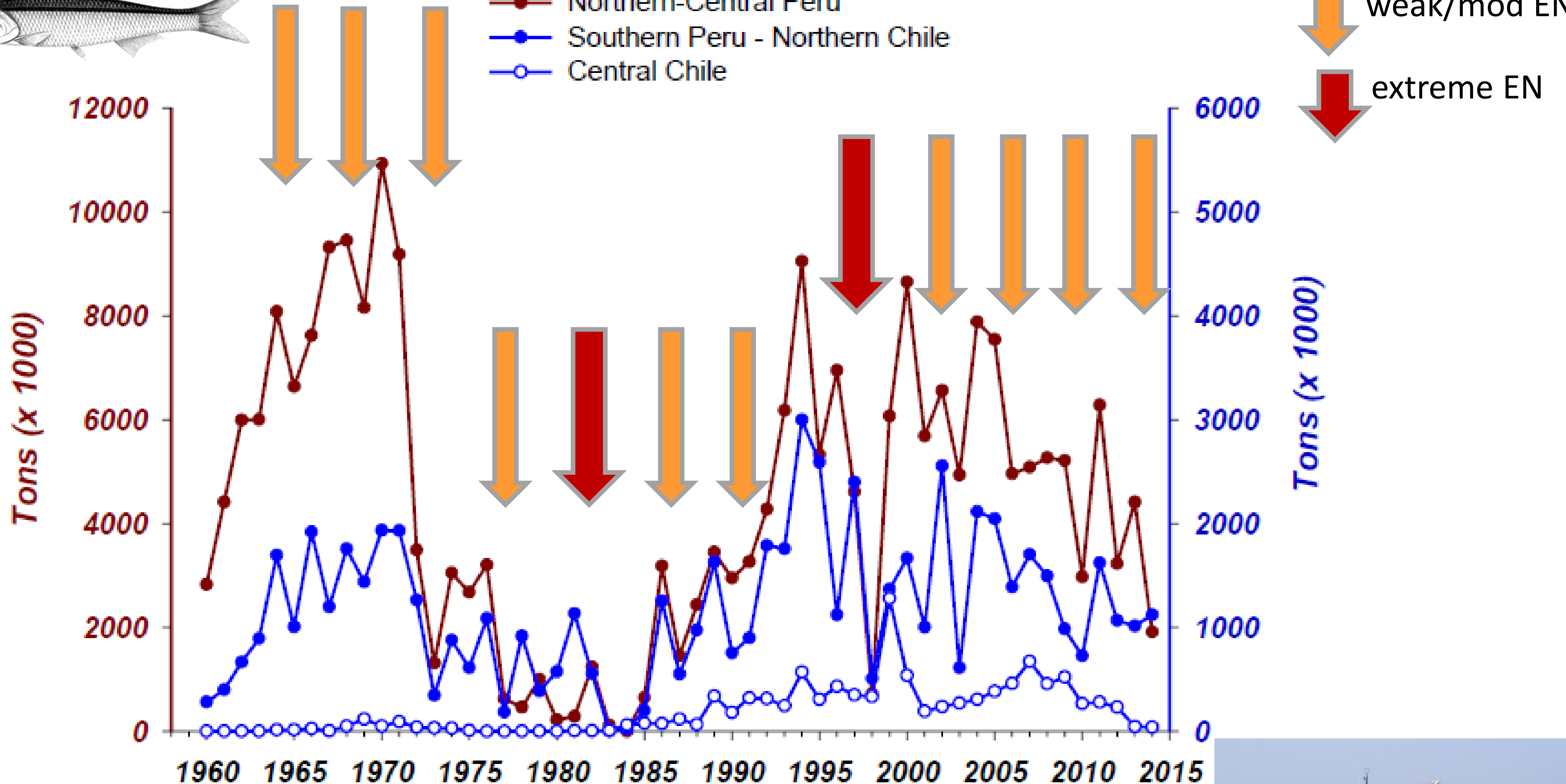


* Sardine= *Strangomera bentincki*

Gutiérrez, D., Akester, M. & Naranjo, 2016.

