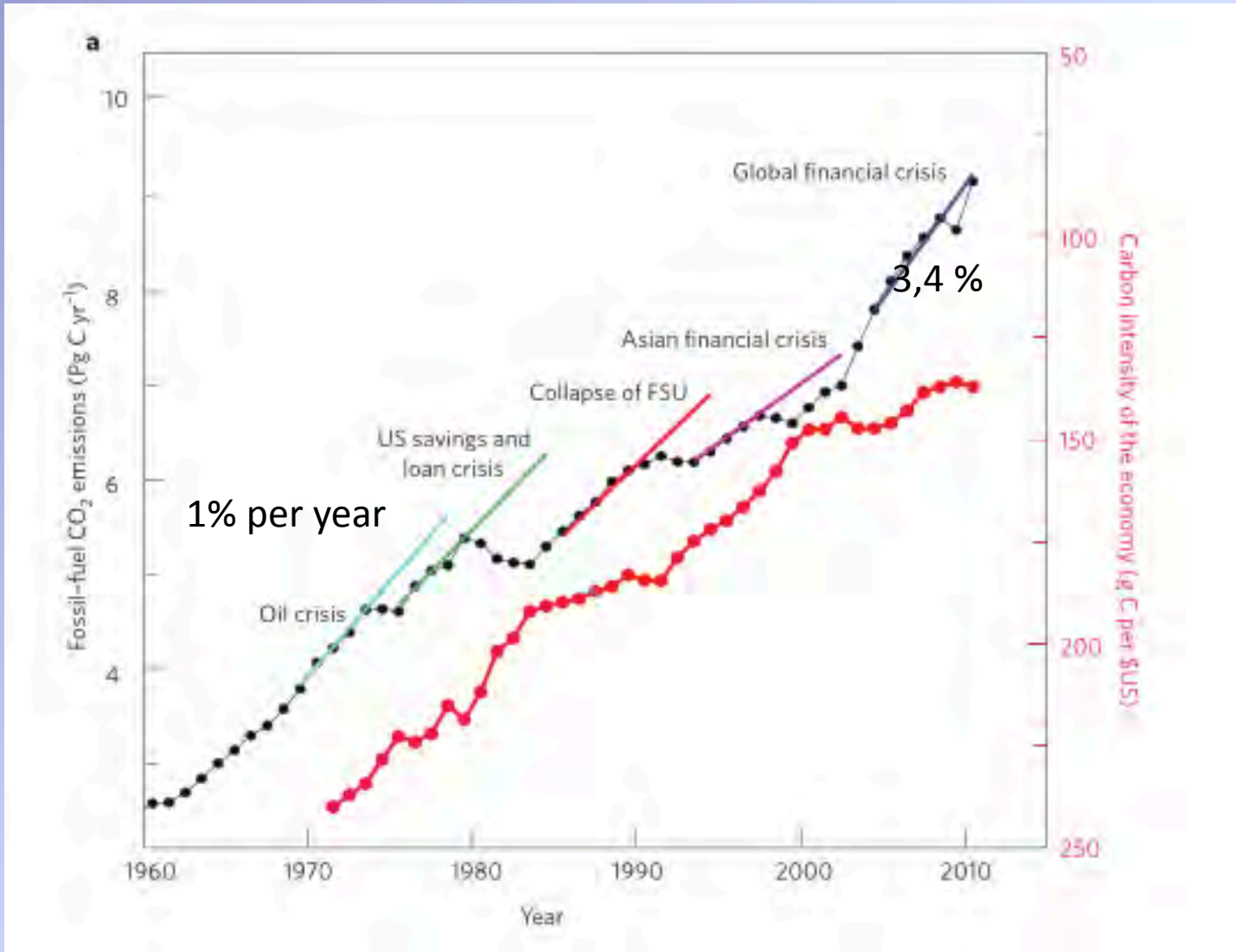
Ocean acidification along the southeastern Pacific coastal ecosystems: biological responses, interactions with multiple stressors and human dimensions

N. **Lagos**, M.Lardies, P.H. Manriquez, B. Broitman, S. Gelcich, F. Vasquez & Cristián Vargas

Presentation

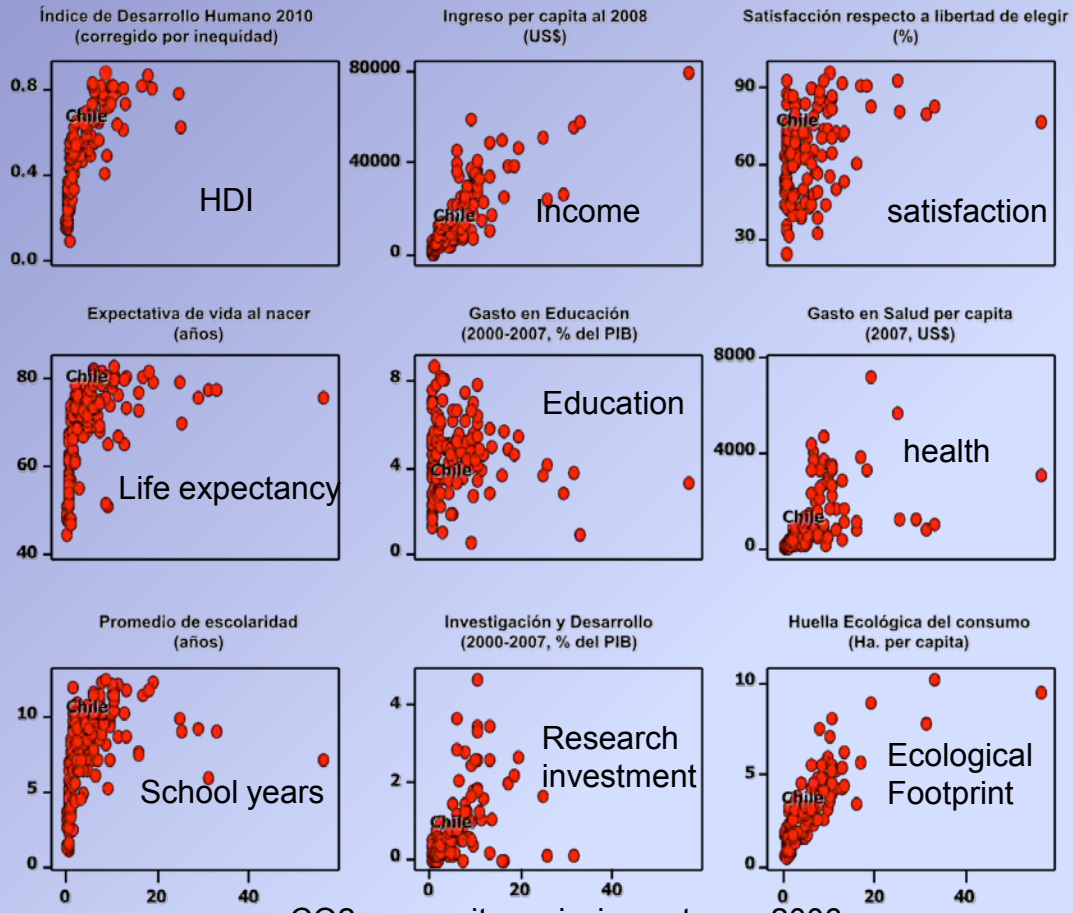
- Climate change in the world oceans
- Variability of the Southern PAcific Coastal Ecosystems (SPACE)
- Results about biological responses to OA of selected species models/resources
- Describe ongoing ecological studies and research projects
- Other efforts to disseminate the message

