Some examples of endpoints measurements in Ocean Acidification experiments off Chilean coast

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Universidad de Concepción

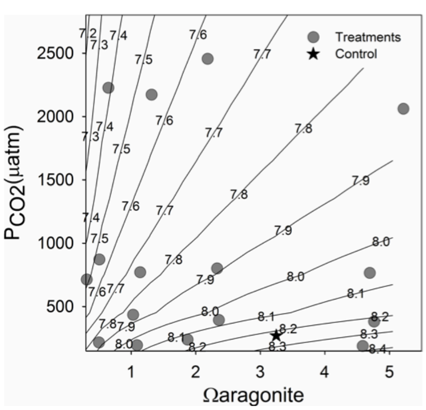
Ocean acidification has multiple modes of action: pH, pCO_2 and/or Ω

PLOS | ONE

RESEARCH ARTICLE

Ocean Acidification Has Multiple Modes of Action on Bivalve Larvae

George G. Waldbusser[1]*, Burke Hales[1], Chris J. Langdon[2], Brian A. Haley[1], Paul Schrader[2], Elizabeth L. Brunner[1na], Matthew W. Gray[2], Cale A. Miller[3nb], Iria Gimenez[1], Greg Hutchinson[2]



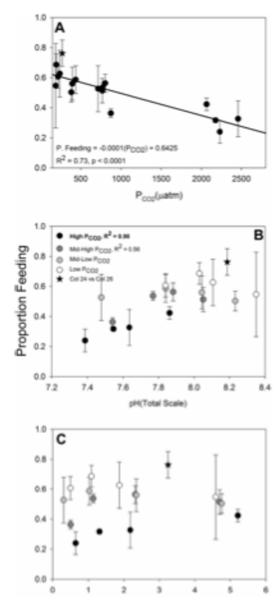
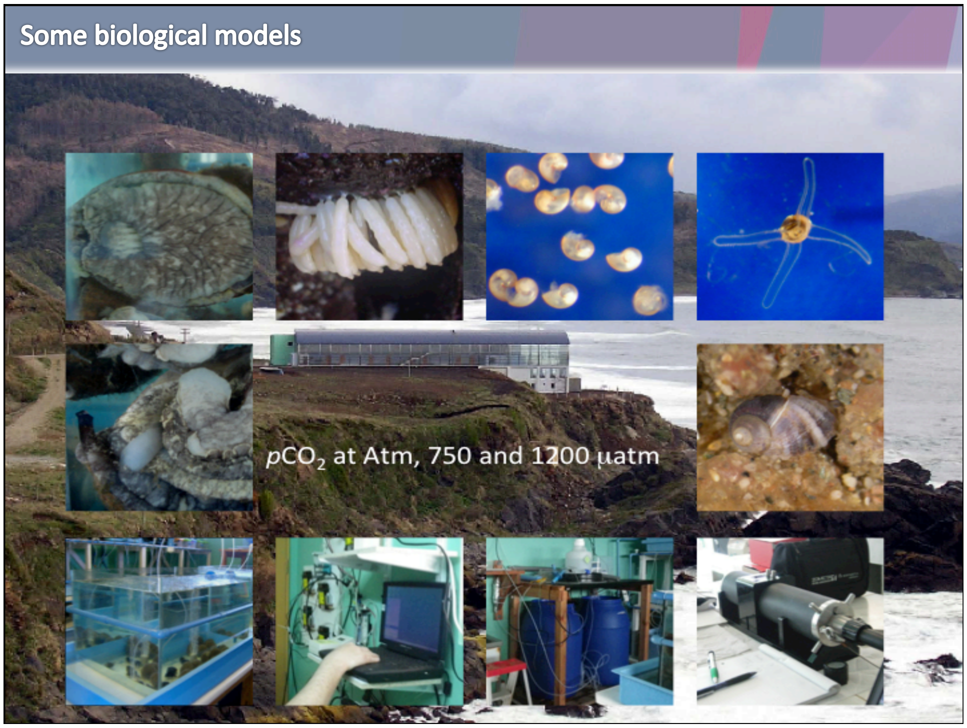
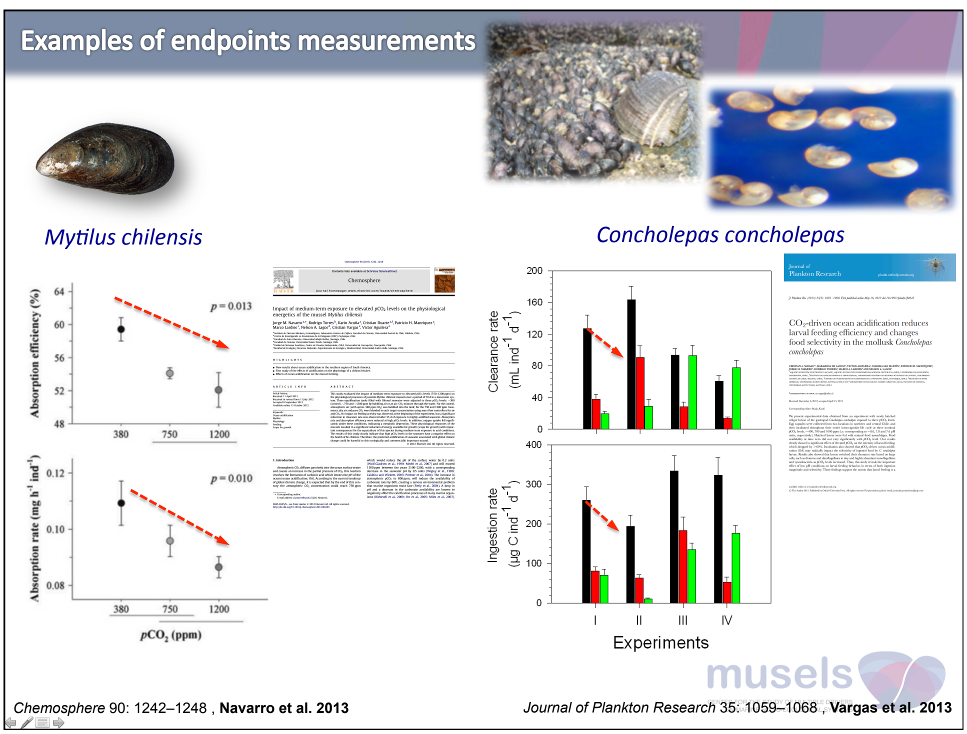