Landings of the three HCLME anchovy stocks since the onset of industrial fishing

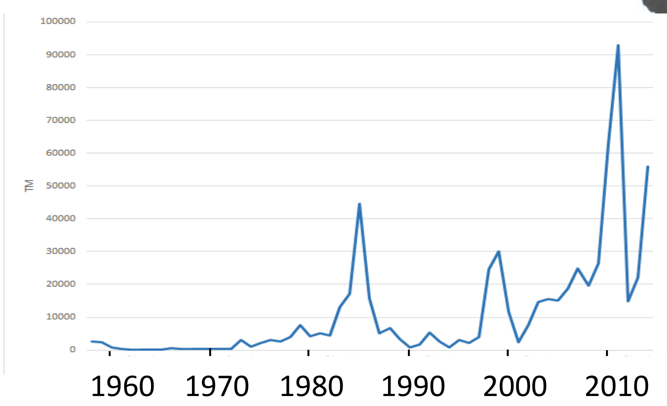




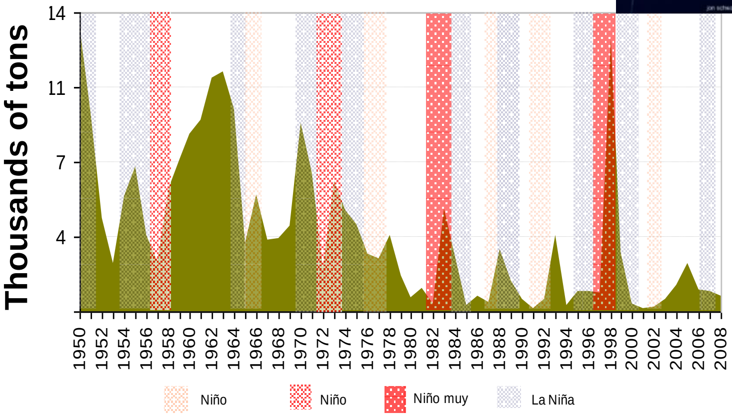
- Imprints of interdecadal natural variability + El Niño impact on fish landings
- (IQ s were introduced in Peru in 2009, and in Chile one decade before)

Biomass and landings of main resources since 2000

Peruvian scallop *(Argopecten purpuratus)*



Yellowfin Tuna *(Thunnus albacares)*



Resource	Trend*	Habitat
Anchovy (B)	→ (black, level) NCP, PCh; ↘ (red, down) CChile	Coastal
Peruvian Sardine	↘ (red, down)	Offshore/coastal
Jack mackerel	↘ (red, down)	oceanic
Mackerel	↘ (red, down)	oceanic
Yellowfin Tuna	→ (black, level)	tropical
Jumbo squid	↗ (up)	oceanic
Mahi mahi	↗ (up)	oceanic/trop.
Peruvian Hake (B)	↗ (up)	demersal
Common sardine – Chile (B)	↗ (up)	Coastal
Scallop (includes aquaculture)	↗ (up) Peru	benthic

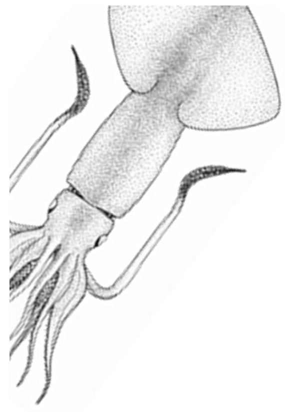
* Sources: IMARPE, SERNAPESCA

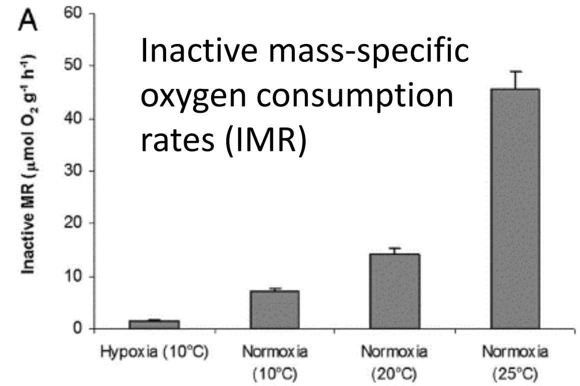
Resources' vulnerability to climatic stressors