Economy increase atmospheric CO_2

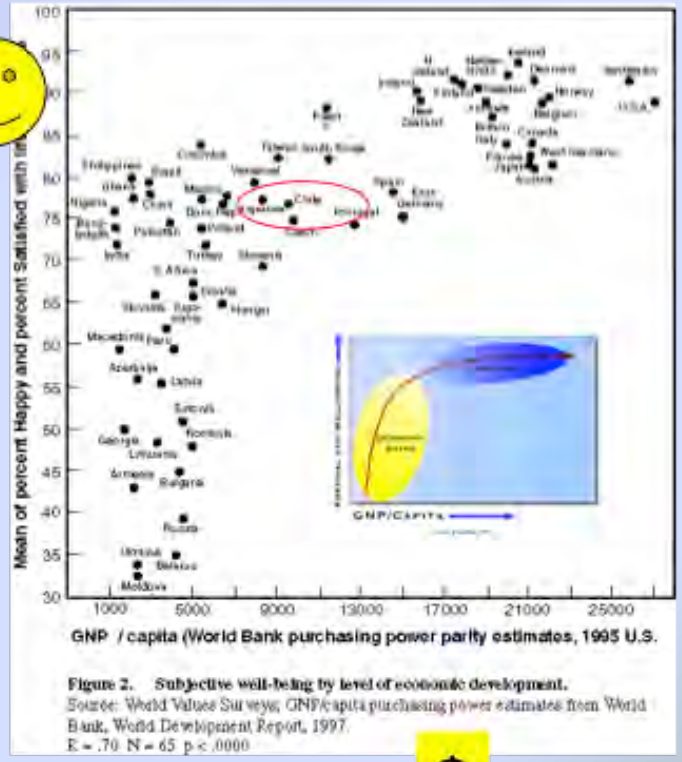


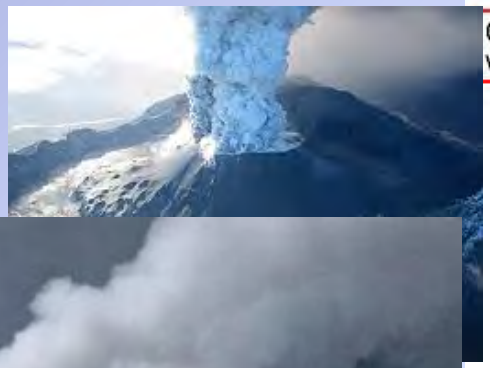
Peters et al. 2012 Nat Clim Change

Chile in the global scenario

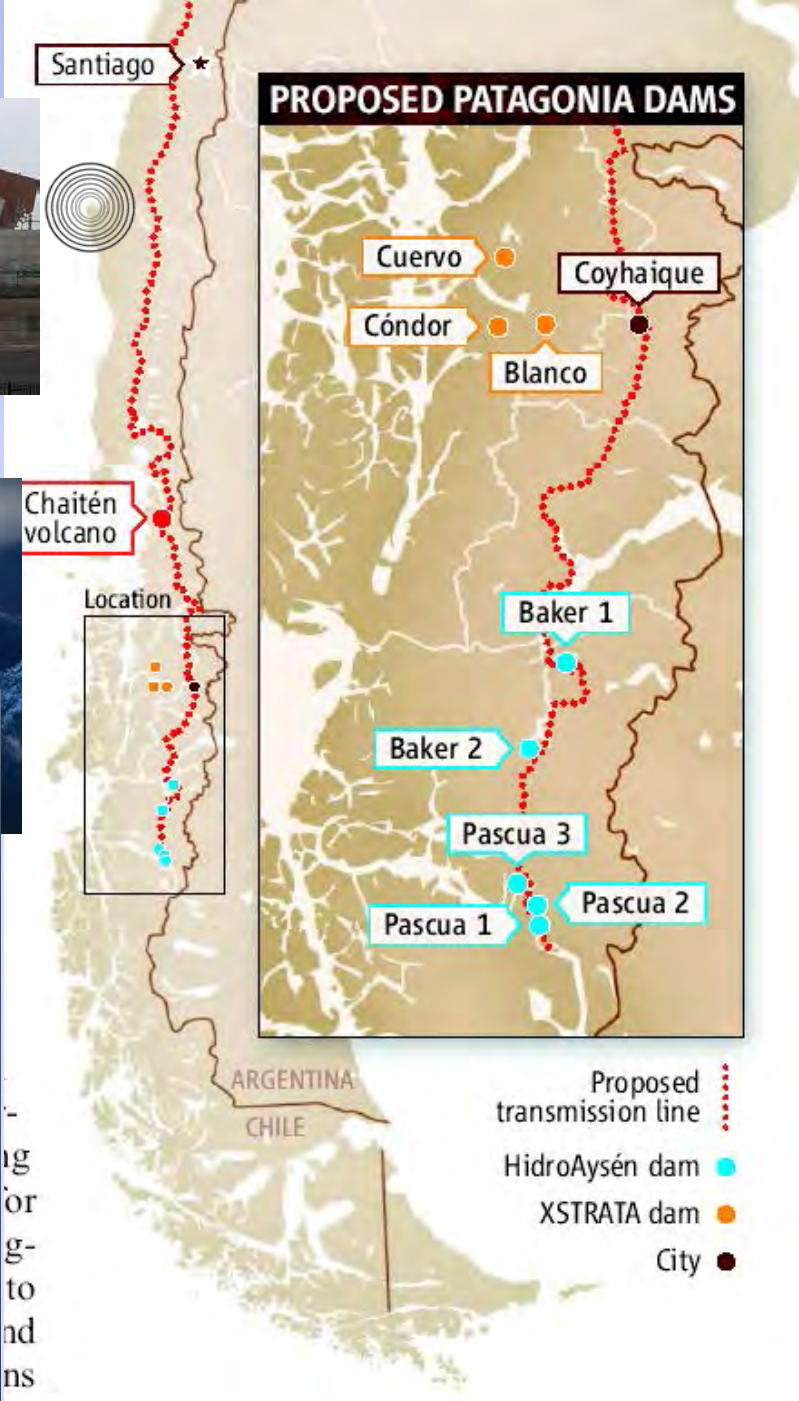


CO2 per capita emissions at year 2006

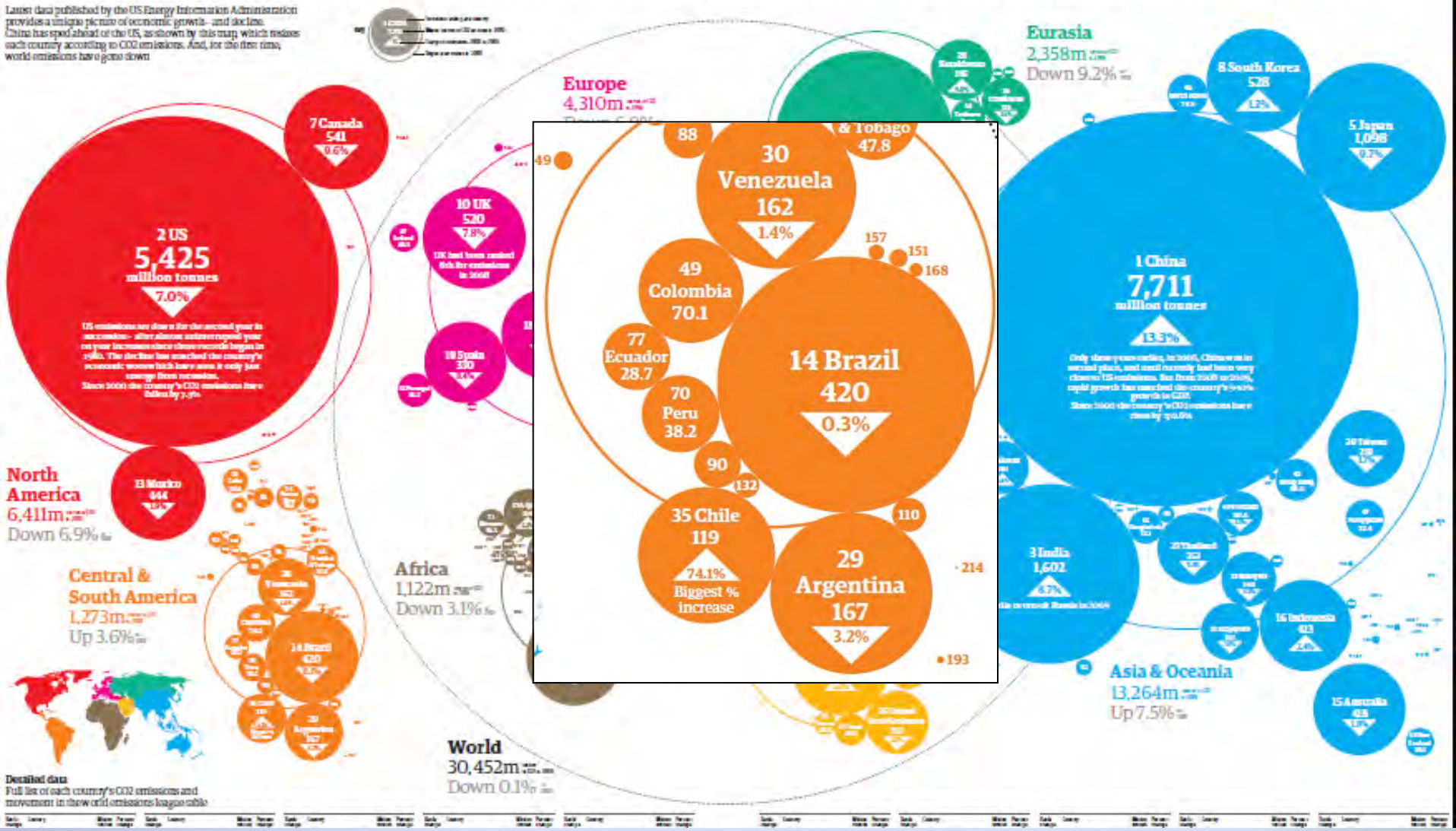




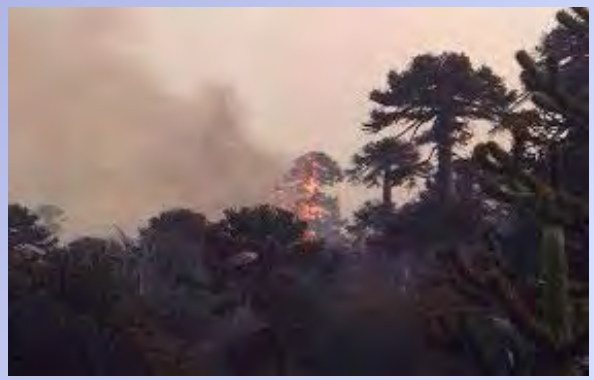
Chile need energy to do work

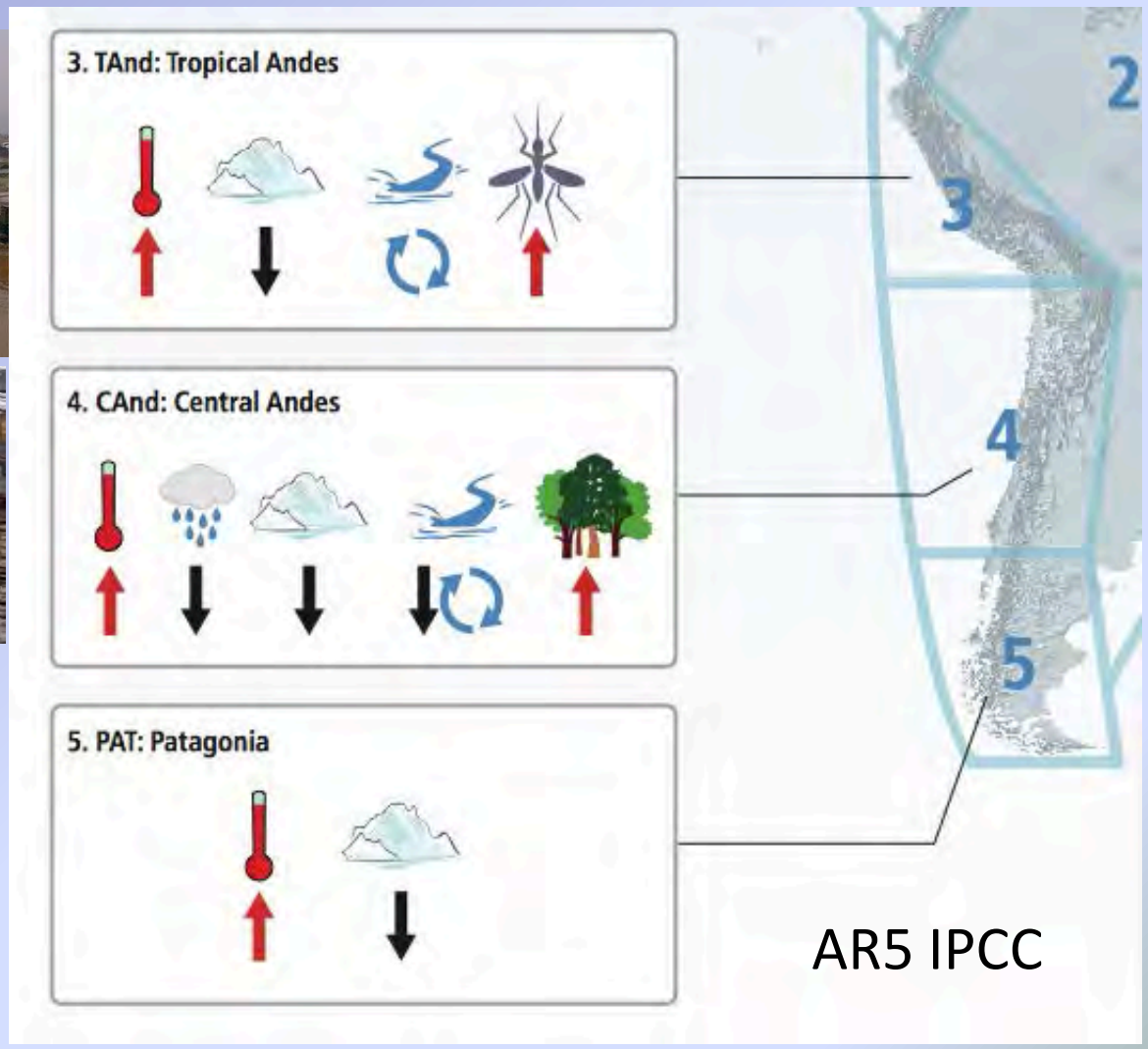


An atlas of pollution: the world in carbon dioxide emissions



In this moment: extreme events



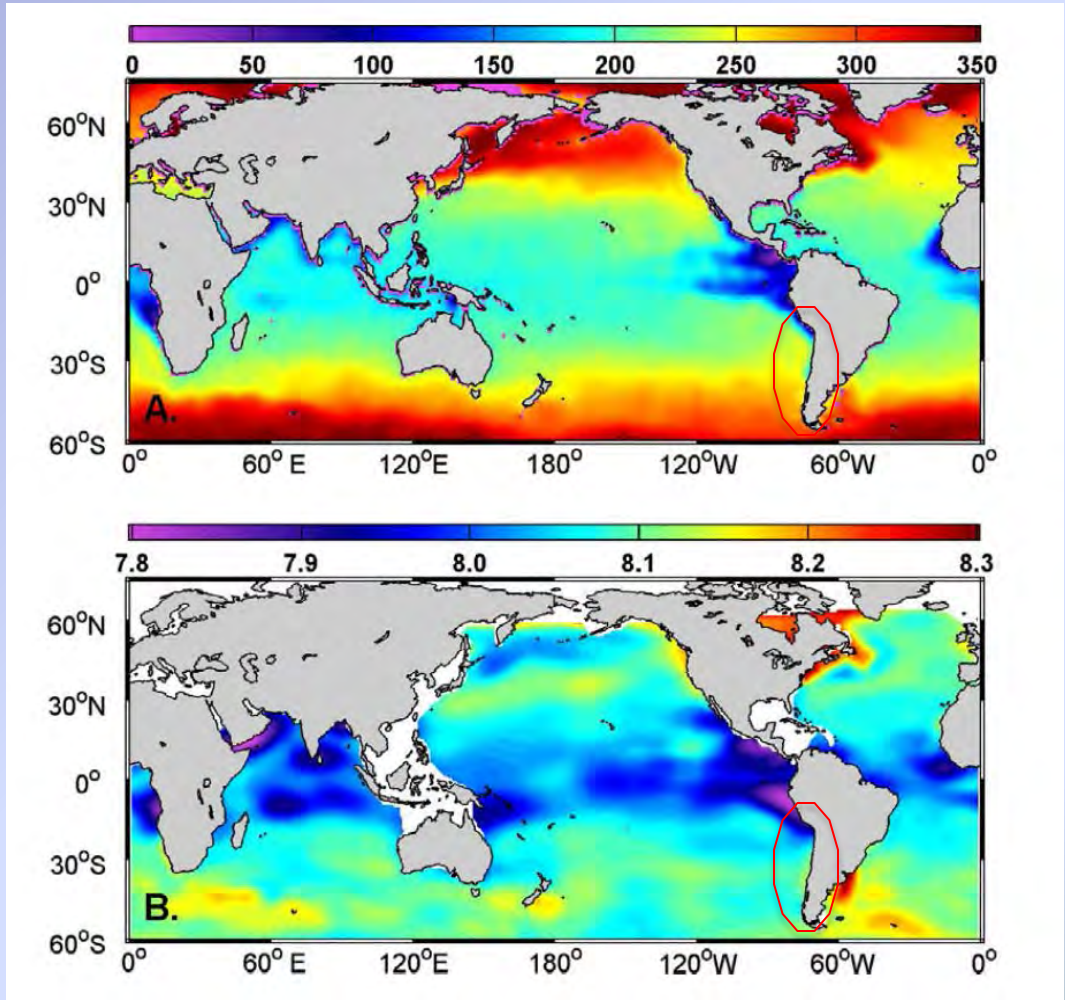



I DON'T BELIEVE IN
GLOBAL WARMING

The Humboldt current system

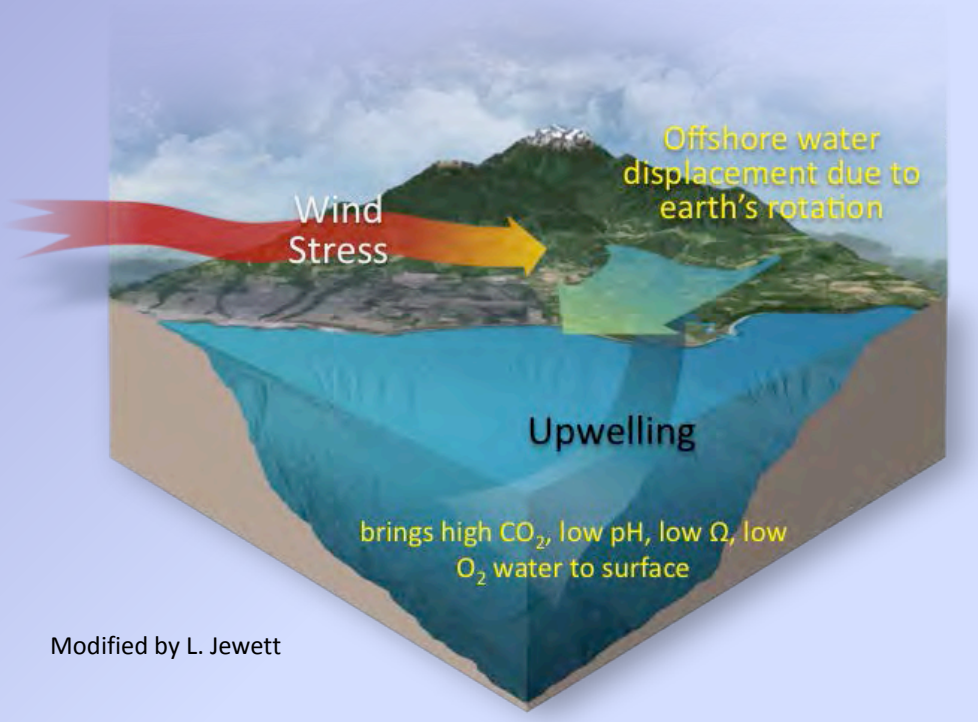
Oxygen (µmol/kg) at 50 m
(modified from Conkright et al, 2002)

pH
(modified from Key et al., 2004)



Chávez et al. 2008

Upwelling ecosystems



Modified by L. Jewett

Upwelling areas are vulnerable to ocean acidification

1850

2100

REPORTS

Evidence for Upwelling of Corrosive "Acidified" Water onto the Continental Shelf

Richard A. Feely,[1]* Christopher L. Sabine,[1] J. Martin Hernandez-Ayon,[2] Debby Ianson,[3] Burke Hales[4]

The absorption of atmospheric carbon dioxide (CO_2) into the ocean lowers the pH of the waters. This so-called ocean acidification could have important consequences for marine ecosystems. To

REPORTS

Rapid Progression of Ocean Acidification in the California Current System

Nicolas Gruber,[1]* Claudine Hauri,[1] Zouhair Lachkar,[1] Damian Loher,[1] Thomas L. Frölicher,[2] Gian-Kasper Plattner[3]

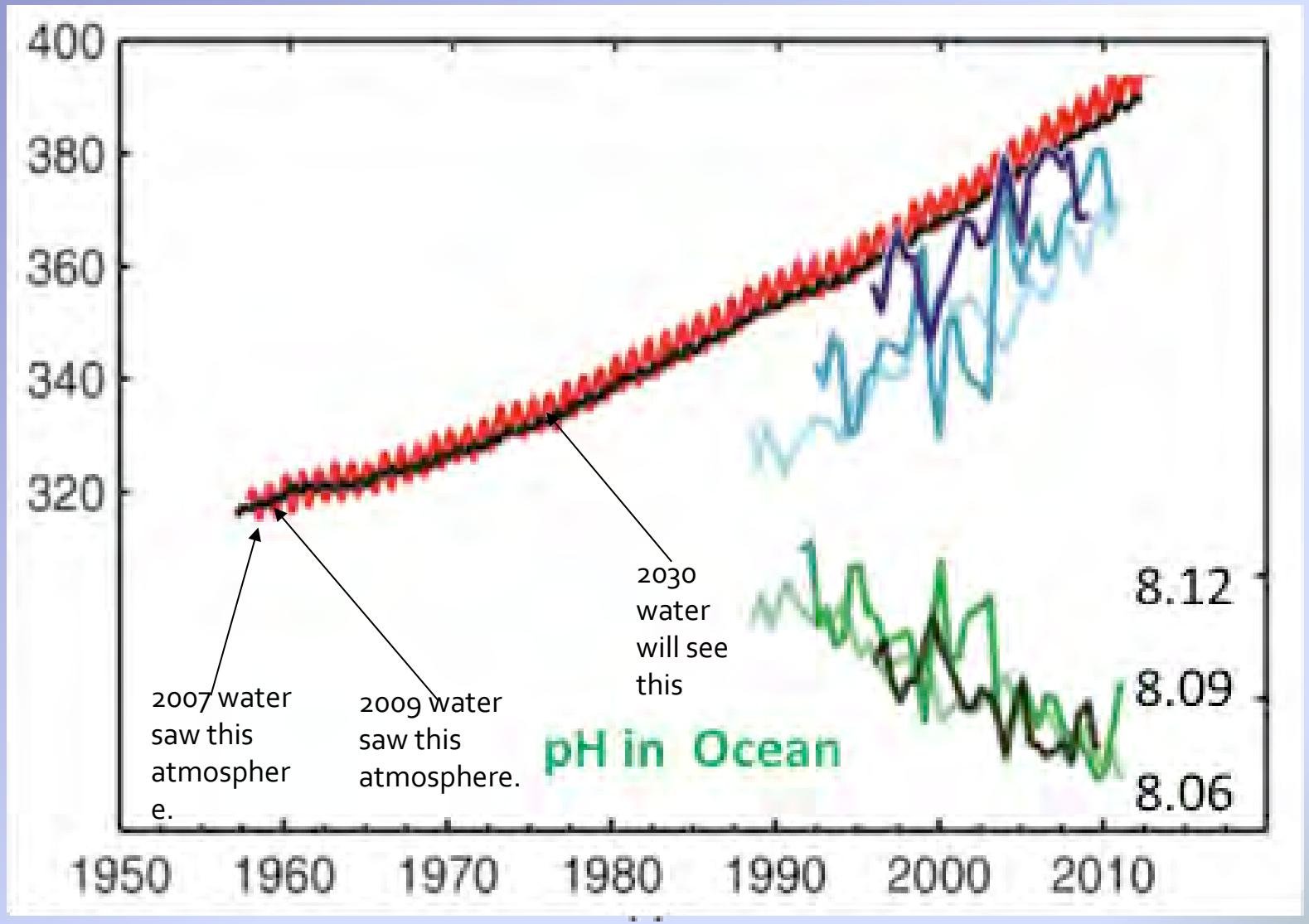
Nearshore waters of the California Current System (California CS) already have a low carbonate saturation state, making them particularly susceptible to ocean acidification. We used

OCEAN ACIDIFICATION (pH)

7.1 7.7 8.3

IGBP, IOC, SCOR (2013) Ocean Acidification Summary for Policy Makers

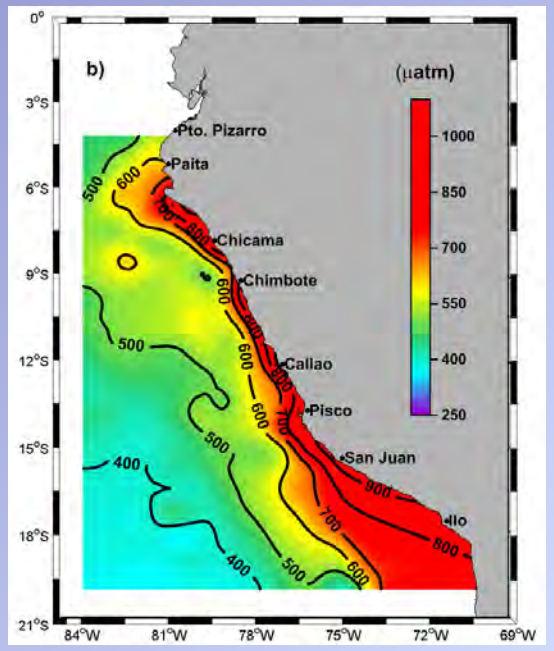
The progressive OA



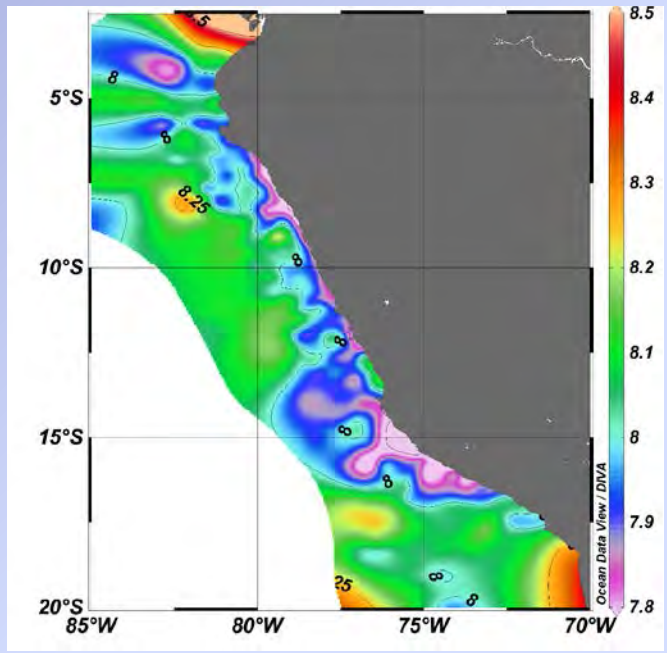
Doney et al 2009; IPCC (2013) WG I, Summary for Policymakers, modified by B. Hales (OSU);

Northern Humboldt Current System (Perú)