Fig 7. Initiation of Larval Feeding. The proportion of larvae feeding 44 hours post-fertilization and exposure in relation to (A) P_{CO2}, (B) pH, and (C) $\Omega_{aragonite}$. Greyscale symbols denote P_{CO2} treatments in panels B and C. Error bars are standard deviations of the three replicate experimental containers per treatment. Bold value


Some biological models
pCO_2 at Atm, 750 and 1200 µatm


Examples of endpoints measurements
Mytilus chilensis
Concholepas concholepas
Absorption efficiency (%)
p = 0.013
Absorption rate (mg h^{-1} ind^{-1})
p = 0.010
380
750
1200
pCO_2 (ppm)
Chemosphere
Impact of medium-term exposure to elevated pCO_2 levels on the physiological energetics of the mussel Mytilus chilensis
Clearance rate (mL ind^{-1} d^{-1})
Ingestion rate (µg C ind^{-1} d^{-1})
I
II
III
IV
Experiments
Journal of Plankton Research
CO_2-driven ocean acidification reduces larval feeding efficiency and changes food selectivity in the mollusk Concholepas concholepas
musels
Chemosphere 90: 1242–1248 , Navarro et al. 2013
Journal of Plankton Research 35: 1059–1068 , Vargas et al. 2013

Contrasting responses of different populations

Estuaries and Coasts
DOI 10.1007/s12237-014-9845-y

Intraspecific Variability in the Response of the Edible Mussel *Mytilus chilensis* (Hupe) to Ocean Acidification

Cristian Duarte · Jorge M. Navarro · Karin Acuña · Rodrigo Torres · Patricio H. Manríquez · Marcos A. Lardies · Cristian A. Vargas · Nelson A. Lagos · Víctor Aguilera

Received: 24 July 2013 / Revised: 28 May 2014 / Accepted: 1 June 2014

Abstract Ocean acidification (OA) has been shown to affect significantly the net calcification process and growth rate of many marine calcifying organisms. Recent studies have shown that the responses of these organisms to OA can vary significantly among species. However, much less is known concerning the intraspecific variability in response to OA. In this study, we compared simultaneously the responses of two populations of the edible mussel *Mytilus chilensis* (Hupe) exposed to OA. Three nominal CO_2 concentrations (380, 700, and 1,000 μatm of CO_2) were used. Negative effects of CO_2 increase on net calcification rate were only found in individuals from Huelmo Bay. However, no effects were found in individuals from Yaldad Bay. Moreover, OA had not significant effects on the shell dissolution rate in individuals from both localities. This suggests that the negative effect of the OA on the net calcification rate of this species is explained by shell deposition, but not by the shell dissolution processes. We do not know the specific underlying mechanisms responsible for these differences, but some possibilities are discussed. These results highlight that the responses of marine organism to OA can be highly variable even within the same species. Therefore, more studies across the distribution range of the species, considering environmental variability, are needed for a better understanding of the consequences of OA on marine organisms. Finally, because mussels exert influence on their physical and biological surroundings, the negative effects of a CO_2 increase could have significant ecological consequences.