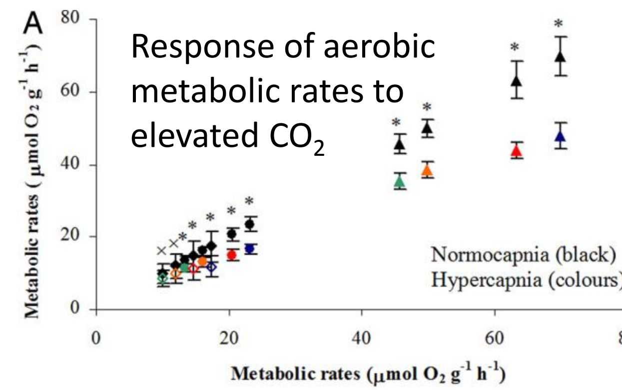
- Jumbo Squid: Ocean acidification substantially depress metabolic rates (31%) and activity levels (45%).

- Synergism between ocean acidification (ΔpH ~ -0.3), global warming, and expanding hypoxia will compress the habitable depth range of the species. (Rosa and Seibel, 2008).

- Growth & calcification rates at risk to ocean acidification (Peruvian scallop *Argopecten purpuratus*)



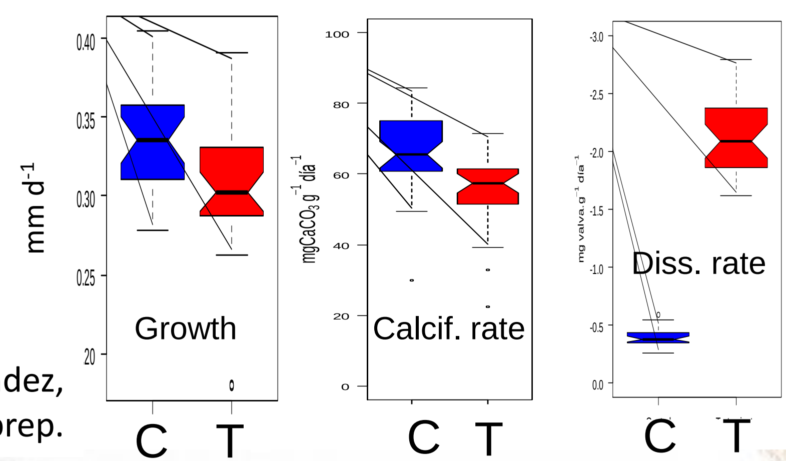




pH_C ~ 7.8

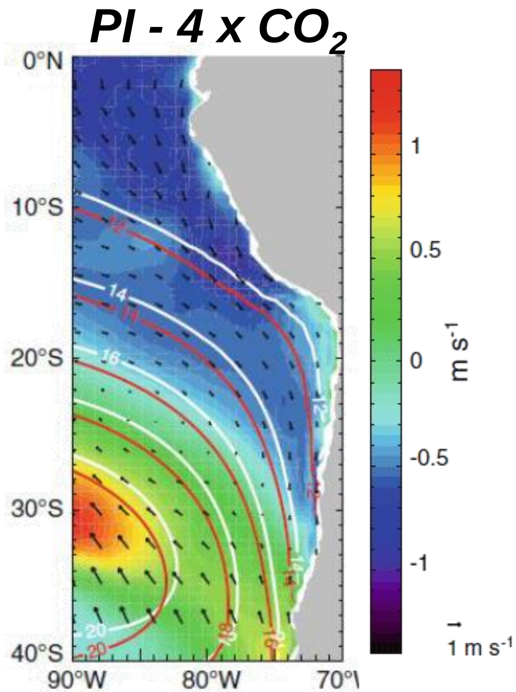
pH_T ~ 7.4

Córdova, Fernández, Aguirre, in prep.