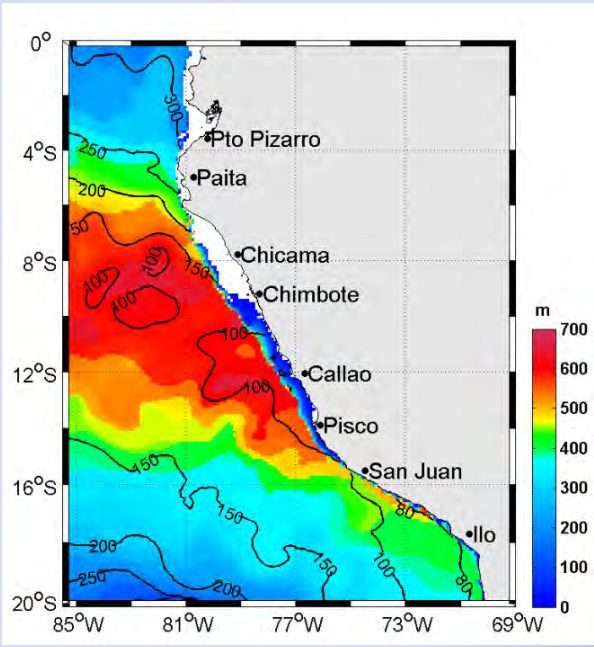
pCO_2



pH

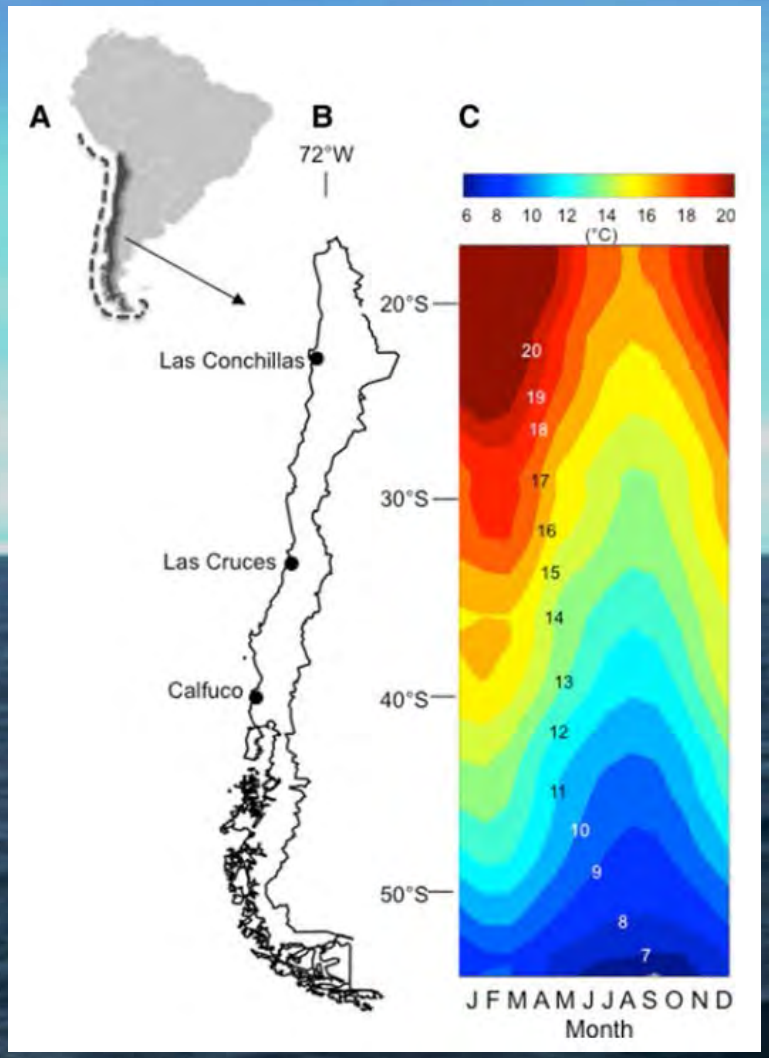


O_2 (< 0,5 ml/L)

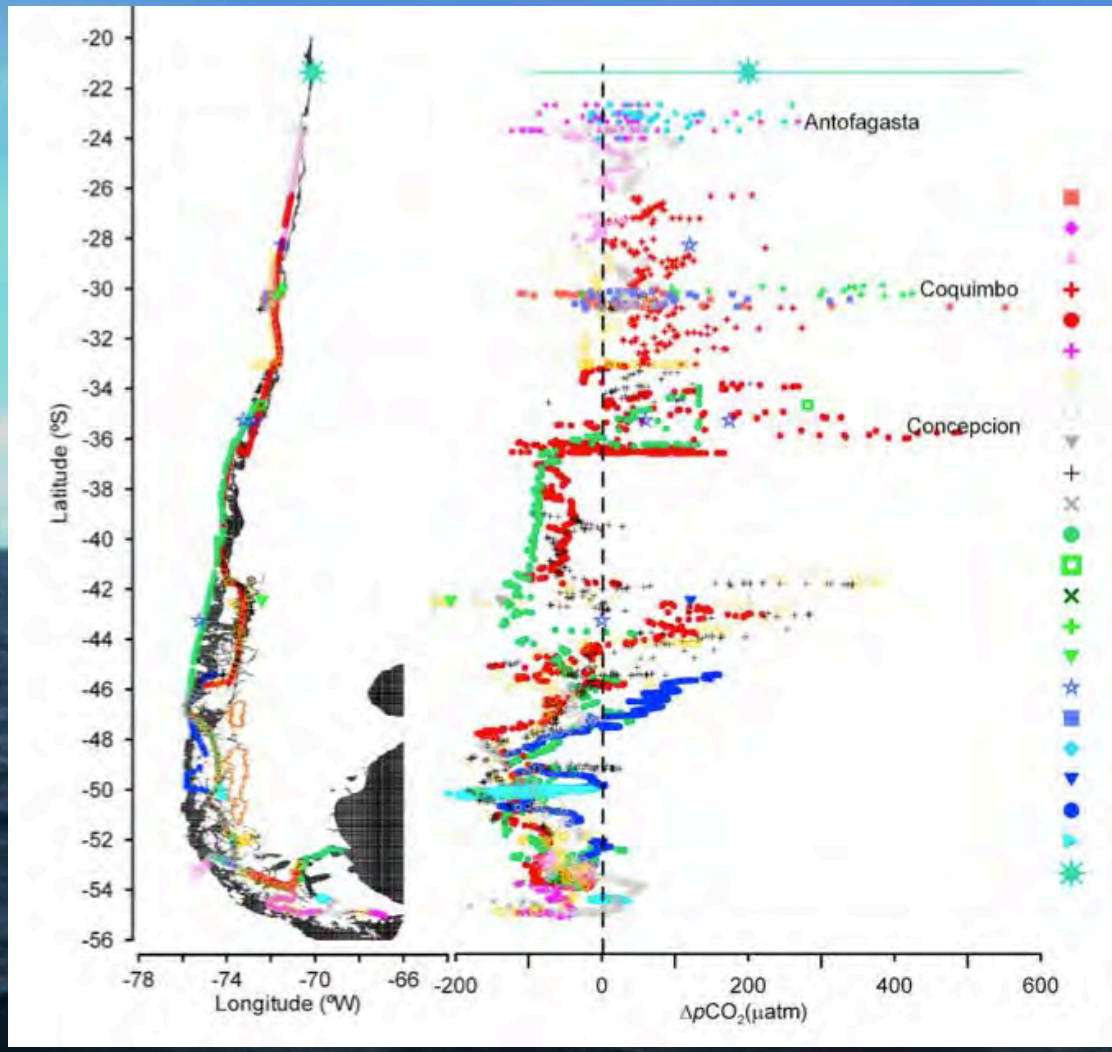


Friederich et al 2008 PIO, Libro de Oro de IMARPE 2014, J. Ledesma, M. Graco

The SPACE is a region of intense variability in temperature, CO_2 fluxes, freshwater inputs

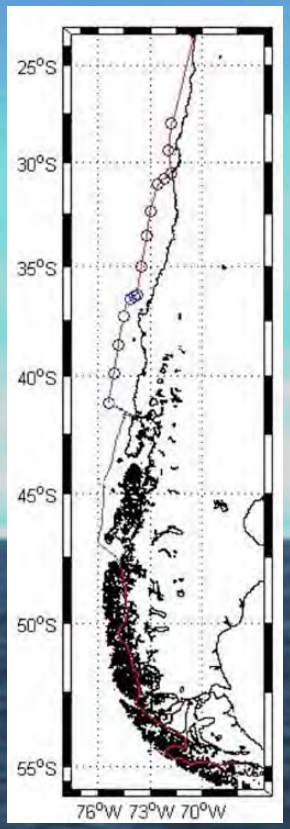


Ramajo et al. 2013
Lardies et al. 2014
Navarrete et al. 2014

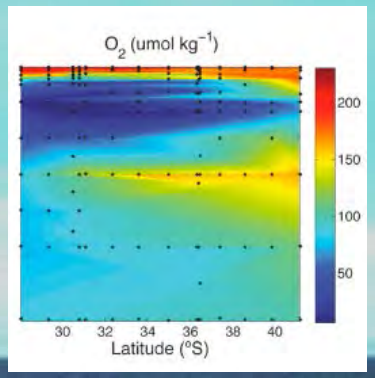


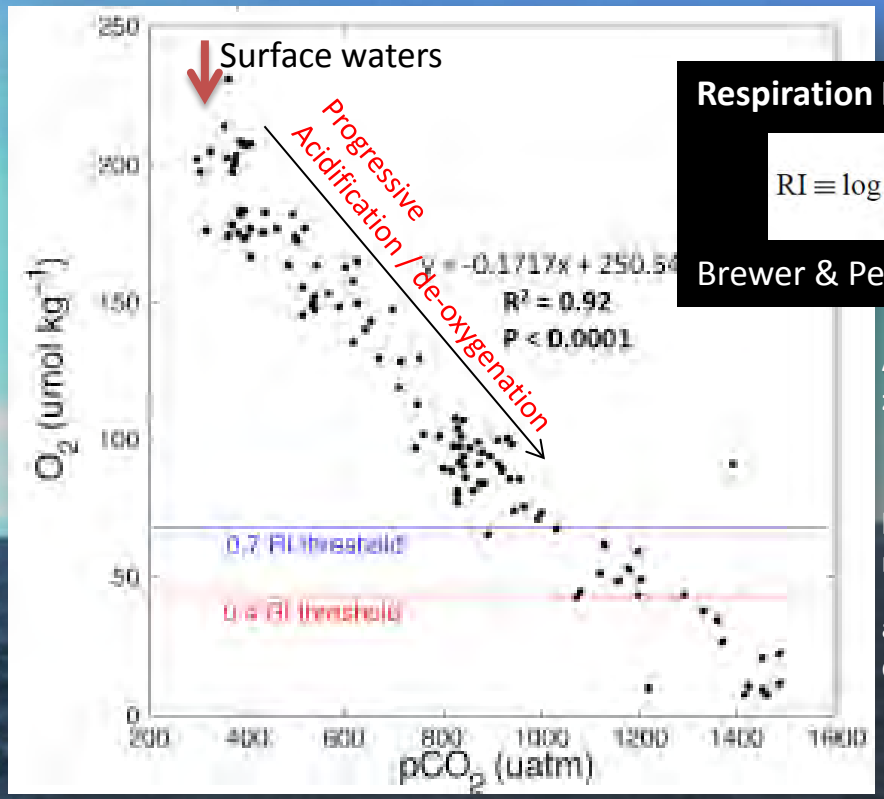
Torres et al. 2011

The ocean is changing to more CO_2 - less Oxygen conditions



Mayol et al. 2012





Respiration Index

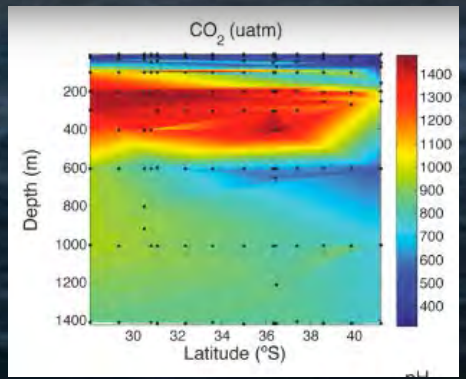
$$RI \equiv \log_{10} \frac{pO_2}{pCO_2}$$

Brewer & Peltzer(2009)

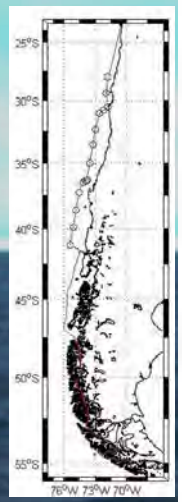
Aerobic stress zone

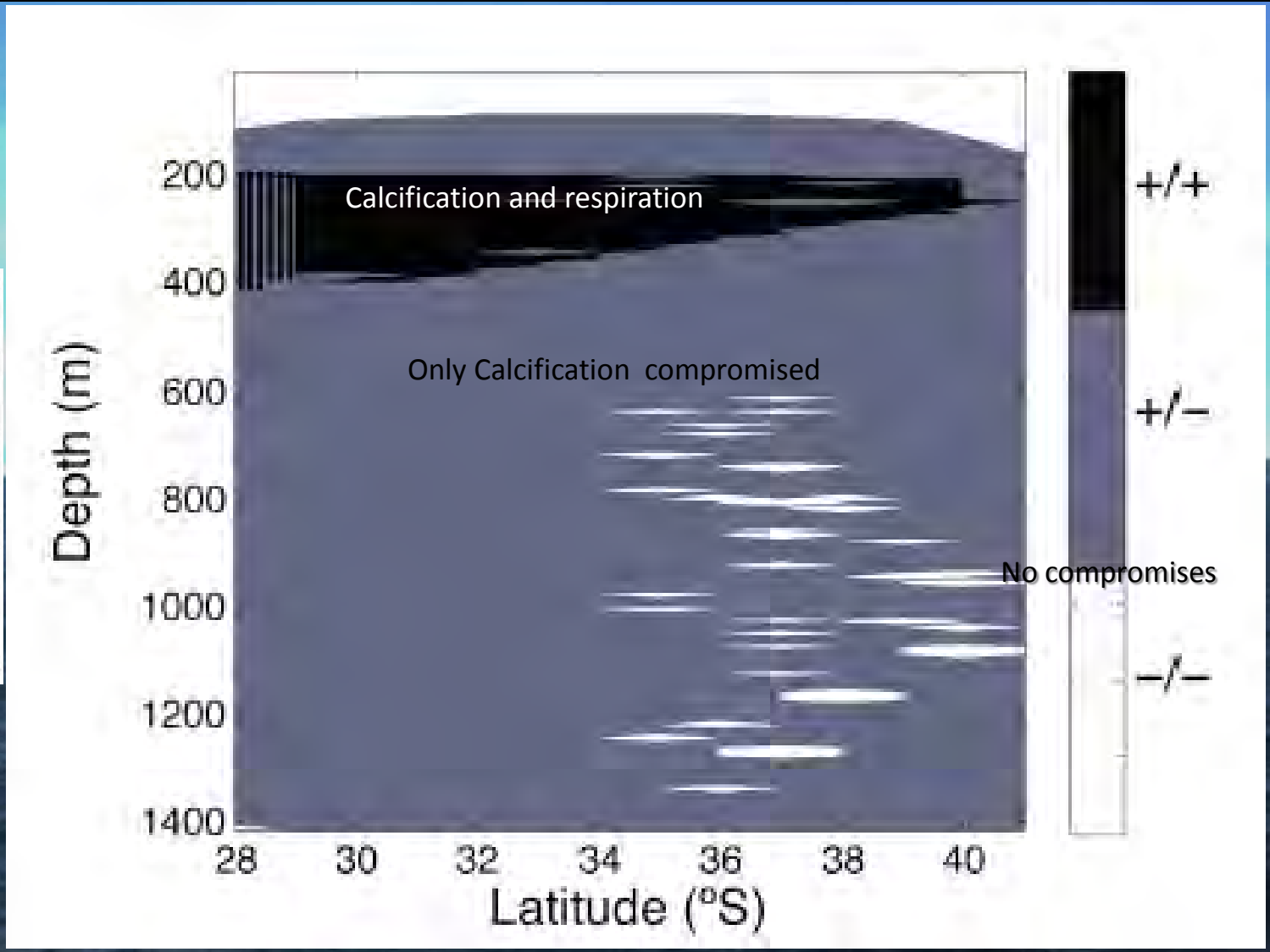
limit for aerobic respiration

aerobic respiration does not occur



Compromising marine life



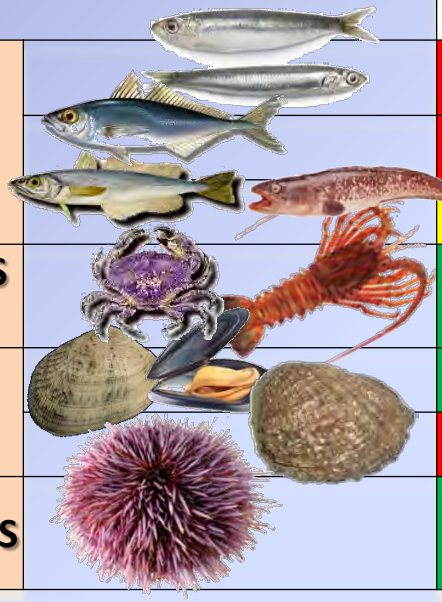


Mayol et al. 2012, Biogeosciences

The system sustain high diversity and coastal productivity (the biggest in the world oceans)

Now these fisheries are vulnerable

H: High (47%)
M: Moderate (22%)
L: Low (30%)



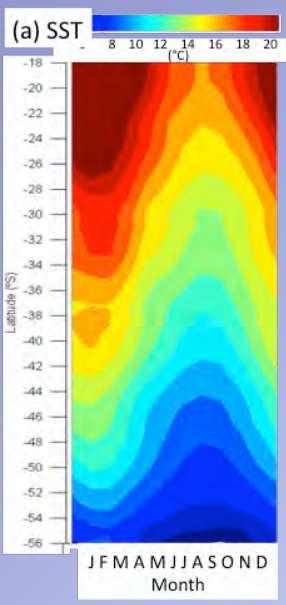
		ECOLOGICAL					SOCIO-ECONOMIC			
		Distribution	Abundance	Growth and reproduction	Diseases	Calcification	Operational cost	Market	Infraestructure	Avalaibility – Access
FISHES		H	H	H	L	L	M	H	L	H
		H	H	H	L	L	H	H	L	H
		M	M	M	L	L	L	L	L	M
CRUSTACEANS		L	M	H	H	H	L	H	L	M
MOLLUSCS		L	M	H	H	H	H	H	L	M
		H	H	H	H	H	M	M	L	H
EQUINODERMS		L	H	H	M	H	M	H	L	M

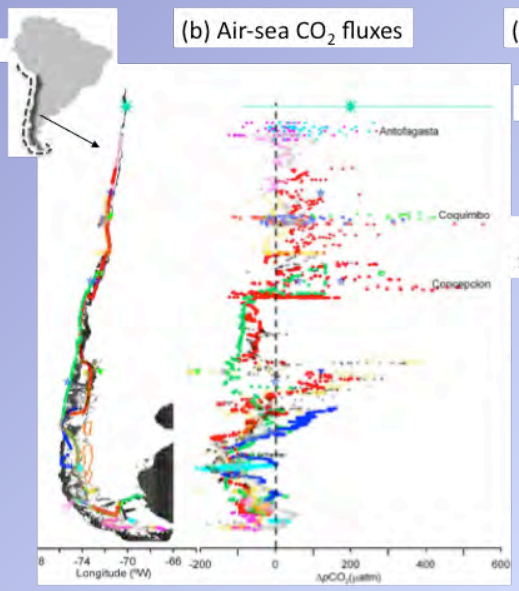
Alarcón et al. Proyecto FIP Nº 2014-26

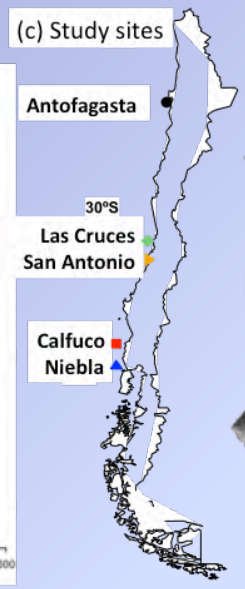
Which are the impacts of OA in the region?