Keywords Ocean acidification · Mussel · Calcification · Growth rate

Communicated by Alberto Vieira Borges

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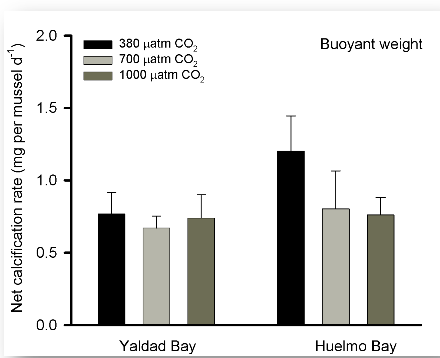
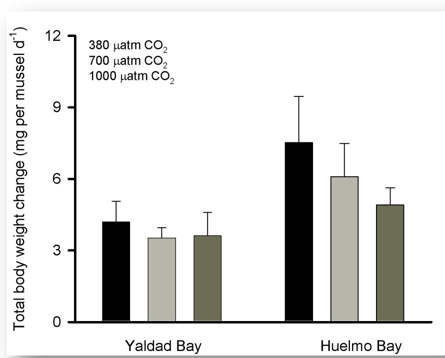
Mytilus chilensis
Chile, Los Lagos, Chiloé Island, Quellon
NMR 17162. Actual size 55 mm

Contrasting responses of different populations

Calcification



Growth

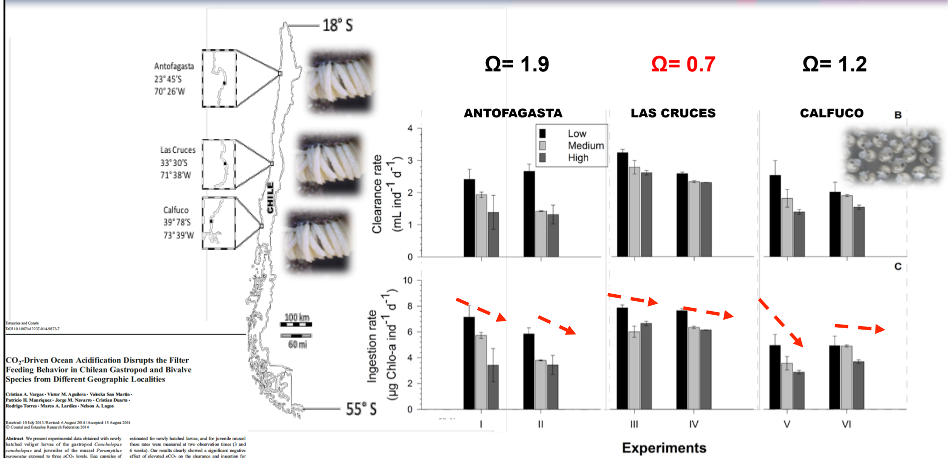


- Individuals from two different populations respond differently to changes in pH and/or pCO_2, which can be associated with different life histories of exposure to low pH.

Yaldad = pH 7.2 - 7.4
Huelmo= pH 8.0 – 8.2

Estuaries & Coasts, ***Duarte et al. 2014***

Contrasting responses of different populations



Planktonic larvae of *C. concholepas* capsules from different localities, respond differently to high pCO_2. Environmental life history of exposition to different pH levels in nature.

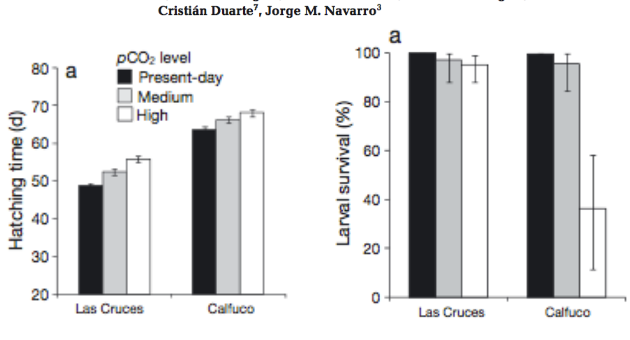
Estuaries & Coasts, **Vargas et al. 2014**