First-generation regional models on PP and anchovy recruitment under climate change scenarios

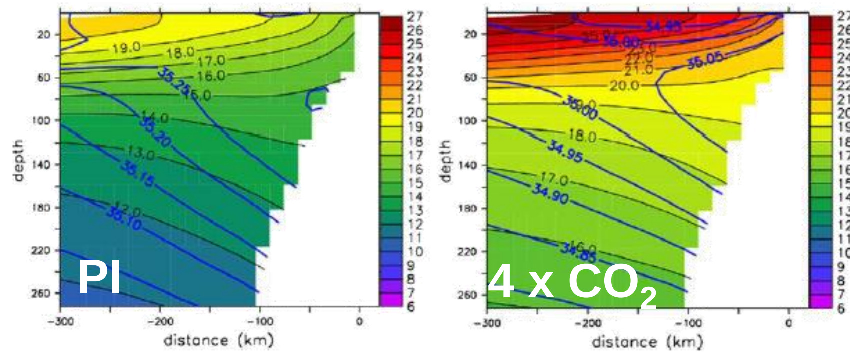
A



Diff. in surface wind intensity between the 2xCO2 and PI scenarios (summer)

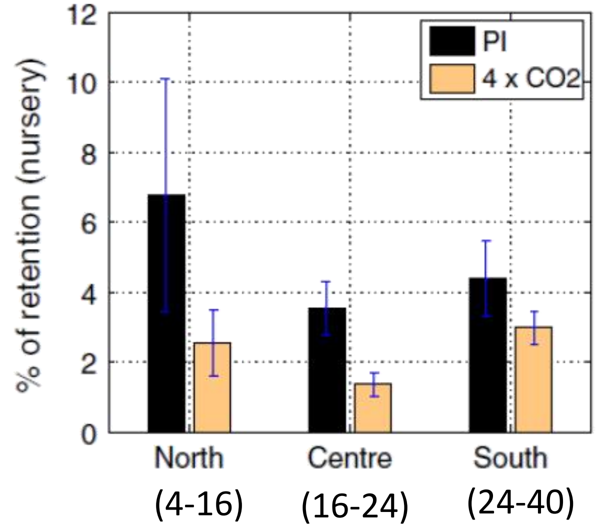
Bel Madani et al., 2013)

B



Temperature and Salinity at 10S (Echevin et al, 2012).