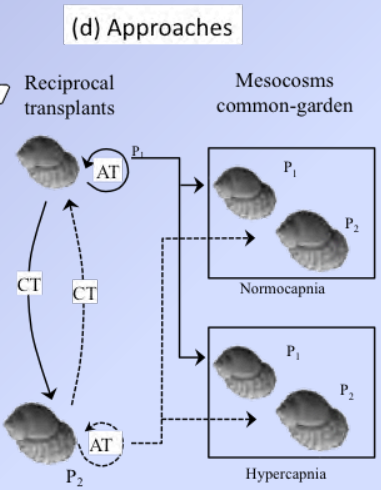
- Selection the species models = the canary in the coalmine

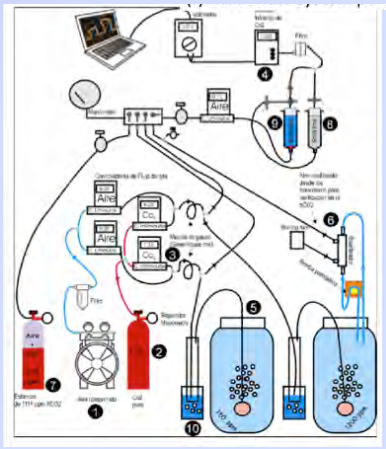
THE APROACHES TO UNDERSTAND OA IMPACTS



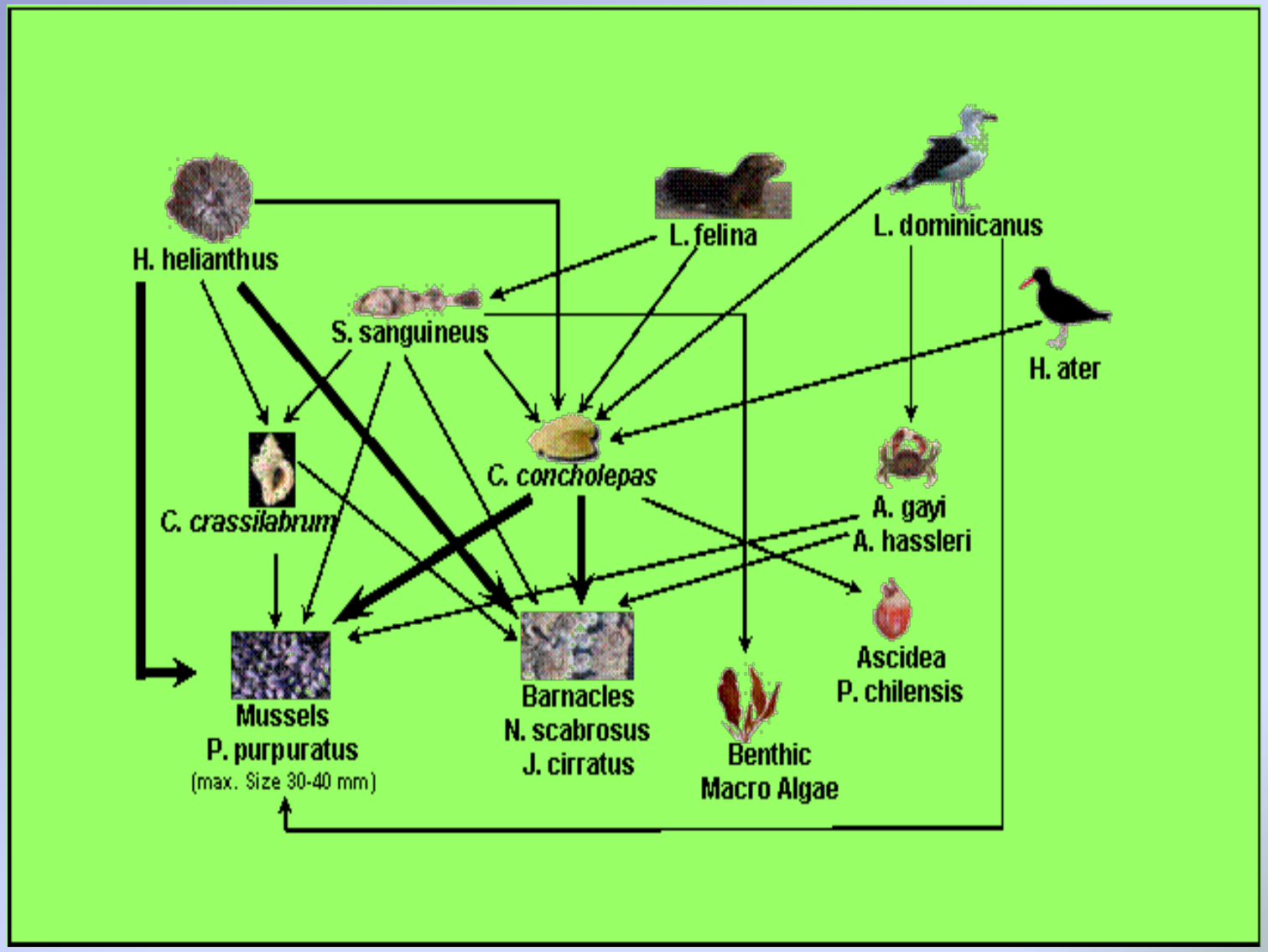




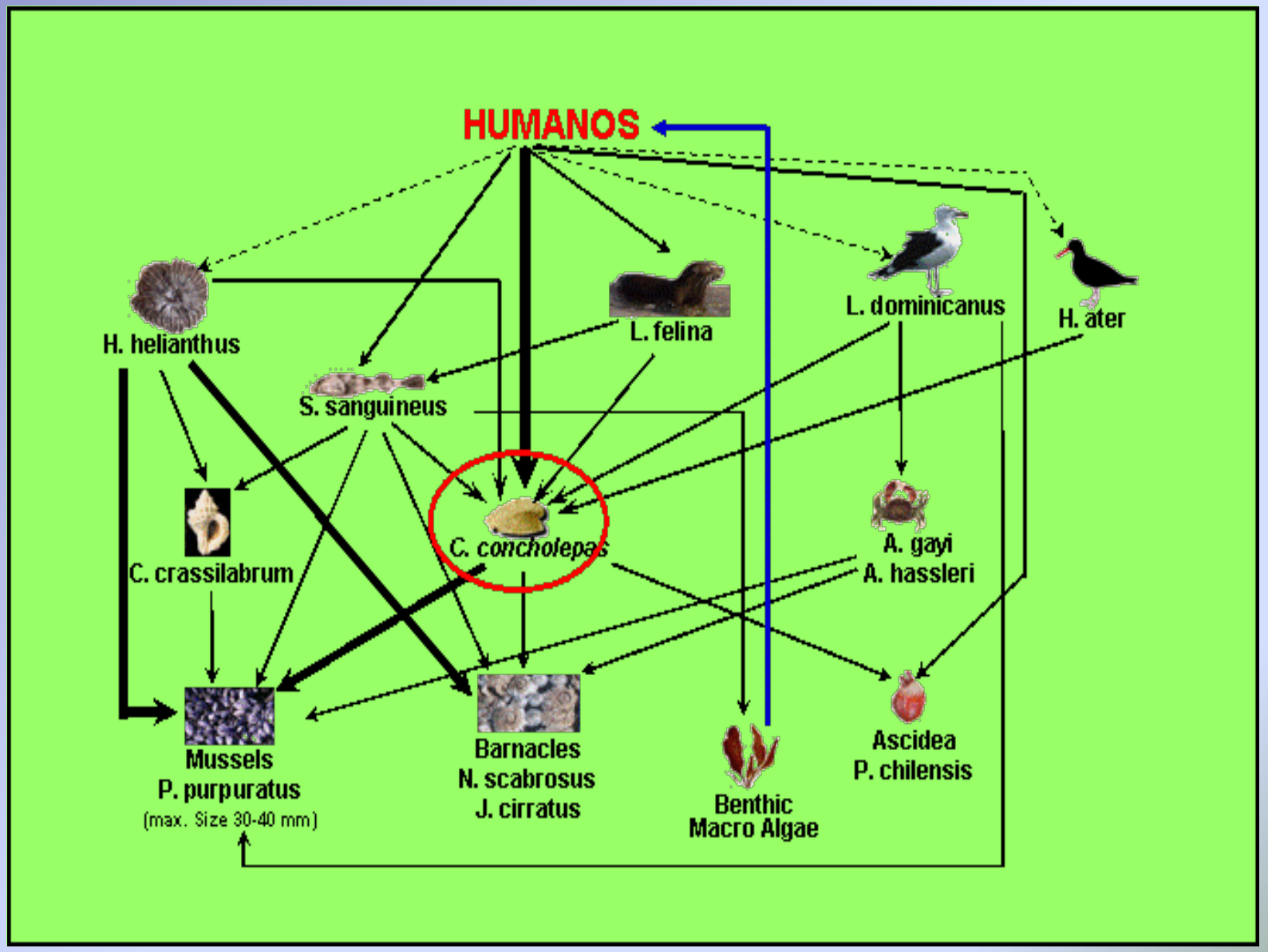


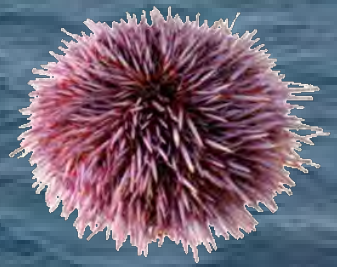


Keystone predator



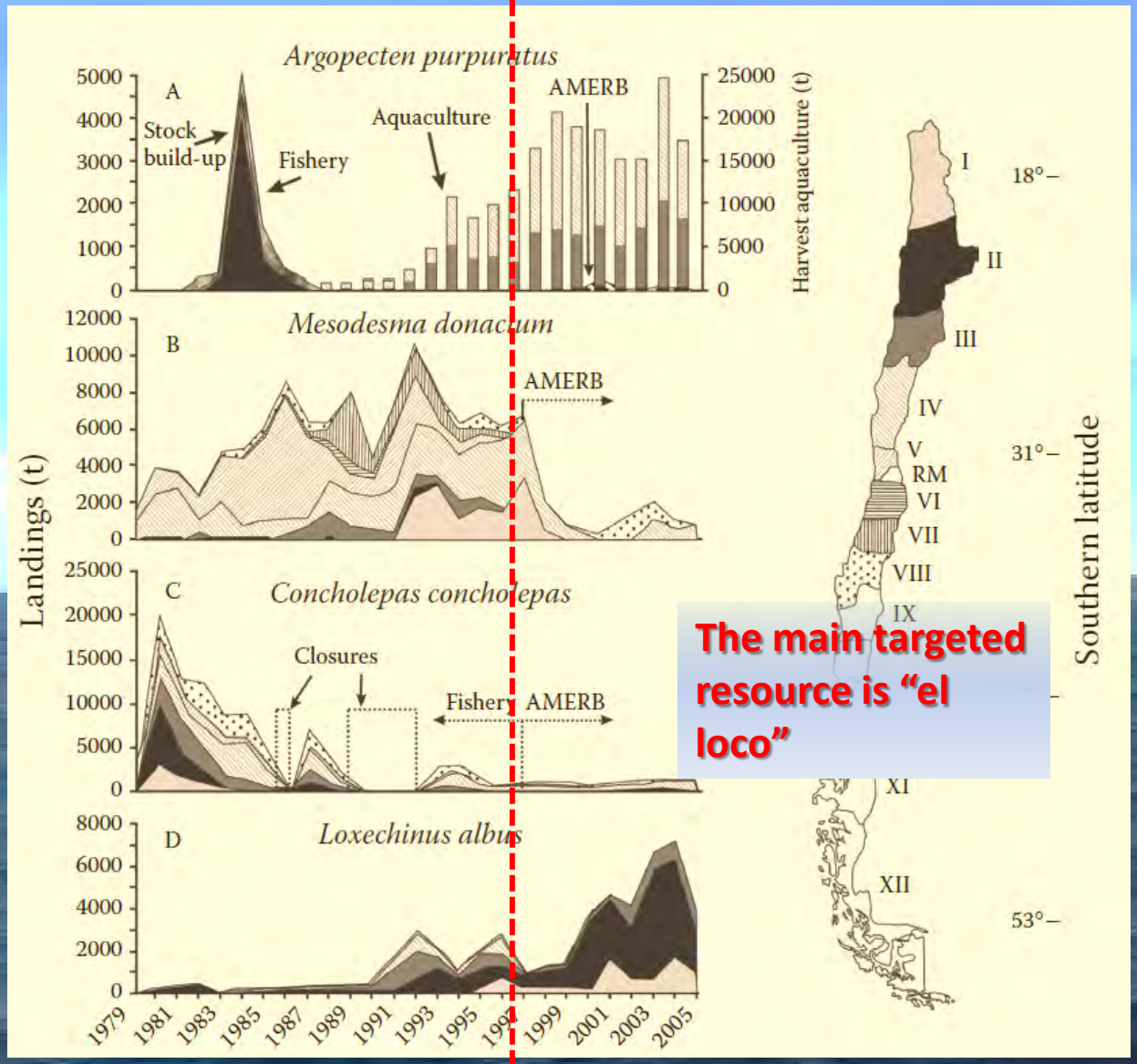
Human impacts





Open access

TURFs



The main targeted resource is “el loco”

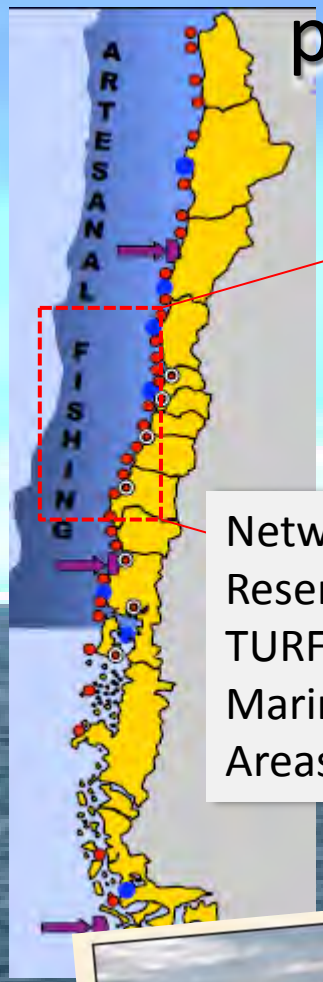
Thiel et al. 2008

Territorial User Right Fisheries (TURFs) to registered ‘associations/ unions’ of artisanal fishers along the Chilean coast

- Empowered by creating a sense of ownership that motivate for sustainable extraction

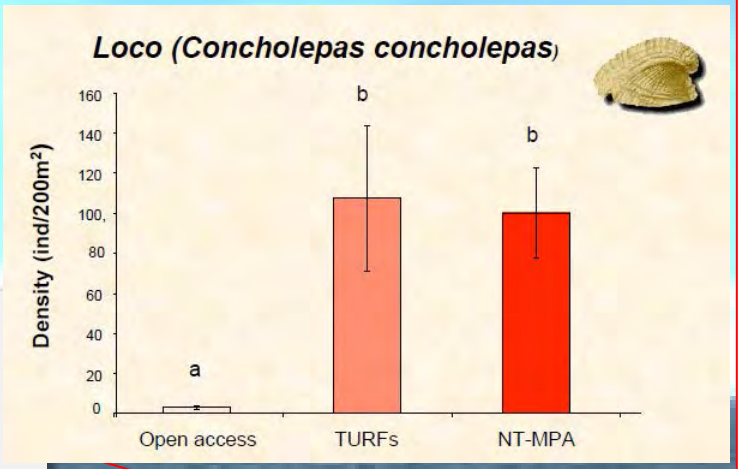
Gelcich et al. 2011

TURFs and “el loco” fishery are located in progressives OA upwelling areas

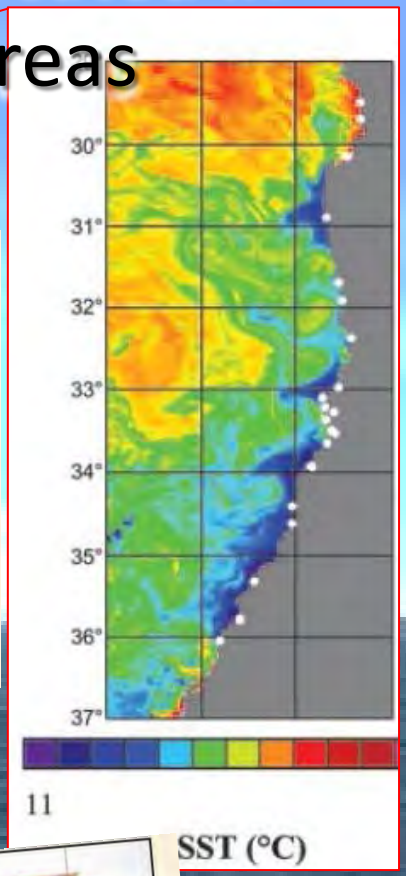


Network of Reserves (blue), TURFs (red) Marine Protected Areas (arrows)

Gelcich et al. 2011



Gelcich et al. 2011



Broitman et al. 2008

Courtesy S. Gelcich

Results indicate that “el loco” is sensitive to ocean acidification

Journal of Plankton Research plankt.oxfordjournals.org

J. Plankton Res. (2013) 0(0): 1–10. First published online Month 00, 0000 doi:10.1093/plankt/fbt045

CO_2-driven ocean acidification reduces larval feeding efficiency and change food selectivity in the mollusk *Concholepas concholepas*

CRISTIAN A. VARGAS[1]*, MAKARENA DE LA HOZ[1], VICTOR AGUILERA[1], VALESKA SAN MARTÍN[1], PATRICIO H. MANRÍQUEZ[1], JORGE M. NAVARRO[2], RODRIGO TORRES[2], MARCO A. LARDIES[1] AND NELSON A. LAGOS[3]

[1]AQUATIC ECOSYSTEM FUNCTIONING LAB (LAFE), AQUATIC SYSTEM UNIT, ENVIRONMENTAL SCIENCES CENTER EULA CHILE, UNIVERSIDAD DE CONCEPCIÓN, CONCEPCIÓN, CHILE, [2]INSTITUTO DE CIENCIAS MARINAS Y LIMNOLÓGICAS, LABORATORIO COSTERO DE RECURSOS ACUÁTICOS DE CALFUCO, UNIVERSIDAD AUSTRAL DE CHILE, VALDIVIA, CHILE, [3]CENTRO DE INVESTIGACIÓN EN ECOSISTEMAS DE LA PATAGONIA (CIEP), COYHAIQUE, CHILE, [4]FACULTAD DE ARTES

Vol. 502: 157–167, 2014
doi: 10.3354/meps10703

MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser

Published April 15

Ocean acidification affects predator avoidance behaviour but not prey detection in the early ontogeny of a keystone species

Patricio H. Manríquez[1,*], María Elisa Jara[1], María Loreto Mardones[1], Rodrigo Torres[2], Jorge M. Navarro[1], Marco A. Lardies[3], Cristian A. Vargas[4], Cristián Duarte[5], Nelson A. Lagos[6]

Others species ?