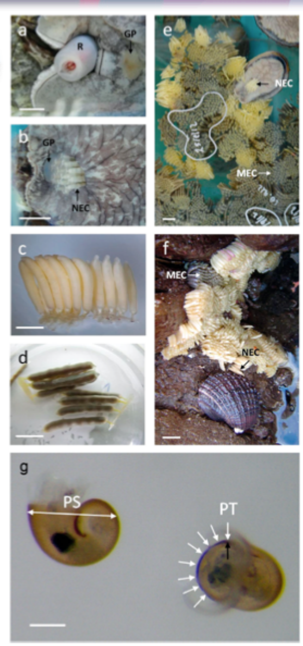
Effects on larval development and early post-hatching traits

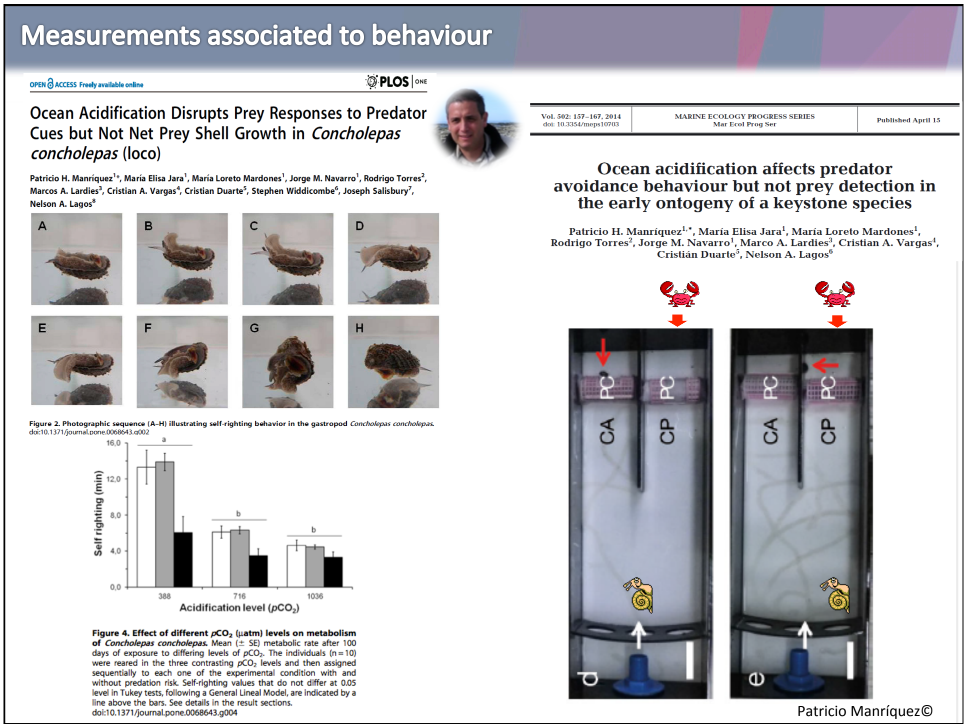
Vol. 514: 87–103, 2014
doi: 10.3354/meps10951
MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser
Published November 6

Effects of ocean acidification on larval development and early post-hatching traits in *Concholepas concholepas* (loco)

Patricio H. Manríquez[1,*], María Elisa Jara[1], Rodrigo Torres[2], María Loreto Mardones[3], Nelson A. Lagos[4], Marco A. Lardies[5], Cristian A. Vargas[6], Cristián Duarte[7], Jorge M. Navarro[3]