C

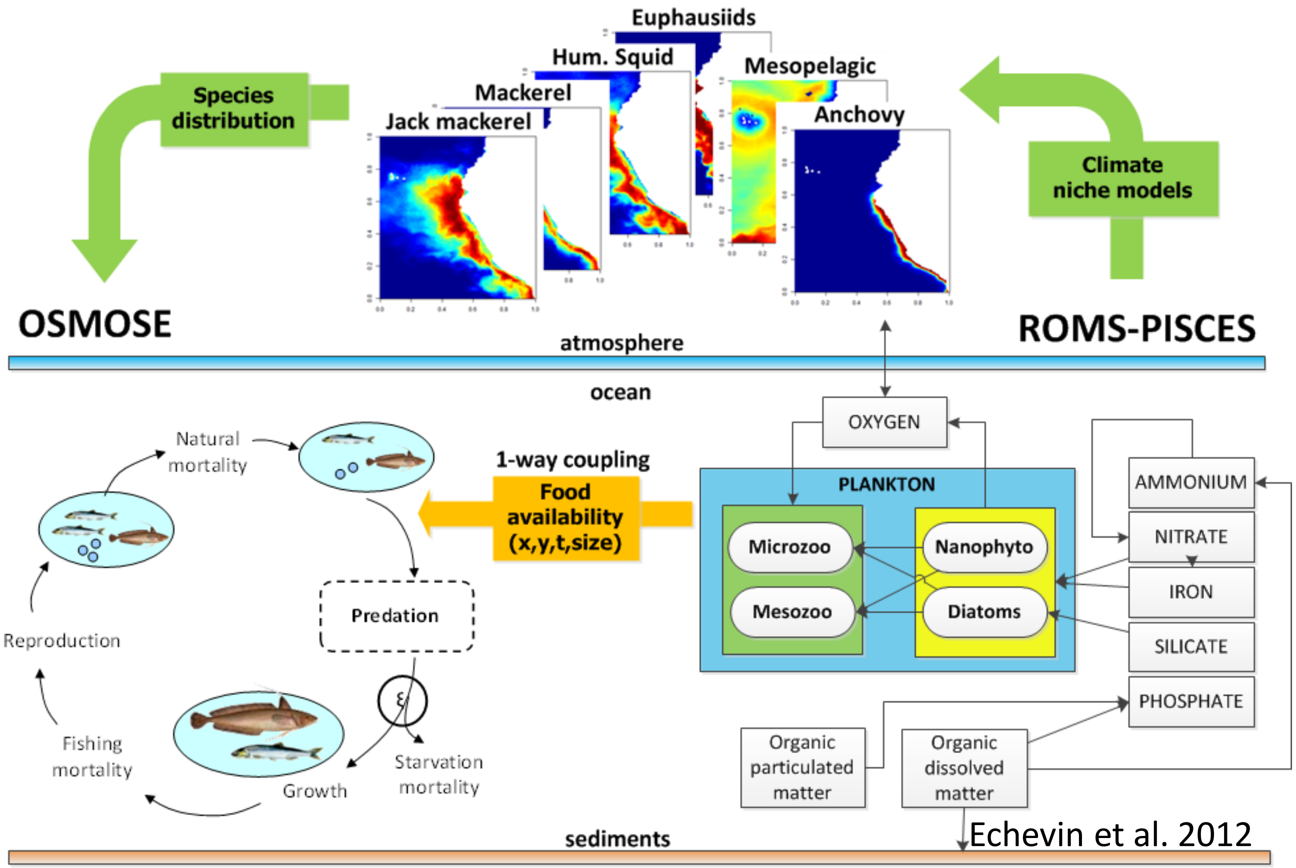


Anchovy larvae retention rates (%) in nursery areas Brochier et al., 2013).

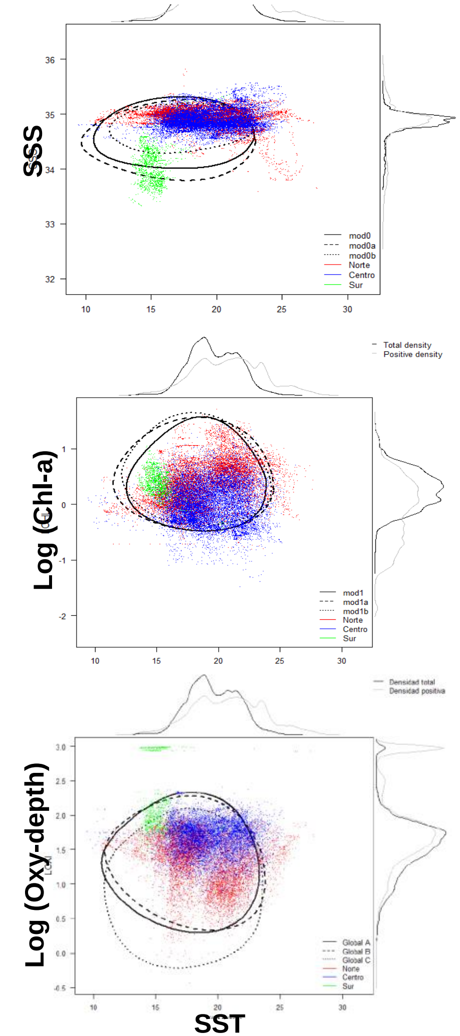
Limitations: time horizons of the models are still very far; need to yield scenarios for the next decades. Oxygen change is not estimated in current models

3. Challenges for sustainable management under climate change

Need to improve scientific knowledge on future scenarios



Mapping anchovy niche



Luján, C. & Oliveros, R. In prep.