Lapas: *Fissurella ssp*


Pulpo: *Octopus mimus*


Piure: *Pyura chilensis*


Erizo: *Loxechinus albus*


Jaibas: *Homalaspis plana*


Bivalvs: *Mesodesma donacium*


Algas: *Durvillea antarctica,*

Human dimension of C. concholepas fisheries

Concholepas concholepas "loco" ("Chanque" in Peru)
(annual landings 2.5 metric tons per year)

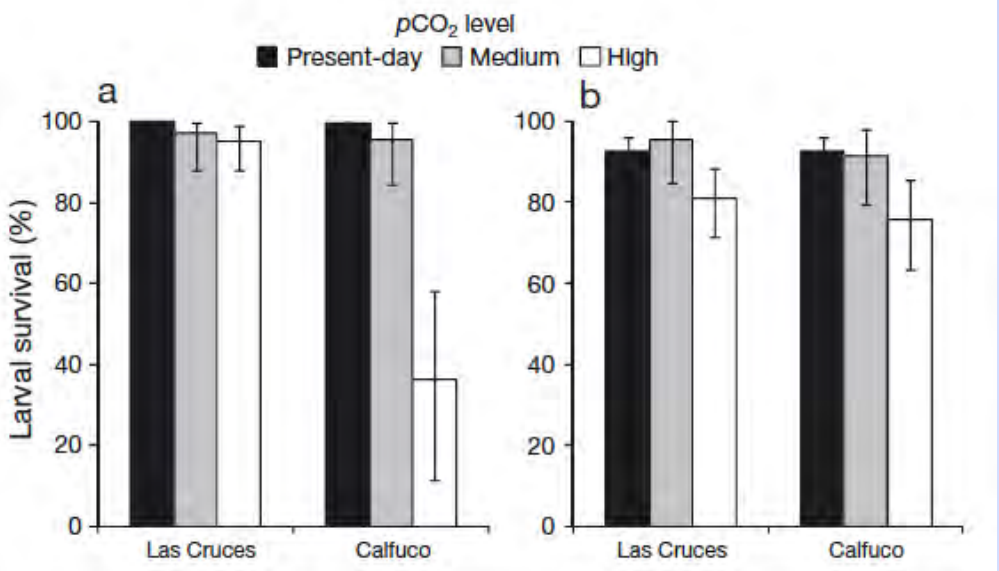


Fig. 4. *Concholepas concholepas*. Average (± SD) early larval survival of larvae hatched from egg capsules collected from Las Cruces and Calfuco, reared at 3 experimental pCO_2 levels and in 2 experimental series (a) and (b). See Table 2 for details of average CO_2 levels used in each experimental series

- ✓ **A reduction of Early Larval Survival of up to 30%,**
- ✓ **annual losses of ~0.8 x 10^3 t of landings**
- ✓ **5.1 x 10^3 US$ per exported ton of *C. Concholepas*.**

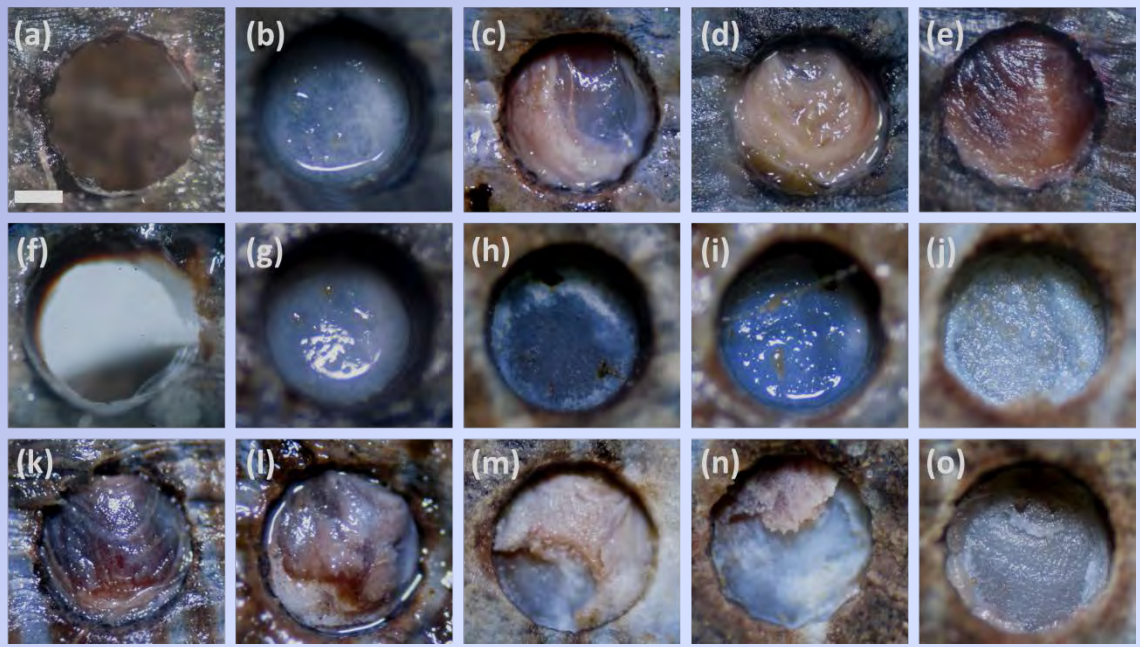
Manríquez et al. 2014a,b. *MEPS*
Lardies et al. 2014. *J. Sea Res.*
Vargas et al. 2014. *Est & Coasts*

*C. concholepas: loss the ability to r*estoring the shell

380 ppm CO_2

750 ppm CO_2

1200 ppm CO_2



+/−

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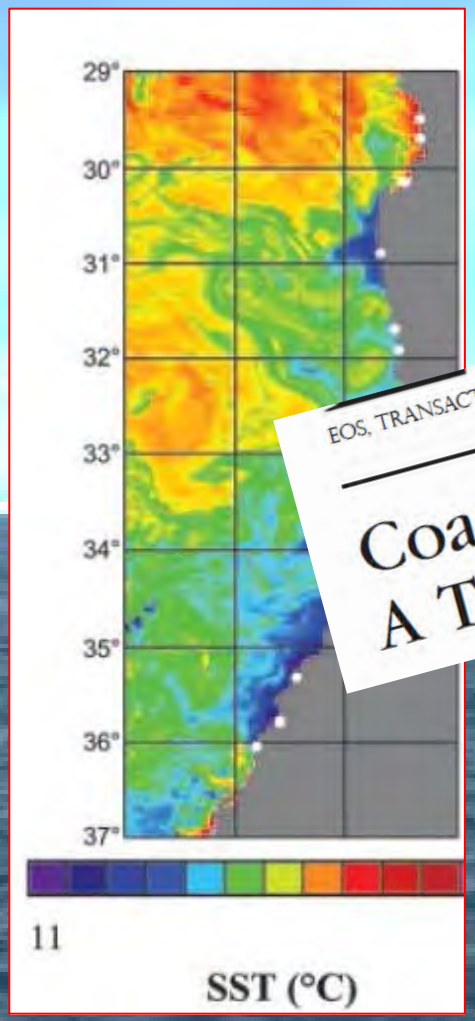
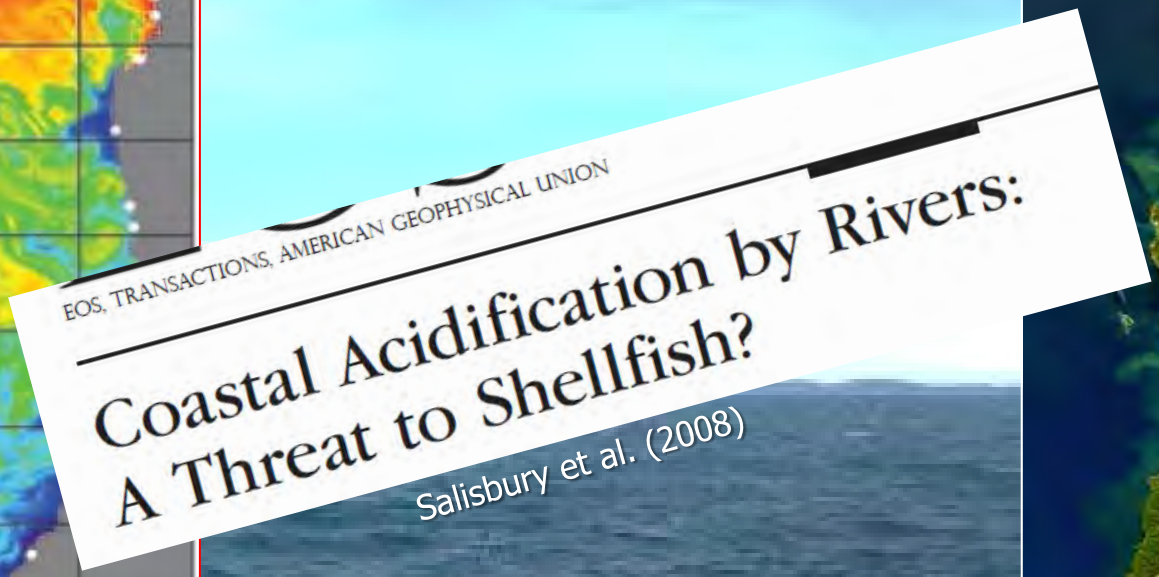
−

Manriquez et al. unpublished

Exposure to corrosive Upwelling in north-central Chile



Exposure to acidic input and CO_2 sequestration in Patagonia



Mussels culture in northern Patagonia (Chiloe island)

Recent concerns

Cultivo de mejillones. (F

Mitilicultores prevén caída de la p

CHILE
Tuesday, April 17, 2012, 03:10 (GMT +

La Asociación de Mitilicultores de Chile (AmiC
(*Mytilus chilensis*) de esta temporada será en
2011, cuando se cosecharon 281.000 tonelad

El año pasado, la escasez de alimento en el
complicaron a este sector de la industria acu

La gerente de AmiChile, Yohana González,
el hecho de que esta temporada la mayoría
más tarde la producción.

Por otro lado, dijo que se proyecta una me
escasez de semillas que se registra este a
70% con respecto a un año normal". Esto
cosechas 2013, e incluso del 2014", señal

Expertos analizan la problemática actual del recurso

Doble Click para ver de cerca

Mitílidos están en el centro de la discusión

Desde la nueva reglamentación ambiental, hasta el impacto del cambio climático en los recursos marinos. Este fue un mes cargado de conferencias para el mundo de la mitilicultura y Visión Acuícola lo pone al día sobre lo más importante.

09 de Octubre de 20

Aparece muerto cultivo de choritos. Mariscadores responsabilizar a la Celulosa Arauco

Este lunes los buzos mariscadores de Laraquete se encontraron con una dramática e indignante situación. El cultivo de choritos que mantenían en un sector cercano estaba completamente muerto y en proceso de putrefacción.

- Resumen conversó con el vocero del sindicato de buzos, Ricardo Ibacache, quien explicó que esta mortandad representa una pérdida económica de 120 millones de pesos, además de un largo tiempo de trabajo por el cual habían conseguido la masificación del marisco en el lugar y las vías de comercialización.

Buscar...

Home / Noticia Destacada / Baja del PH en el mar habría provocado muerte de choritos araucanos

Baja del PH en el mar habría provocado muerte de choritos araucanos

Escrito por Jeannette Valenzuela
10 de octubre de 2012

Me gusta 12 Enviar Twittear 4

Un evento anómalo, relacionado a un cambio en el PH en el mar, estaría detrás de la muerte masiva de choros araucanos (Mytillus galloprovincialis) que pescadores de Laraquete mantenían en cultivo como parte de un proyecto Innova -Corfo ejecutado por la UdeC desde diciembre de 2010, en tres caletas de la zona.

La iniciativa -conducida por el académico de la facultad de Ciencias Naturales y Oceanográficas, Eduardo Tarifeño, y cuyo objetivo era fomentar la mitilicultura como alternativa productiva para las áreas de manejo- había concluido exitosamente en agosto, con promisorios resultados para la producción del recurso en la región, especialmente en Laraquete, donde se visualizó el mayor potencial para el cultivo.

No obstante, el lunes los pescadores se percataron de la muerte de casi la totalidad de los ejemplares que quedaron en las líneas de cultivo (de 3 a 4 toneladas) luego de una última cosecha, en mayo, y que se mantuvieron en producción con el fin de analizar su comportamiento en la estación invernal.

Mussel farming is an important socio-economic activity in northern Patagonia

mussels farming in Chiloe island is part of the cultural heritage

Mussels are sensitive to OA and may impact coastal communities

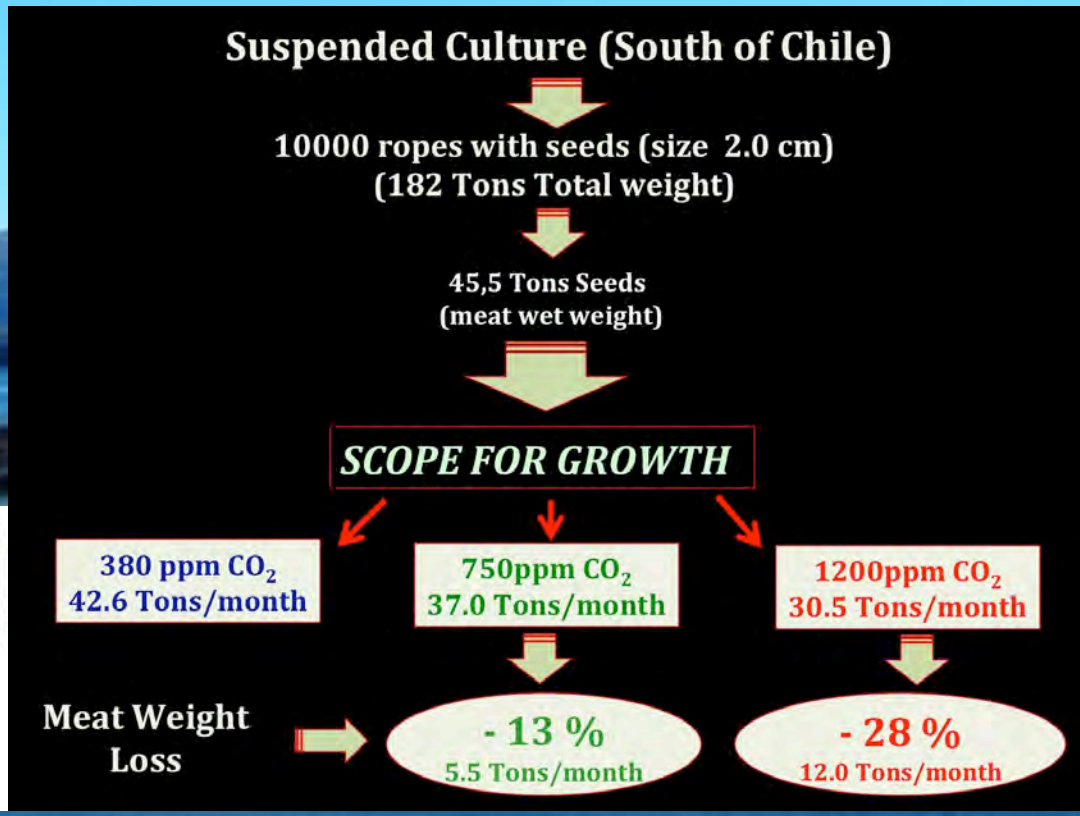
Contents lists available at SciVerse ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Impact of medium-term exposure to elevated pCO_2 levels on the physiological energetics of the mussel *Mytilus chilensis*

Jorge M. Navarro [a,*], Rodrigo Torres [b], Karin Acuña [a], Cristian Duarte [a,f], Patricio H. Manriquez [a], Marco Lardies [c], Nelson A. Lagos [d], Cristian Vargas [e], Victor Aguilera [e]



Navarro et al. 2013

Duarte et al. 2013, 2014

Is There Anybody Out There?

musels

CENTER FOR THE STUDY OF MULTIPLE DRIVERS
ON MARINE SOCIO-ECOLOGICAL SYSTEMS

Dr. Cristian Vargas G.
Director
Departamento de Sistemas Acuáticos,
Facultad de Ciencias Ambientales
Universidad de Concepcion.

Dr. Bernado Broitman R.
Sub-director
Universidad Católica del Norte &
Centro de Estudios Avanzados
en Zonas Áridas-CEAZA.

Dr. Stefan Gelcich C.
Investigador Asociado
Departamento de Ecología,
P. Universidad Católica de Chile.

Dra. Leyla Cárdenas T.
Investigador Adjunto
Instituto de Ciencias
Ambientales & Evolutivas,
Universidad Austral de Chile.

Dr. Marco Lardies C.
Investigador Asociado
Facultad de Artes Liberales,
Universidad Adolfo Ibáñez.

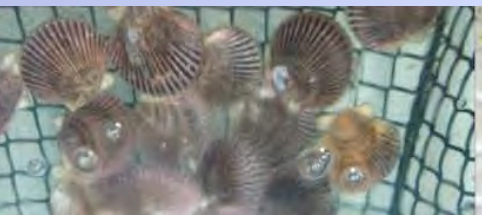
Dr. Ricardo Barra R.
Investigador Adjunto
Departamento de Sistemas Acuáticos,
Facultad de Ciencias Ambientales
Universidad de Concepción.

Dr. Felipe Vásquez L.
Investigador Asociado
Facultad de Economía y Negocios,
Universidad del Desarrollo.

Dr. Nelson Lagos S.
Investigador Adjunto
Facultad de Ciencias,
Universidad Santo Tomás &
Centro de Investigación en
Ciencias Ambientales CIENCIA-UST.