Measurements associated to behaviour
OPEN ACCESS Freely available online
PLOS ONE
Ocean Acidification Disrupts Prey Responses to Predator Cues but Not Net Prey Shell Growth in Concholepas concholepas (loco)
Patricio H. Manríquez, María Elisa Jara, María Loreto Mardones, Jorge M. Navarro, Rodrigo Torres, Marcos A. Lardies, Cristian A. Vargas, Cristian Duarte, Stephen Widdicombe, Joseph Salisbury, Nelson A. Lagos
A
B
C
D
E
F
G
H
Figure 2. Photographic sequence (A–H) illustrating self-righting behavior in the gastropod Concholepas concholepas.
Self righting (min)
Acidification level (pCO2)
388
716
1036
Figure 4. Effect of different pCO2 (μatm) levels on metabolism of Concholepas concholepas. Mean (± SE) metabolic rate after 100 days of exposure to differing levels of pCO2. The individuals (n = 10) were reared in the three contrasting pCO2 levels and then assigned sequentially to each one of the experimental condition with and without predation risk. Self-righting values that do not differ at 0.05 level in Tukey tests, following a General Lineal Model, are indicated by a line above the bars. See details in the result sections.
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, María Elisa Jara, María Loreto Mardones, Rodrigo Torres, Jorge M. Navarro, Marco A. Lardies, Cristian A. Vargas, Cristián Duarte, Nelson A. Lagos
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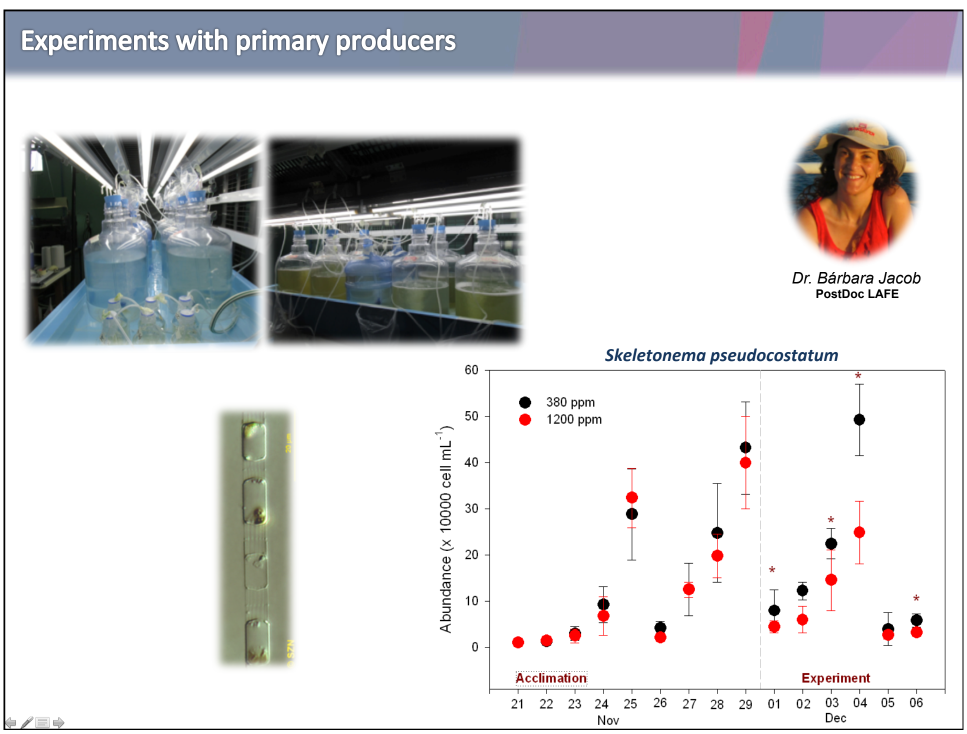
Experiments with primary producers
Dr. Bárbara Jacob
PostDoc LAFE
Skeletonema pseudocostatum
380 ppm
1200 ppm
Abundance (x 10000 cell mL⁻¹)
Acclimation
Experiment
21
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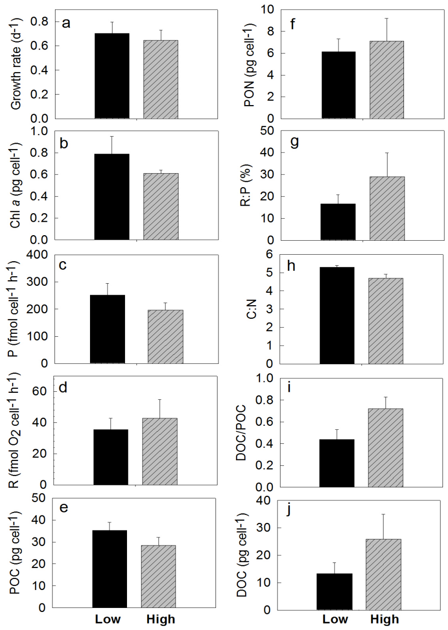
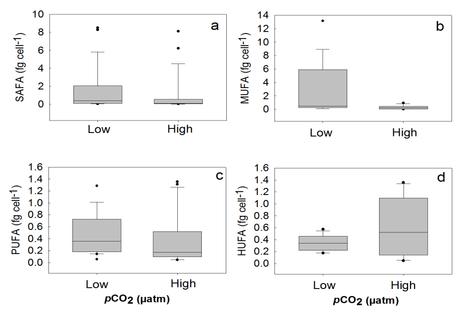
06
Nov
Dec

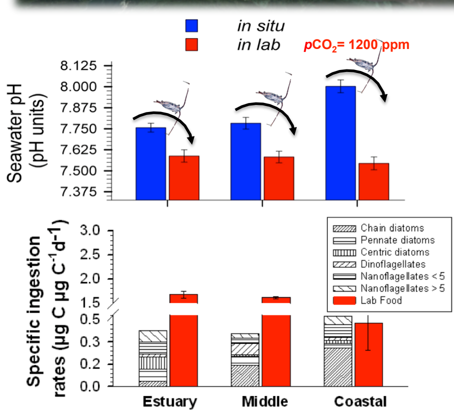
Some biological models



Many endpoints measurements, such as: growth, Chl-a, photosynthesis, respiration, C:N ratio, DOC, but also fatty acids concentration.