Combination of ‘bioclimatic’ approach with ecological modelling (trophic interactions & IBM). Oliveros, Grados, Tam, Gutiérrez. IADB project: *Adaptación a los impactos del cambio climático en los ecosistemas marino-costeros y el sector pesquero peruanos*

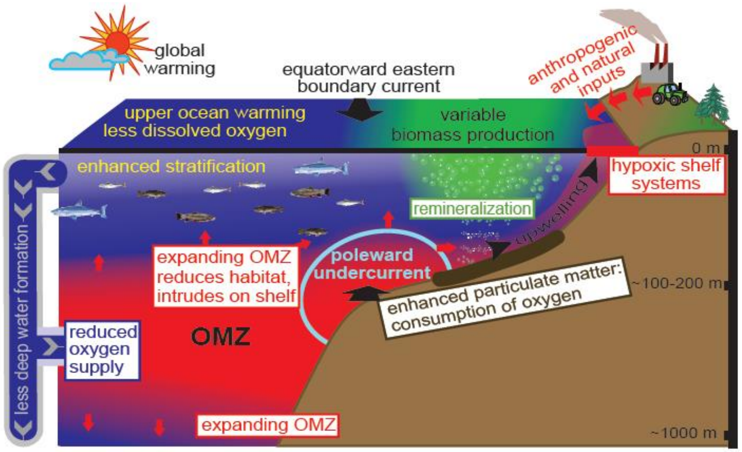
Need to address pollution hazards for the ecosystem and its resources

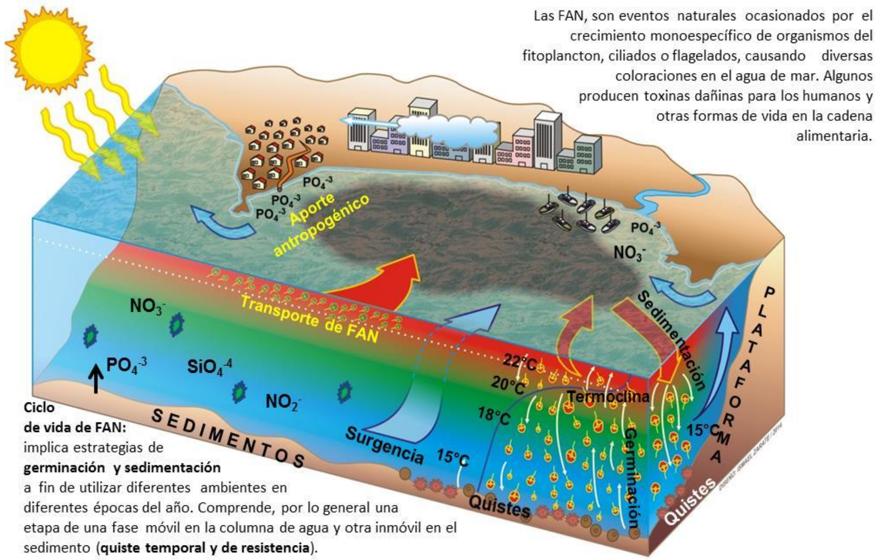
- Transboundary diagnostic analysis (GEF Project) identified two main transboundary problems in the HCLME:
  - suboptimal exploitation of fisheries resources(TP1)
  - anthropogenic disturbance of marine habitat (TP2).

- **Pollution** degrades habitats and amplify natural hipoxia (e.g. HABs); need to promote more investment to reduce pollution (sewage treatment, industrial & agricultural effluents) and protect the environmental quality, according to regional agreements and programs (e.g. CPPS- PNUMA).

- **Sewage treatment** still a pending issue to solve for several coastal cities.