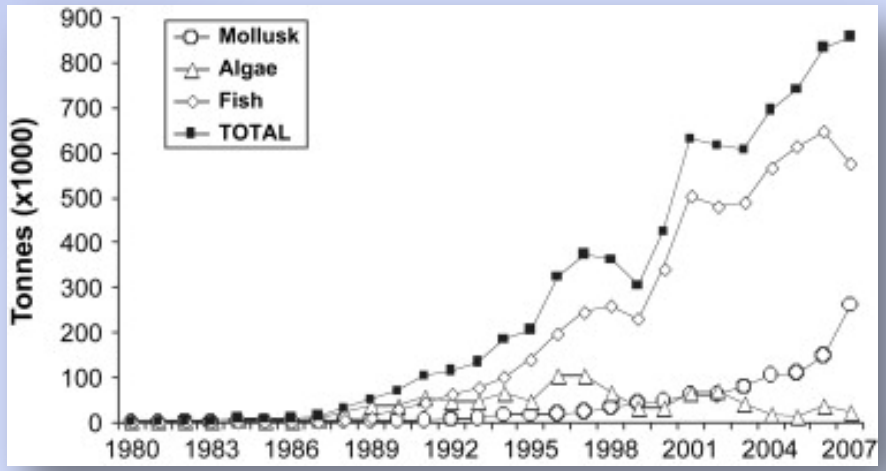
Dr. Benjamin Halpern
Asesor Internacional
Center for Ocean Solutions,
University of California
Santa Barbara CA, USA.

Dr. Steve Widdicombe
Asesor internacional
Director of the UK Ocean Acidification Program,
Plymouth Marine Laboratory, United Kingdom.

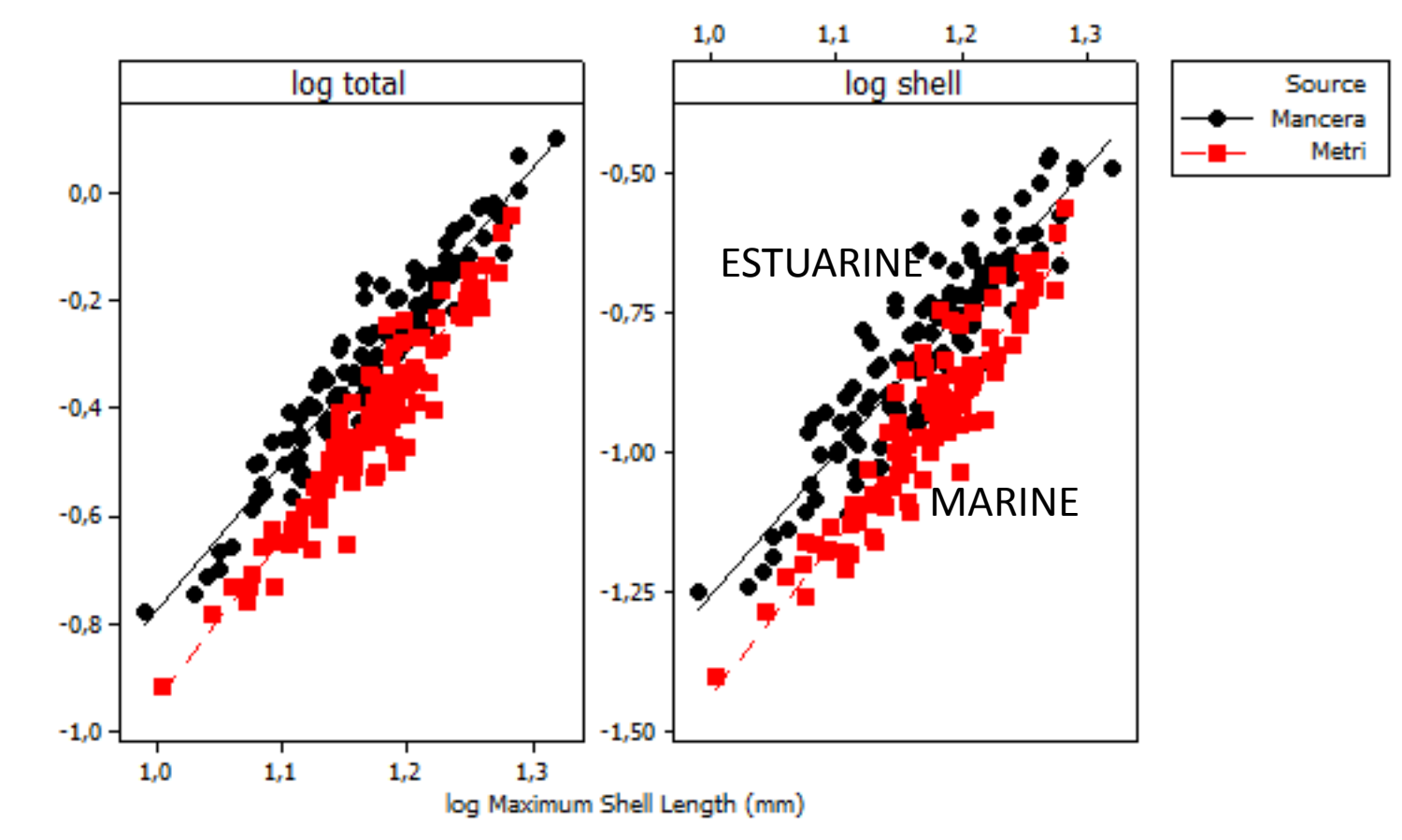


AQUACULTURE IN CHILE

- ✓ From 1990, increased ~20%.
- ✓ Shellfish farming accounted ca. 350,000 tons, or 16 % of total biomass.
- ✓ Chile is the third and second largest producer of scallops and mussels in the world.
- ✓ Employment generation (only mussels industry ~14.000), socio-cultural aspects.

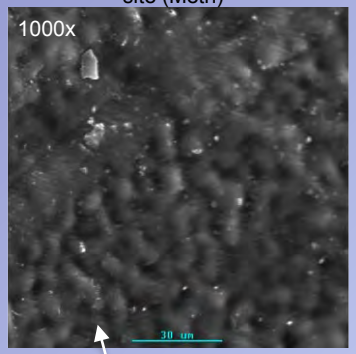


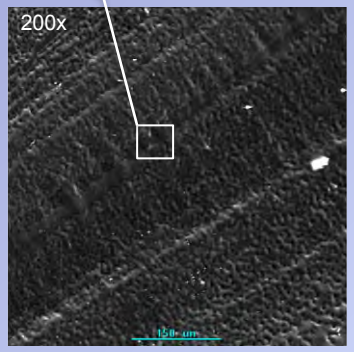
VARIABILITY IN CALCIMASS of MUSSELS

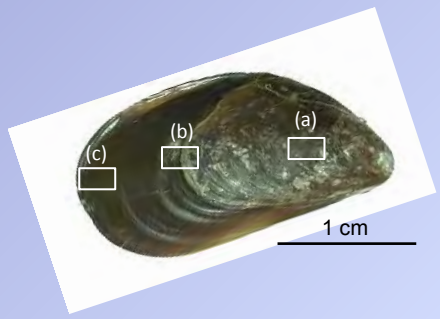


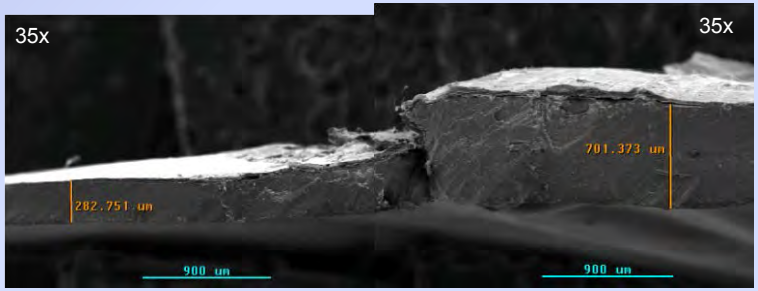
TRANSLOCATION: ESTUARINE TO MARINE

2nd growth period at the destination site (Metri)

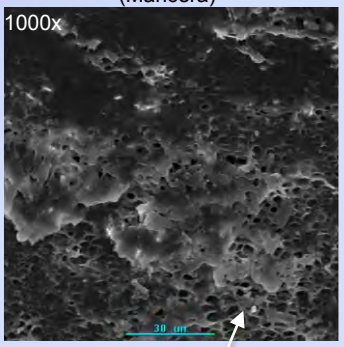


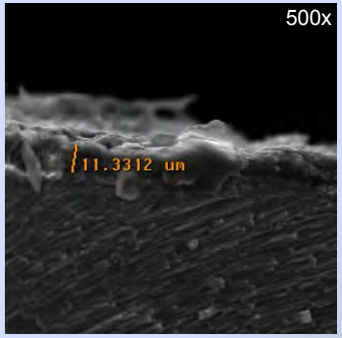






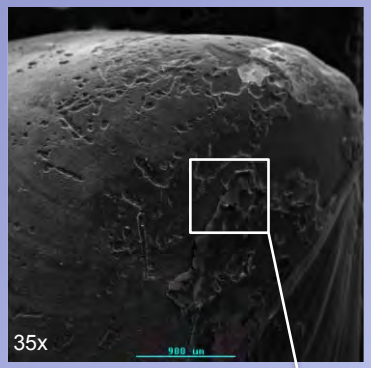
First growth period at origin site (Mancera)

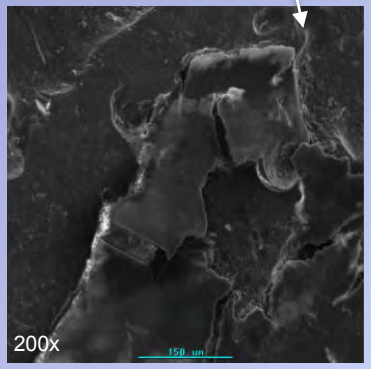


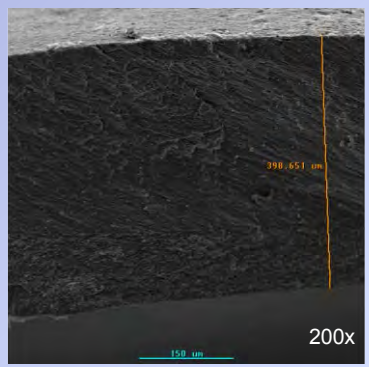


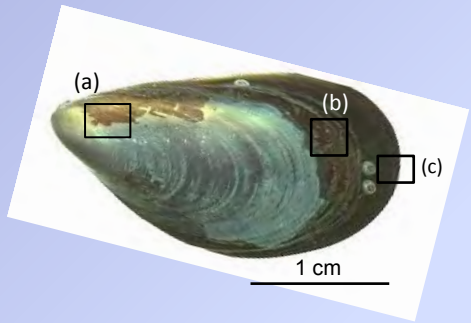
TRANSLOCATION: MARINE TO ESTUARINE

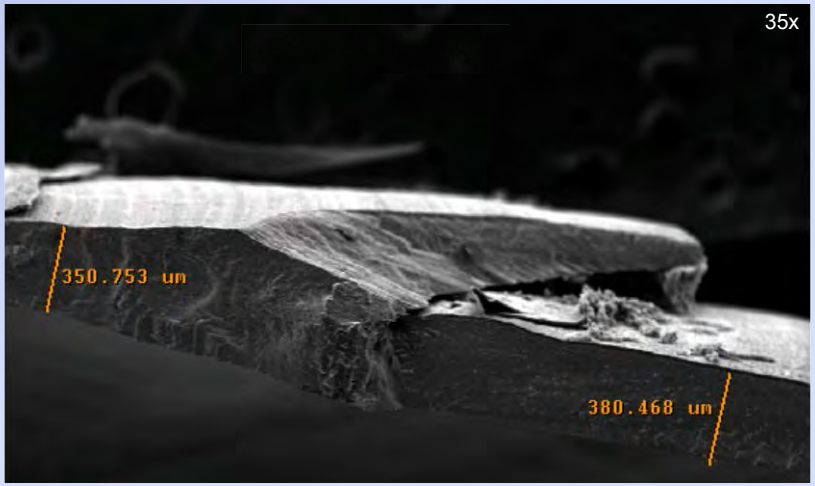
First growth period at origin site (Metri)



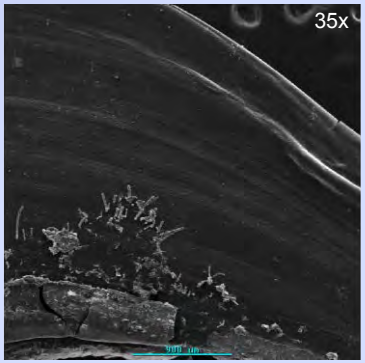


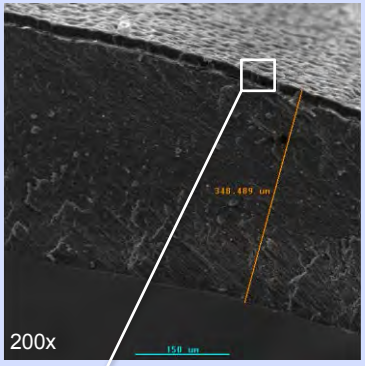


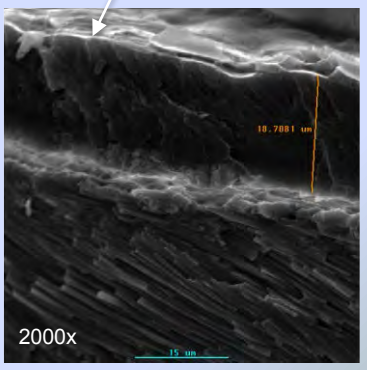




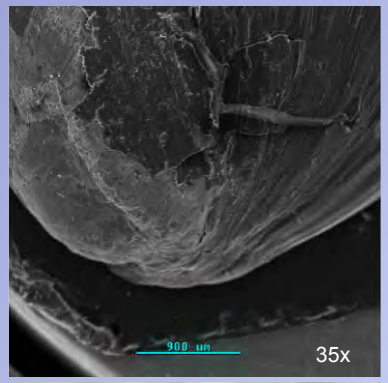
2nd growth period at the destination site (Mancera)