Experiments with organisms form high pCO_2 environments



Estuaries and Coasts (2013) 36:1084–1092
DOI 10.1007/s12237-013-9615-2

NOTE

Low-pH Freshwater Discharges Drive Spatial and Temporal Variations in Life History Traits of Neritic Copepod *Acartia tonsa*

Victor M. Aguilera · Cristian A. Vargas · Patricio H. Manríquez · Jorge M. Navarro · Cristian Duarte

Local populations of estuarine environments (low pH), respond better when exposed to high levels of CO_2 (1200 µatm CO_2).

MARINE ECOLOGY, Aguilera et al. 2016

musels

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

Multiple-stressors: temperature vs. ocean acidification

ICES Journal of Marine Science (2016), 73(3), 764–771. doi:10.1093/icesjms/fsv249

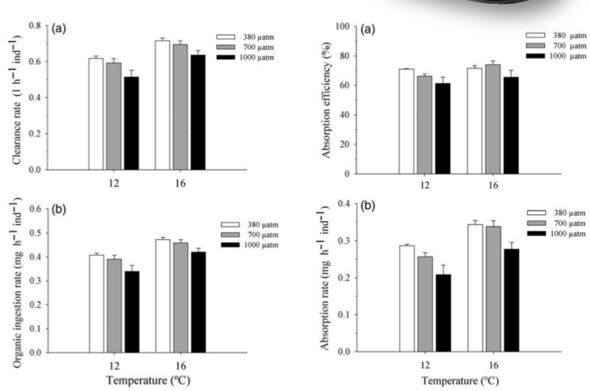
Contribution to Special Issue: 'Towards a Broader Perspective on Ocean Acidification Research'

Original Article

Ocean warming and elevated carbon dioxide: multiple stressor impacts on juvenile mussels from southern Chile

Jorge M. Navarro[1,2]*, Cristian Duarte[3,4], Patricio H. Manríquez[5], Marco A. Lardies[6], Rodrigo Torres[7], Karin Acuña[1], Cristian A. Vargas[8], and Nelson A. Lagos[9]

Temperature does not have a negative effect on calcification rates or growth, but individuals are not able to overcome the negative effects of increased CO_2 and low pH



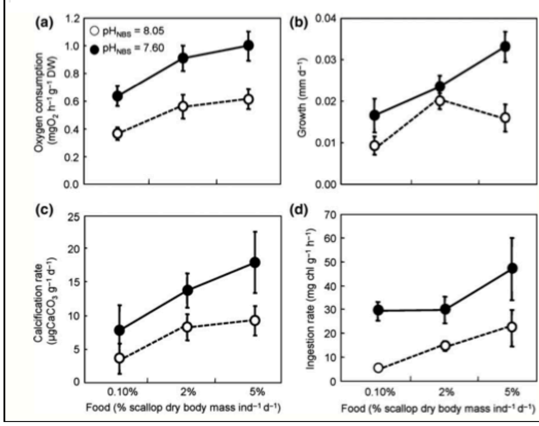
Multiple-stressors: food vs. ocean acidification

Global Change Biology

Global Change Biology (2016) 22, 2025–2037, doi: 10.1111/gcb.13179

Biomineralization changes with food supply confer juvenile scallops (*Argopecten purpuratus*) resistance to ocean acidification

LAURA RAMAJO[1,2], NÚRIA MARBÀ[1], LUIS PRADO[2], SOPHIE PERON[3], MARCO A. LARDIES[4,5], ALEJANDRO B. RODRIGUEZ-NAVARRO[6], CRISTIAN A. VARGAS[5,7], NELSON A. LAGOS[2,5] and CARLOS M. DUARTE[8]



- pH and food levels had additive effects on the physiological response of the juvenile scallops.
- Metabolic rates, shell growth, net calcification, and ingestion rates increased significantly at low pH conditions, independent of food.
- These physiological responses increased significantly in organisms exposed to intermediate and high levels of food supply.