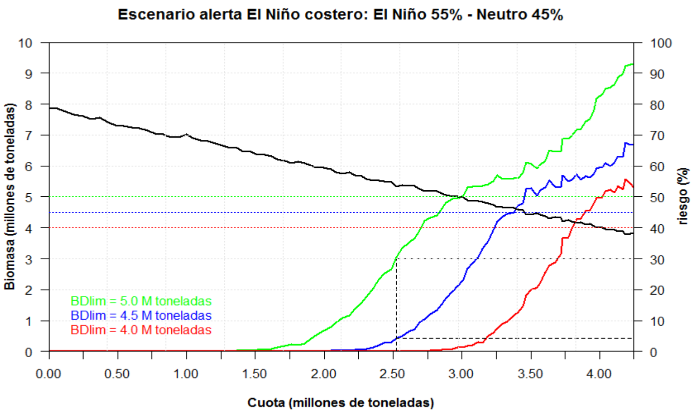
- Development of sustainable aquaculture need to consider impacts on coastal habitats and vulnerability to oceanographic fluctuations, hypoxia and low pH)





Combine fishery management with CC adaptation

- **Increasing demand for fish consumption and food security** justify promotion of **direct human consumption**, but this deals with several challenges and barriers (market demand, technology conversion, cold-supply food chains, etc.).



- Continue and/or strengthen adaptive management and control of **fishing power** (fleet size, fishing effort, IQs, etc.).
- Take profit of opportunities because of higher availability of warmer-water spp: tuna, mahi-mahi, developing management strategies and ensuring good practices
- Extend governance, incentives and **law enforcement** for ensuring **good practices** and sustainability, applying effective management for artisanal fishing.

- Consider **co-management** options for coastal resources (valuable lessons achieved in Chile), articulation between sectors (energy, environment, fisheries) and with local governments.
- Capacity building at different levels towards **value-addition** and **win-win** activities to increase resilience of ecosystem and stakeholders, while attending food security needs **(case: Program ' A Comer Pescado' - Peru)**

Concluding remarks (current knowledge)

- Humboldt Current ecosystems and fisheries highly vulnerable to climate variability. High-order socioeconomic importance for Peru and Chile of HCLME goods and services.

- Contrasts between current **SST** trends (-) and models for future SST (+). High degree of spatial **primary productivity** trends; uncertainty in temporal patterns of **oxygenation**; paucity of historic records of **pH**.

- First models (running IPCC scenarios **for the second half of the XXI century**) predict decrease of PP and of biomass yields of current main biological resources.

- **Multiple stressors add vulnerability** through habitat compression and physiological constraints (oxygen depletion and low pH), not included yet in regional models.

- Status of main fisheries for the past 15 years exhibit **differences among resources**:
    - Jack Mackerel, Mackerel and Peruvian sardine show lower availability
    - Positive trends for mahi-mahi, jumbo squid, Peruvian hake and Chilean sardine
    - Fluctuations and differences among stocks for Anchovy biomass

Concluding remarks (sustainable management challenges)

- Concile food security needs and current production model (IHC-oriented) with increased vulnerability of fish resources due to climate change stressors.

- Urgent issues to mitigate are sewage treatment and nutrient loading that worsen natural hypoxia in coastal areas. For effective management, combine governance policies, adaptive instruments related with climate variability and **improvement of law enforcement** for all stakeholders

- Need to **foster research for development of natural and social science- based tools** useful not only for day-to-day decision making, but for strategic planning (long-term); research outreach can help to:
  - Extend effective management to artisanal fisheries, providing capacity building and assistantship for value addition of the products.
  - Promote co-management for local resources; that might imply changes in current normativity and regulations
  - To reduce vulnerability of local population and fishers, need to diversify income sources, esp. environmental-friendly (sustainable aquaculture, eco-tourism) etc.
  - Extend effective management instruments and good practices for transboundary ‘benefited’ spp by climate change (tuna, mahi-mahi and other oceanic spp)

Thank you
Gracias