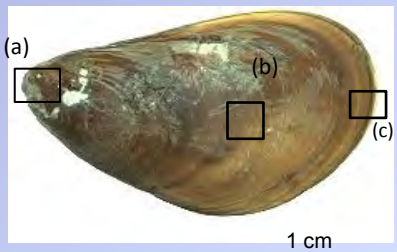


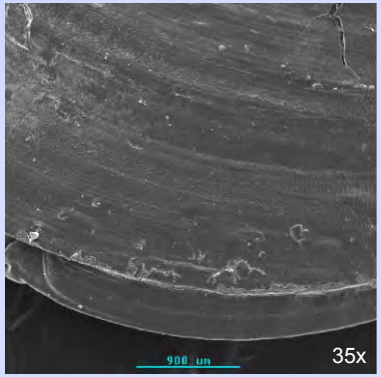


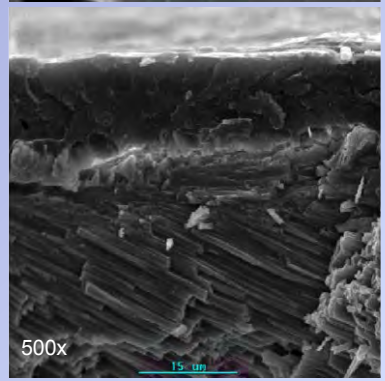


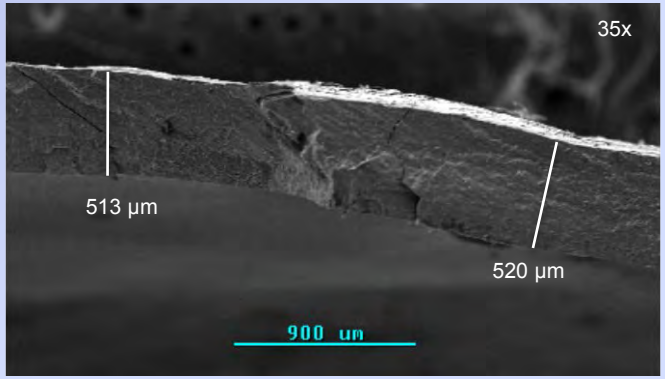
ESTUARINE TO ESTUARINE

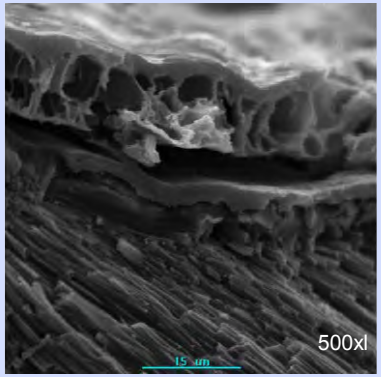




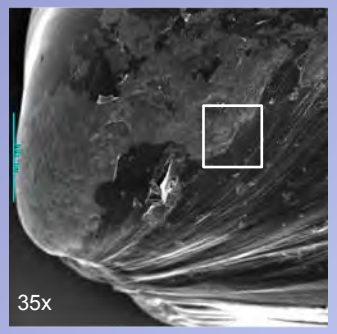


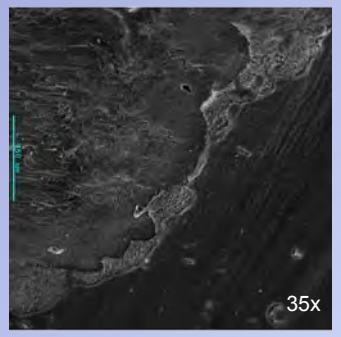


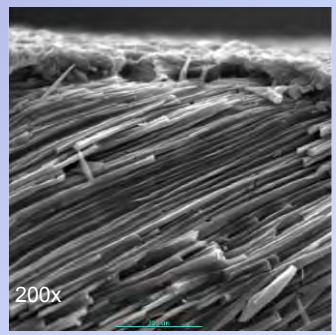


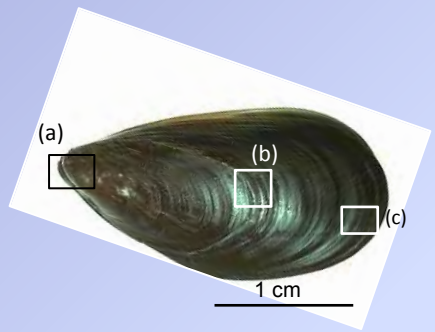


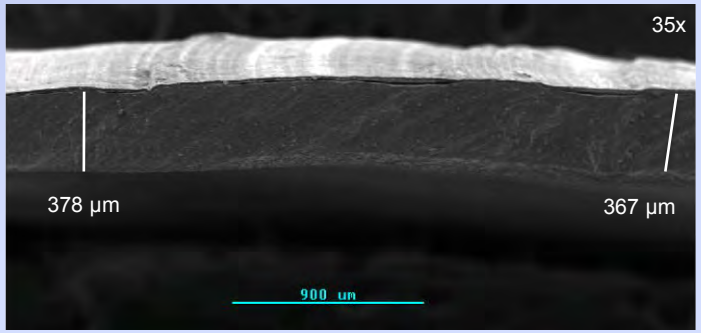
MARINE TO MARINE

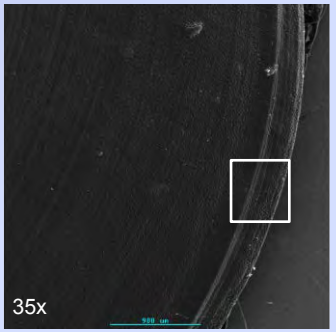


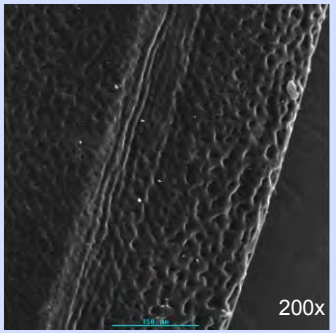


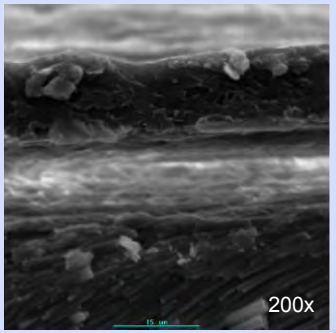










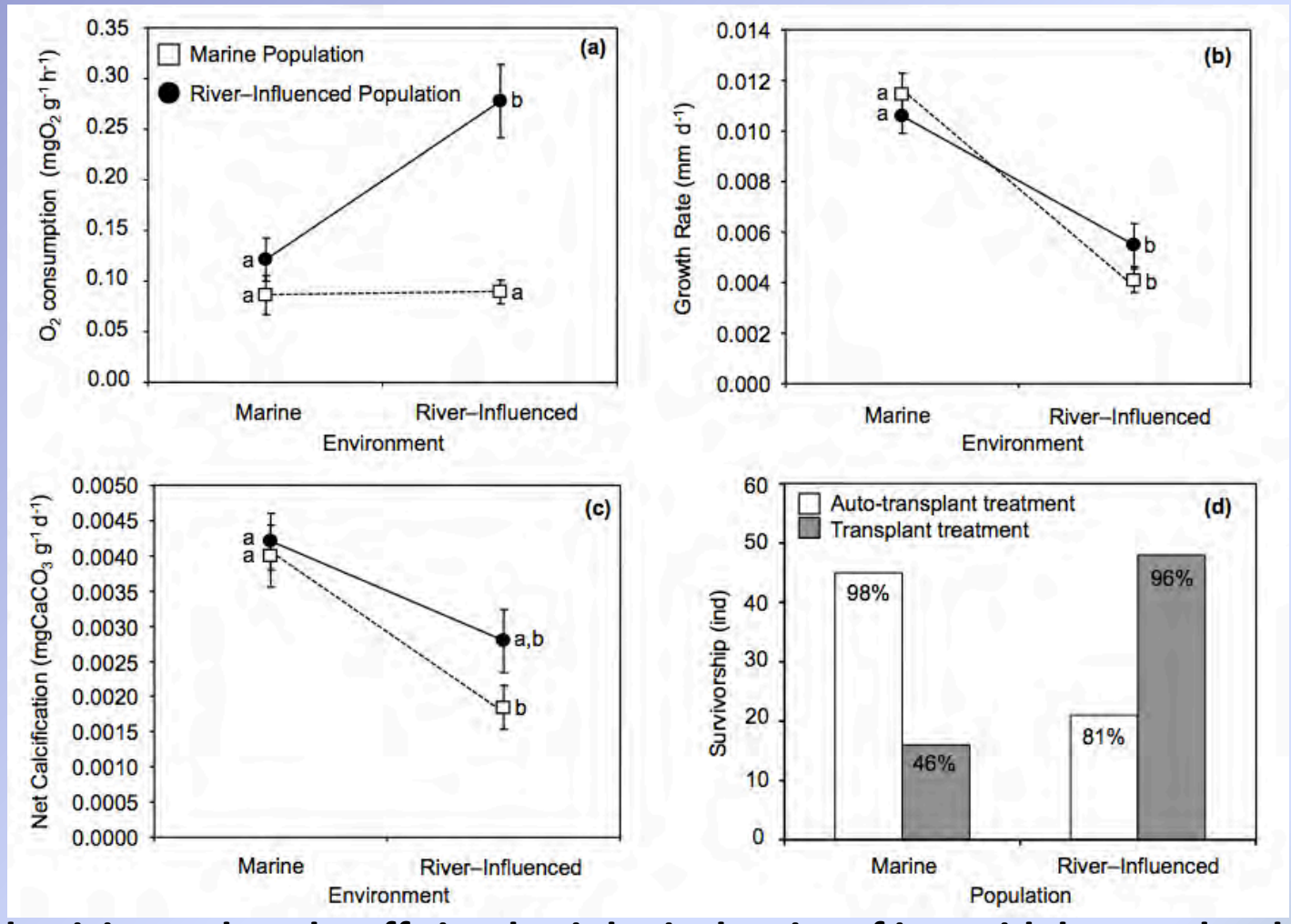


Some preliminar conclusions

- Mussels calcification and carbonate production varies locally
- Marine conditions stimulate periostracum production
- Estuarine (corrosive) conditions stimulate increased shell thickness
- Trade-offs: shell vs periostracum thickness

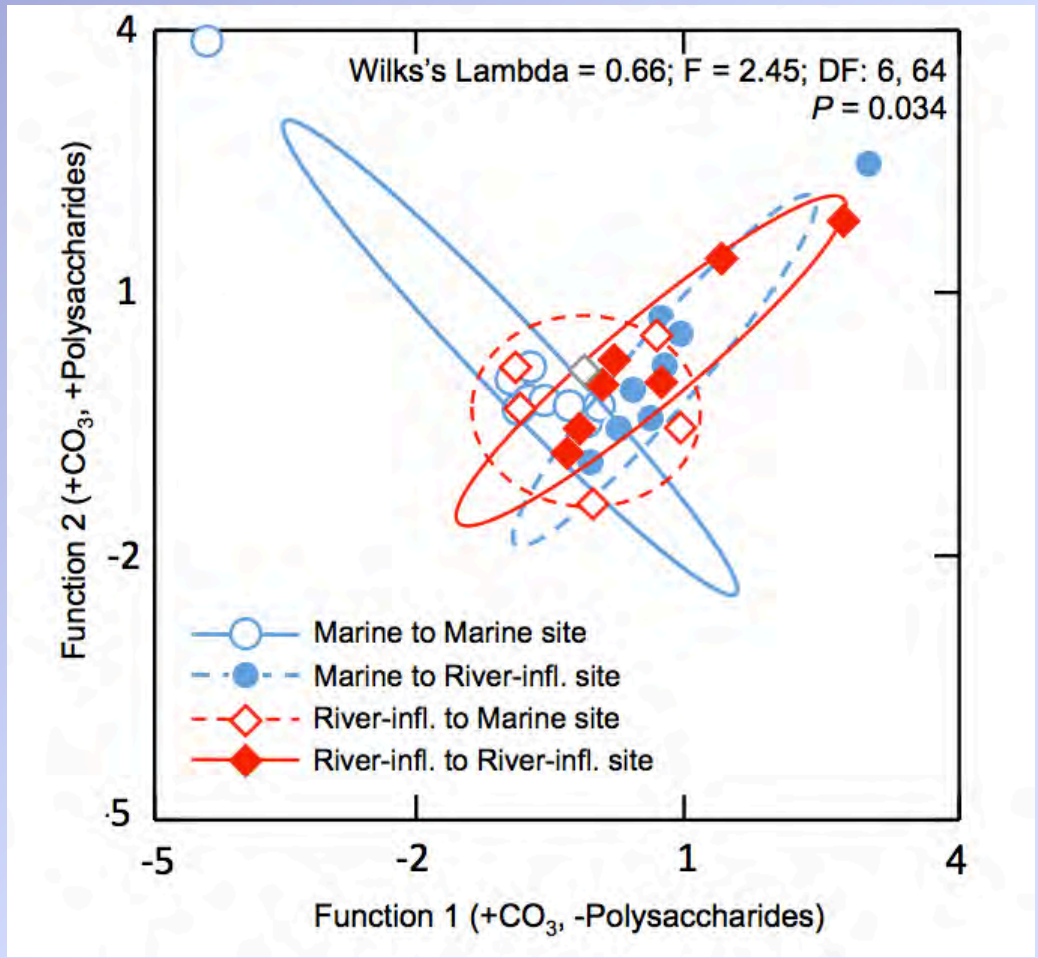
Other species model: intertidal mussels

- *Perumytilus purpuratus*
- Reciprocal transplant experiment



Plasticity and trade-offs in physiological traits of intertidal mussels when confronting freshwater-induced environmental variation

Plasticity in the organic composition of the Periostracum



Multiple stressors

Scallops as study model: 3 food treatment x 2 pH treatments

Growth and calcification rates in juveniles scallops

Metabolic rate (oxygen consumption)

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Cleareance rates

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Protein expression

Crecimiento y tasas netas de calcificación

Medición de las Tasas metabólicas (FIBOX 4 canales)

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Medición de las tasas de filtración

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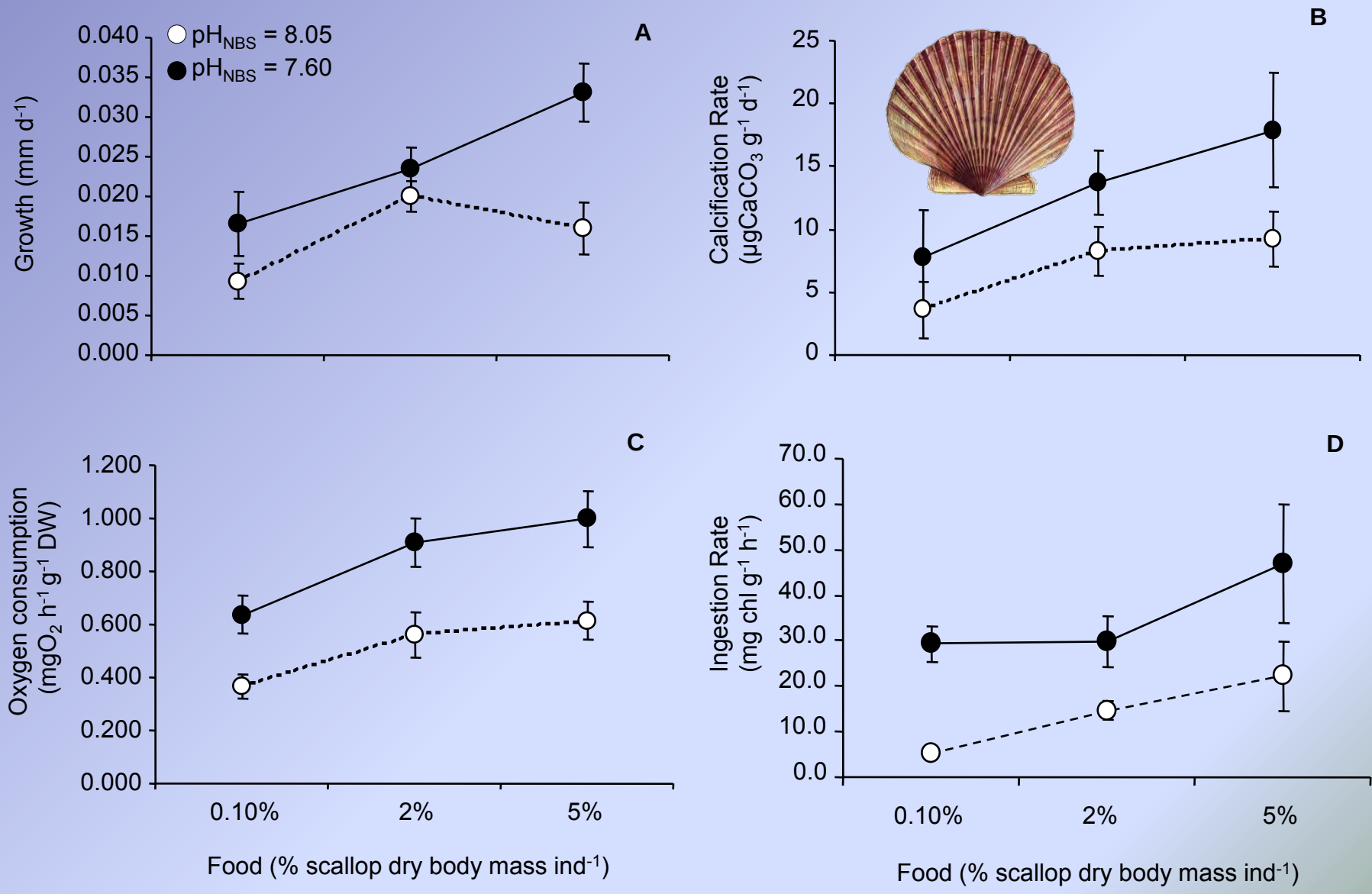
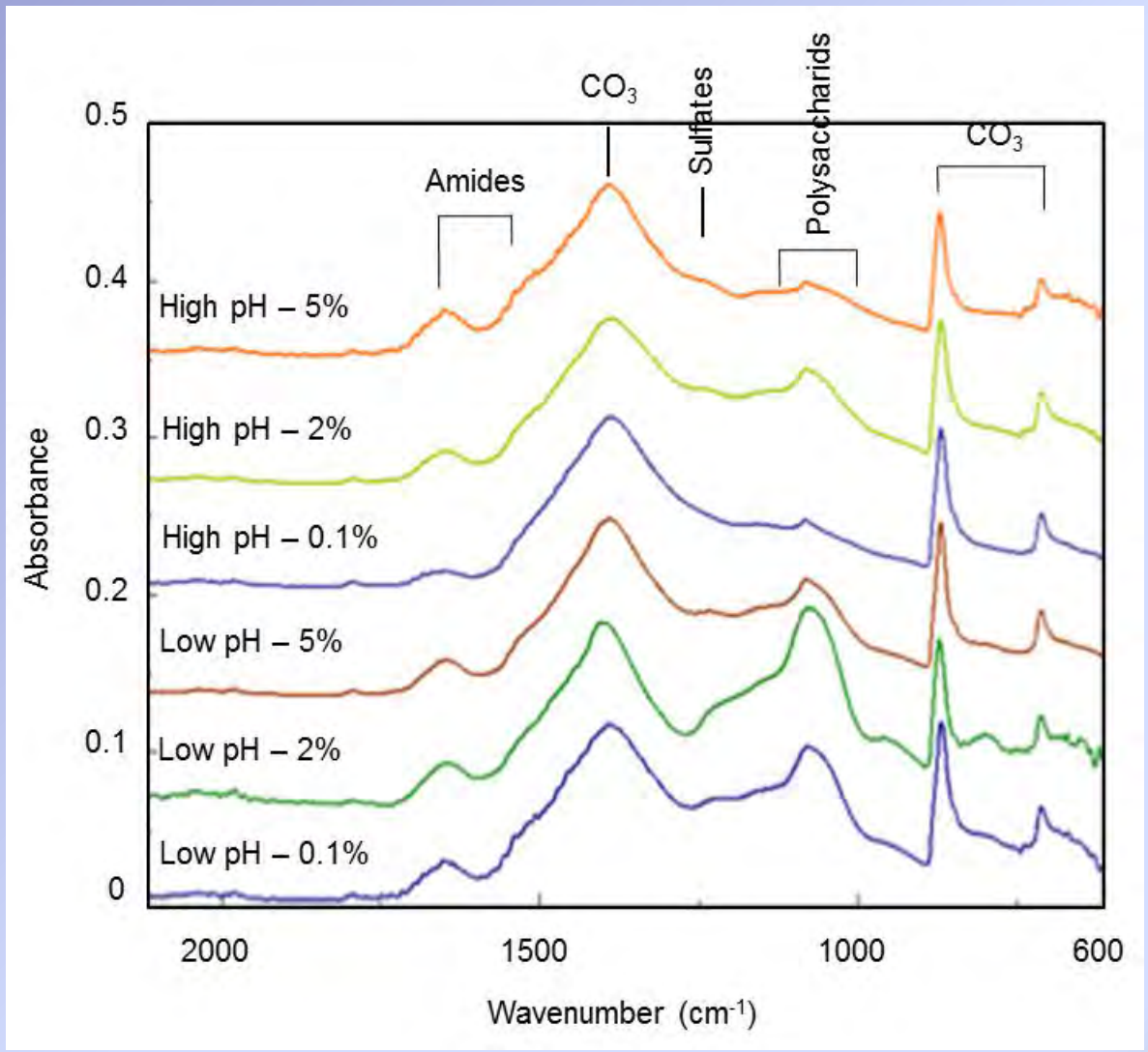
Extracción de tejidos para análisis de expresión de proteínas