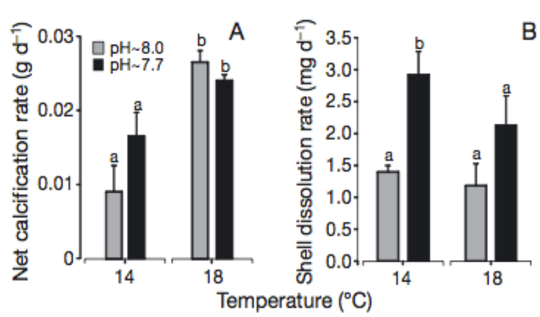
Multiple-stressors: food vs. ocean acidification

Vol. 8: 357–370, 2016 doi: 10.3354/aei00183 | AQUACULTURE ENVIRONMENT INTERACTIONS Aquacult Environ Interact | Published May 25

Effects of temperature and ocean acidification on shell characteristics of *Argopecten purpuratus*: implications for scallop aquaculture in an upwelling-influenced area

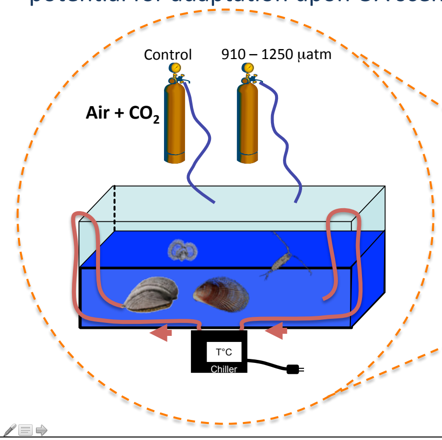
Nelson A. Lagos[1,*], Samanta Benítez[1], Cristian Duarte[2], Marco A. Lardies[3], Bernardo R. Broitman[4], Christian Tapia[5], Pamela Tapia[5], Steve Widdicombe[6], Cristian A. Vargas[7]

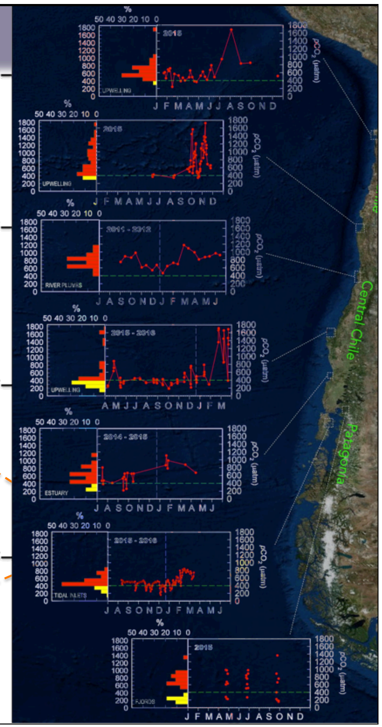
- The net calcification rate over the study period was not affected by low pH, but temperature had a significant positive effect.
- Shell dissolution, estimated from changes in shell weight of dead scallops, was significantly higher at the combination of low pH and at control temperature.



Environmental-variability and common-garden experiments in Chile

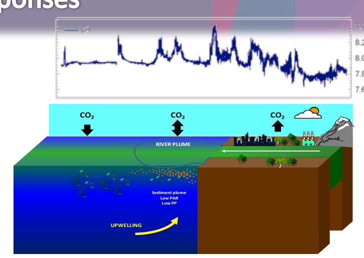
- Between 2009 and 2014 different 'common-garden' experiments were carried out for studying the phenotypic plasticity of different local populations along Chilean coast, in order to characterize the *reaction norms*, and therefore understand the potential for adaptation upon OA scenarios.

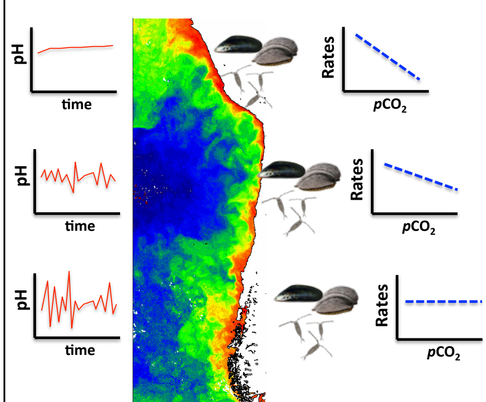




Natural pH/pCO_2 variability and plastic responses

- Important for validate OA experiments with species from coastal environments, such as coral reefs, rocky shores, upwelling zones, estuaries or fjords, salt marshes, etc, where pCO_2 levels vary dramatically over different temporal/spatial scales.





- However, studies on the effects of OA using scenarios give us insights about the role of pH/pCO_2 levels as a selective agent.
- Plastic responses help us to better understand the adaptive shifts that have evolved in marine species to deal with natural pH/pCO_2 variability, but do not assess the real effects of OA.
- As a consequence, meta-analyses should take the natural variability into account rather than consider absolute pH/pCO_2.