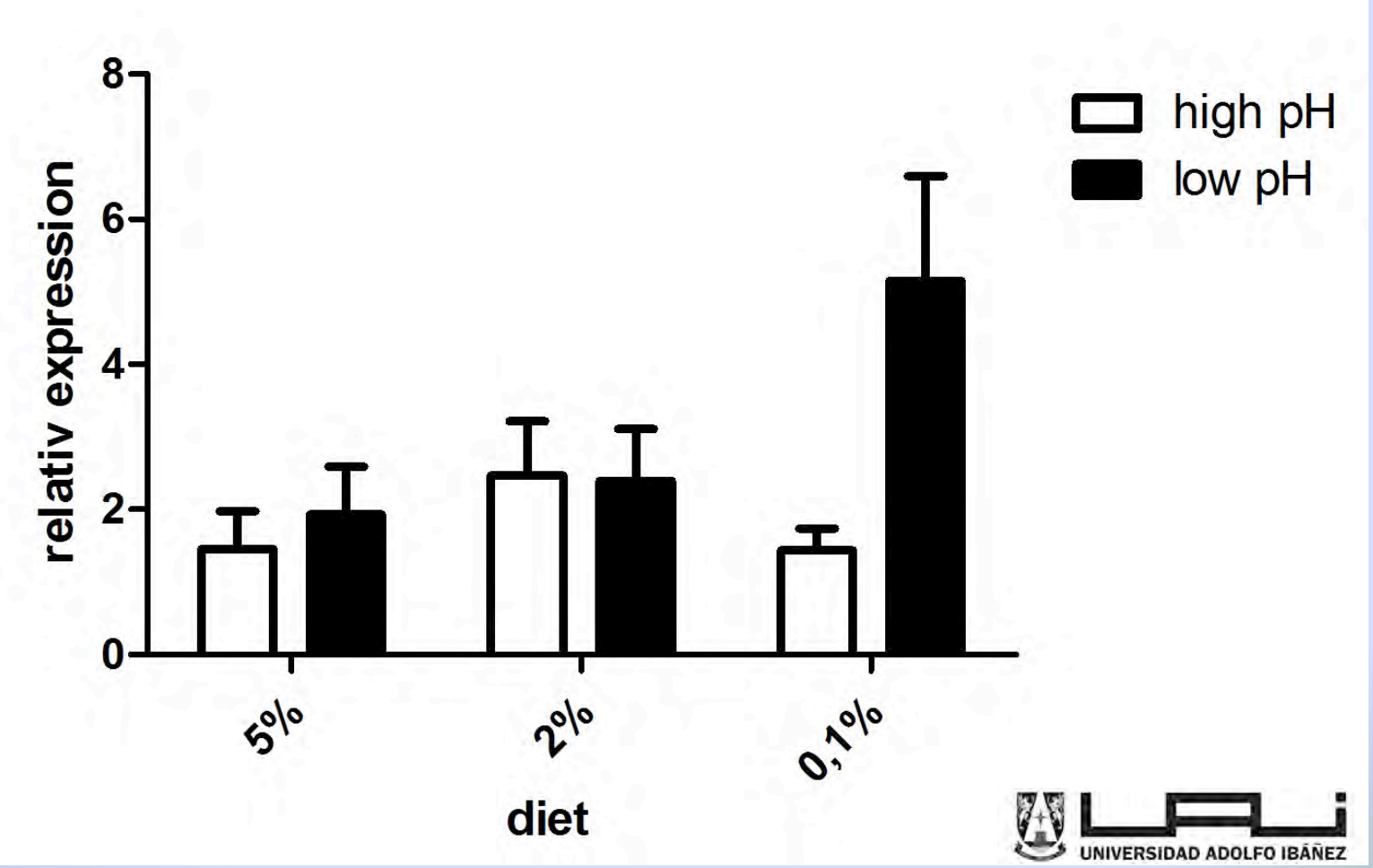
Juvenile scallops are resilient to OA if food provided



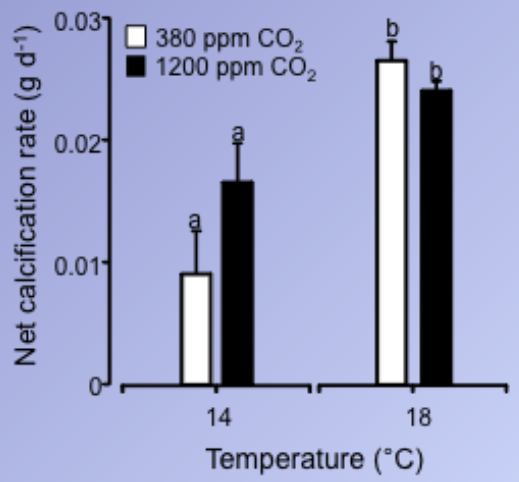
Organic composition of the periostracum (FTIR analyses)

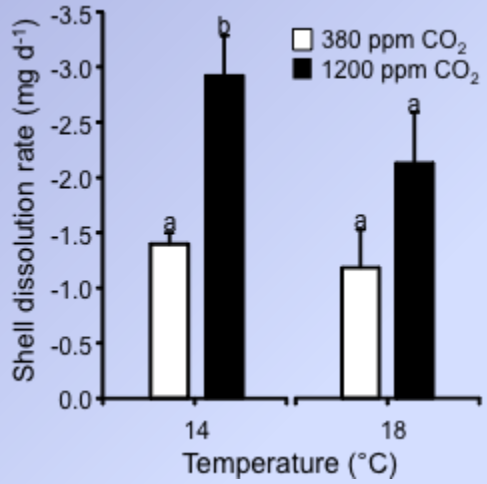


Expression of calcification-related genes
CHITIN SYNTHASE (CHS)

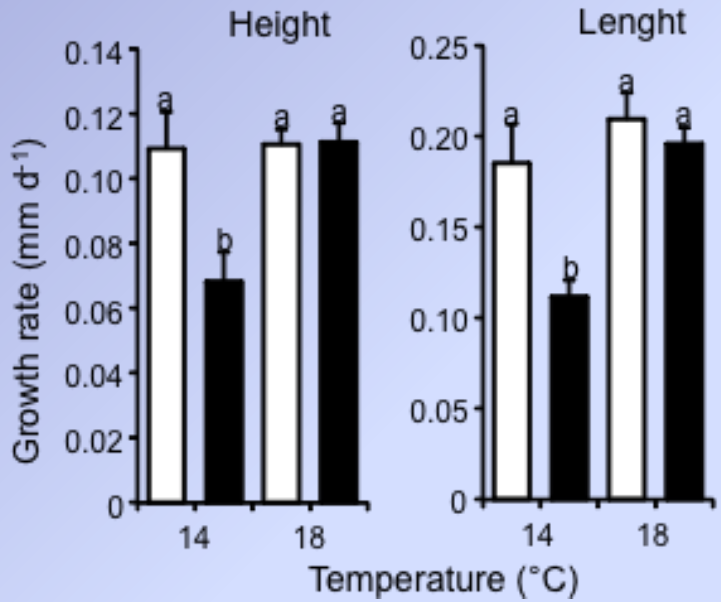


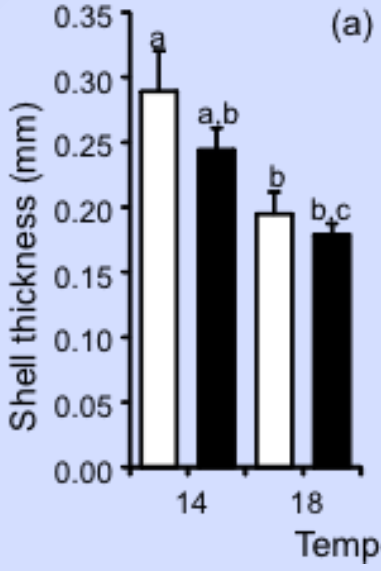
But adults scallops are sensitive to OA

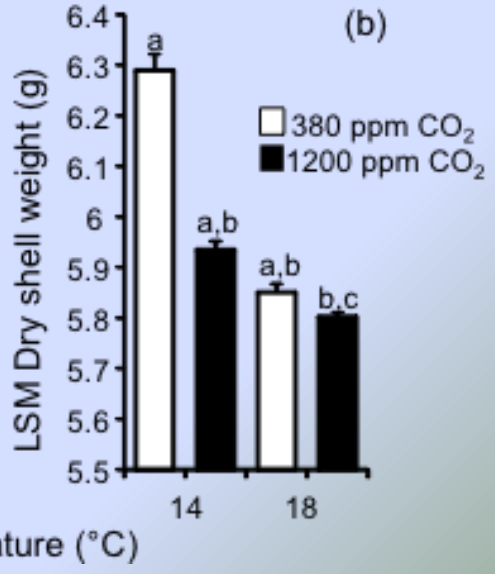




Synergistic







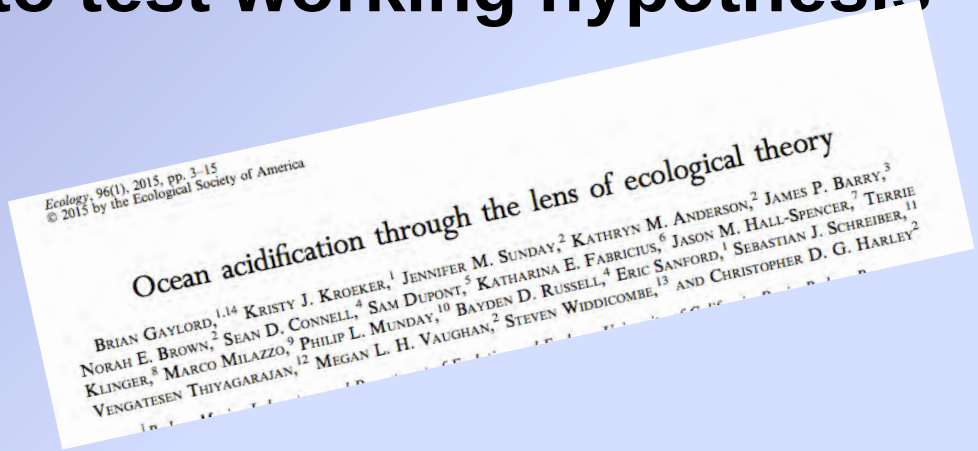
MORE CONCLUSIONS

- ✓ The aquaculture in the Humboldt current system is already experiencing effects of multiple environmental stressors.

- ✓ We demonstrate negative but variable effects of OA in species used in aquaculture along the Chilean coast.
- ✓ The role of organic layer in shell growth

- ✓ ***We provide insights about the potential consequences of OA on aquaculture species which may affect the economic revenues provided by this species and add uncertainty to the future of seafood production in South Pacific.***

- Exploring patterns of variability in carbonate standing stock and production in benthic habitats
- Population, community and ecosystems implications
- **Taking advantages of the natural variability to test working hypothesis**


Ecology, 96(1), 2015, pp. 3–15
© 2015 by the Ecological Society of America

Ocean acidification through the lens of ecological theory

Brian Gaylord,[1,14] Kristy J. Kroeker,[1] Jennifer M. Sunday,[2] Kathryn M. Anderson,[2] James P. Barry,[3] Norah E. Brown,[2] Sean D. Connell,[4] Sam Dupont,[5] Katharina E. Fabricius,[6] Jason M. Hall-Spencer,[7] Terrie Klinger,[8] Marco Milazzo,[9] Philip L. Munday,[10] Bayden D. Russell,[4] Eric Sanford,[1] Sebastian J. Schreiber,[11] Vengatesen Thiyagarajan,[12] Megan L. H. Vaughan,[2] Steven Widdicombe,[13] and Christopher D. G. Harley[2]

Carbonate budget, secondary production and CO_2 fluxes in intertidal barnacles experiencing natural variability in Temperature and Ocean Acidification along the Southeastern Pacific Coastal Ecosystems

Lagos N.A. (FONDECYT 1040938; 2014-2017)

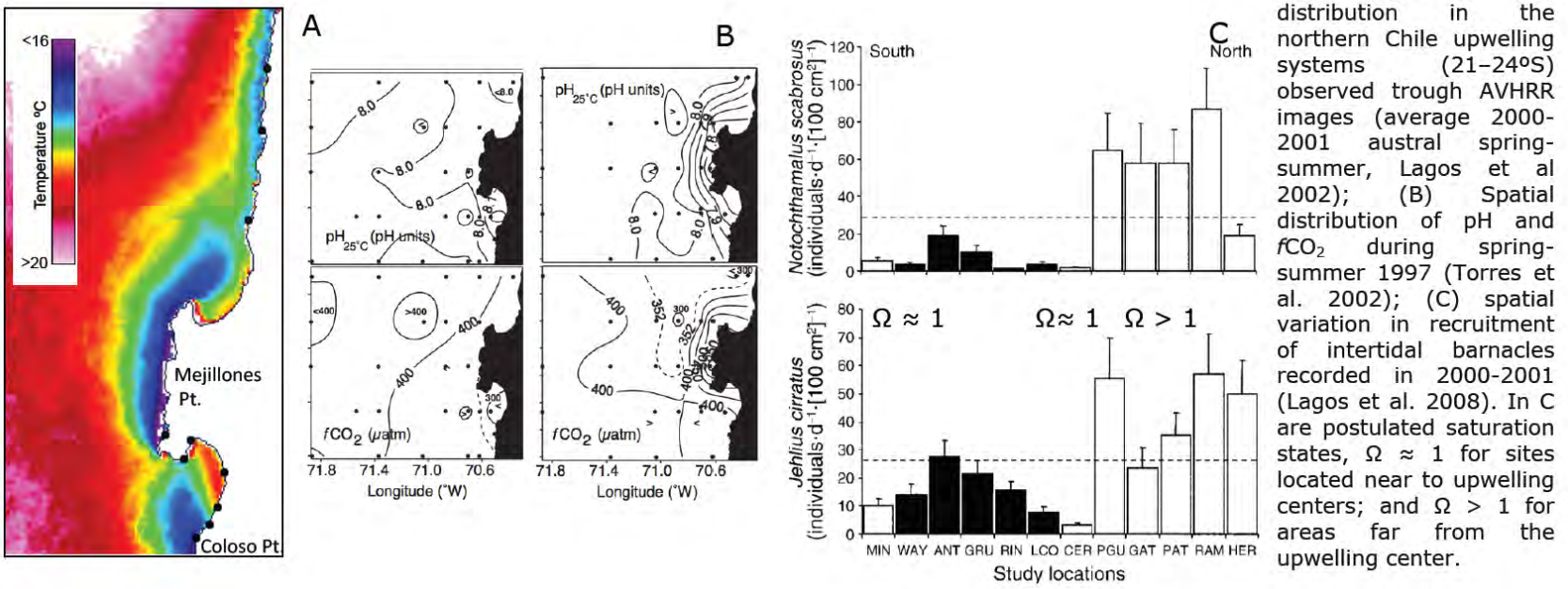


Fig. 1. A) SST distribution in the northern Chile upwelling systems (21–24ºS) observed trough AVHRR images (average 2000-2001 austral spring-summer, Lagos et al 2002); (B) Spatial distribution of pH and fCO_2 during spring-summer 1997 (Torres et al. 2002); (C) spatial variation in recruitment of intertidal barnacles recorded in 2000-2001 (Lagos et al. 2008). In C are postulated saturation states, Ω ≈ 1 for sites located near to upwelling centers; and Ω > 1 for areas far from the upwelling center.

Topics:

- Carbonate production and shell cycling in upwelling ecosystems
- Benthic ecosystems as CO2 sources.
- Intertidal carbon budget and cycling

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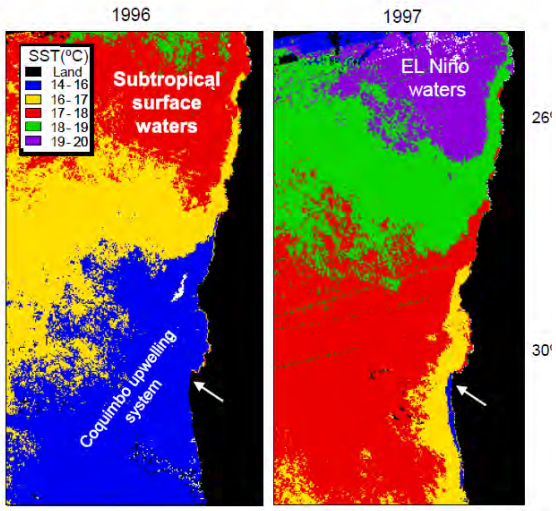
CONICYT
Ministerio de Educación
Gobierno de Chile

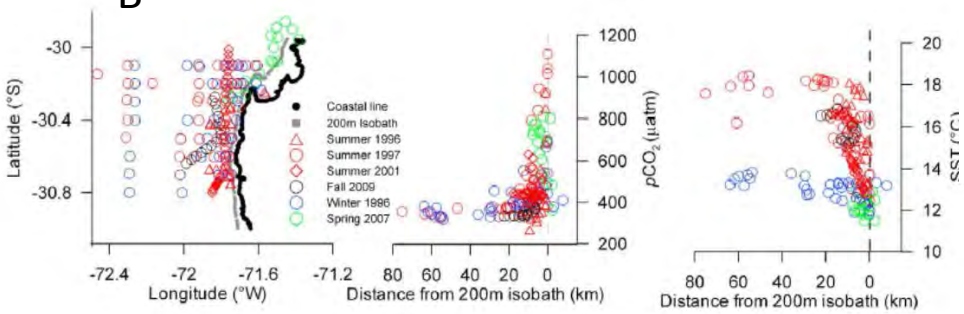
Determinants of marine biogeographic breaks: the underestimated relevance of pH variation

Lardies M.A., Lagos N.A., Broitman B. (FONDECYT 1140092; 2014-2018)

A



B



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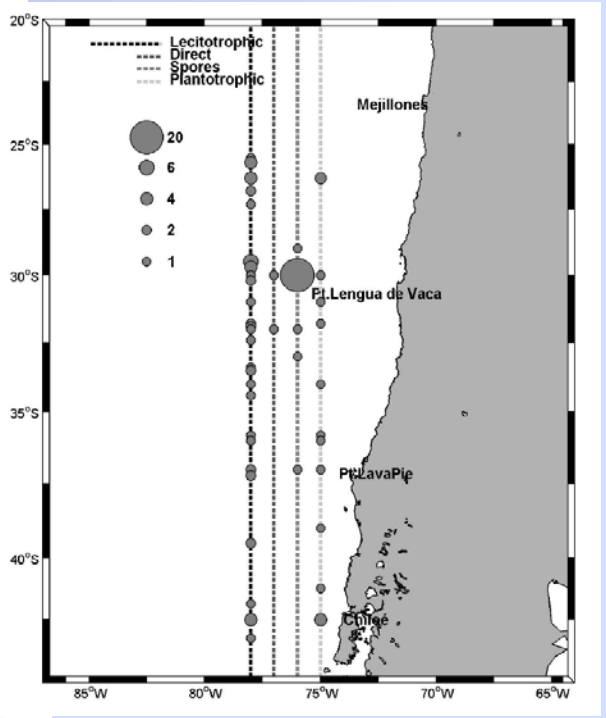

UNIVERSIDAD ADOLFO IBÁÑEZ

CENTRO DE ESTUDIOS AVANZADOS EN ZONAS ÁRIDAS CEAZA

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CONICYT Ministerio de Educación Gobierno de Chile

Education and dissemination

Conclusions

- Is important to promote in OA research
  - Reduce emissions
  - To study regionally important species, ecologically, socio-economically (avoiding to rediscover the wheel)
  - Using natural variability to make prediction and design field experiments
  - To be integrative, measuring severals biological traits as possible and enviromental stressor
  - disseminate

Many thanks…