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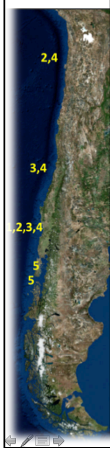
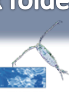
Intraspecific variability in the responses of different taxa collected in environments with naturally contrasting pCO_2 levels upon laboratory exposition to high-pCO_2 levels



Taxa	Environment	Mean ± SD environmental pCO_2 levels (µatm)	Control pCO_2 levels (µatm)	Experimental pCO_2 levels (µatm)	Response	Mean effect	Reference
	Coastal ocean	405.9 ± 95.4	398 - 405	1255	Ingestion	-72%	1
	Estuarine	618.0 ± 229.4	398 - 405	1255	Ingestion	+ 5%	1
	Coastal ocean	465.1 ± 121.2	380	1500	Respiration	+ 213%	2
	Estuarine	618.0 ± 229.4	380	1500	Respiration	+147%	2
	Estuarine	618.0 ± 229.4	365 - 398	979 - 1077	Larval survival	-60%	3
	River-plume area	793.2 ± 200.5	365 - 398	979 - 1077	Larval survival	-17	3
	Coastal ocean	465.1 ± 121.2	376 - 410	980 -1100	Ingestion	-47%	4
	Estuarine	618.0 ± 229.4	376 - 410	980 -1100	Ingestion	-33%	4
	River-plume area	793.2 ± 200.5	376 - 410	980 -1100	Ingestion	-17%	4
	Estuarine	618.0 ± 229.4	347 - 377	910 - 960	Ingestion	-60%	4
	River-plume area	793.2 ± 200.5	347 - 377	910 - 960	Ingestion	-13%	4
	Tidal inlet	438 ± 170.8	388	979	Calcification Growth	-37% -35%	5
	Freshwater-influenced tidal inlet	564.0 ± 284.3	380	979	Calcification Growth	-4% -13%	5

Papers are in our dropbox folder !!!!!!!!



marine ecology

Marine Ecology. ISSN 0173-9565

SHORT COMMUNICATION

Adaptive variability to low-pH river discharges in *Acartia tonsa* and stress responses to high $_pCO_2$ conditions

Victor M. Aguilera[1,2], Cristian A. Vargas[2,3,4], Marco A. Lardies[4,5] & María J. Poupin[6]

1 Instituto de Ciencias Naturales Alexander von Humboldt, Universidad de Antofagasta, Antofagasta, Chile
2 Millenium Institute of Oceanography, Universidad de Concepción, Concepción, Chile
3 Aquatic Ecosystem Functioning Lab (LAFE), Department of Aquatic Systems, Faculty of Environmental Sciences & Environmental Sciences Center EULA Chile, Universidad de Concepción, Concepción, Chile
4 Center for the Study of Multiple-drivers on Marine Socio-Ecological Systems (MUSELS), Universidad de Concepción, Concepción, Chile
5 Departamento de Ciencias, Facultad de Artes Liberales & Laboratorio de Bioingeniería, Facultad de Ingeniería y Ciencias, Universidad Adolfo Ibañez, Santiago, Chile
6 Laboratorio de Bioingeniería, Facultad de Ingeniería y Ciencias, Center of Applied Ecology and Sustainability (CAPES), Universidad Adolfo Ibañez, Santiago, Chile

Estuaries and Coasts (2015) 38:1163–1177
DOI 10.1007/s12237-014-9873-7

CO_2-Driven Ocean Acidification Disrupts the Filter Feeding Behavior in Chilean Gastropod and Bivalve Species from Different Geographic Localities

Cristian A. Vargas · Victor M. Aguilera · Valeska San Martín · Patricio H. Manríquez · Jorge M. Navarro · Cristian Duarte · Rodrigo Torres · Marco A. Lardies · Nelson A. Lagos

Estuaries and Coasts (2015) 38:590–598
DOI 10.1007/s12237-014-9845-y

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Differential response to ocean acidification in physiological traits of *Concholepas concholepas* populations

Marco A. Lardies[a,b,*], María Belén Arias[a], María Josefina Poupin[b], Patricio H. Manríquez[c,1], Rodrigo Torres[d], Cristian A. Vargas[e], Jorge M. Navarro[c], Nelson A. Lagos[f]

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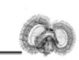

Vol. 514: 87–103, 2014
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MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser
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[3]Instituto de Ciencias Marinas y Limnológicas, Facultad de Ciencias, Universidad Austral de Chile, Valdivia, Chile
[4]Centro de Investigación e Innovación para el Cambio Climático (CIICC), Universidad Santo Tomás, Santiago, Chile
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