“MULTIPLE OCEAN STRESSORS AND INVASIVE ALIEN SPECIES: INTRODUCTION AND INSIGHT INTO THE CCLME”

Kick-off meeting of the project *Invasive alien species and other ocean stressors: Furthering the scientific knowledge and capacity basis in the Canary Current Large Marine Ecosystem*

VENUE: ON-LINE MEETING (MICROSOFT TEAMS)

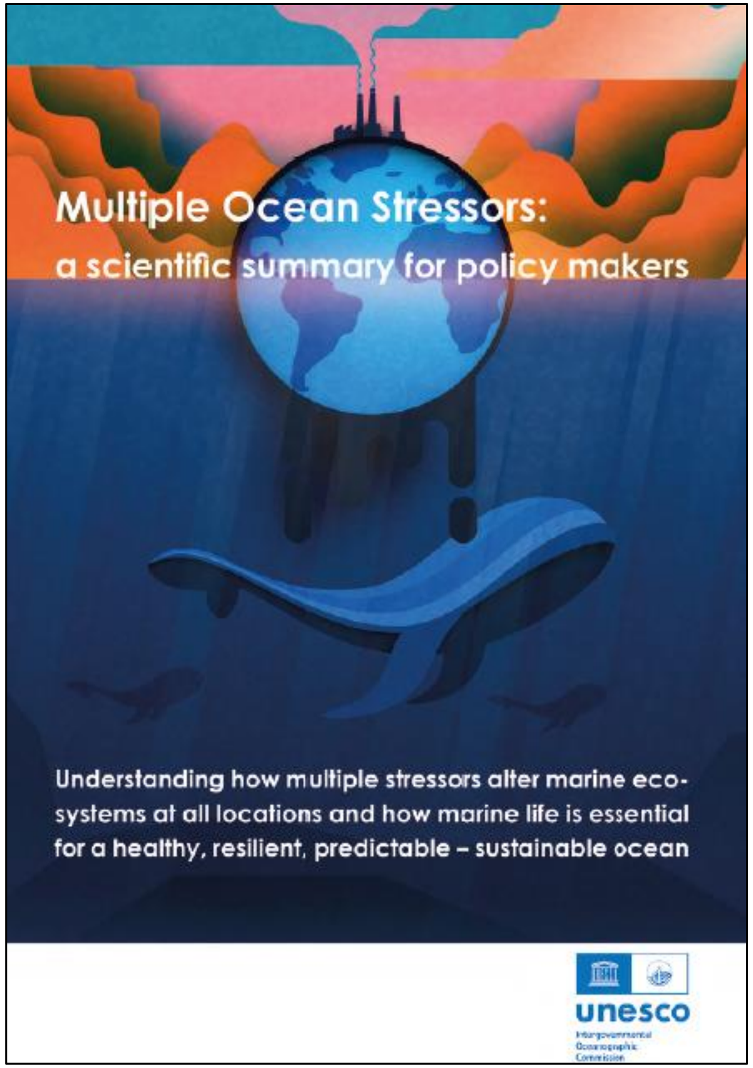
DATE: 24 FEBRUARY 2022

TIMES INDICATED IN CET (UTC+1)

INTRODUCTION TO MULTIPLE OCEAN STRESSORS

Sam Dupont
Kirsten Isensee and Philip Boyd

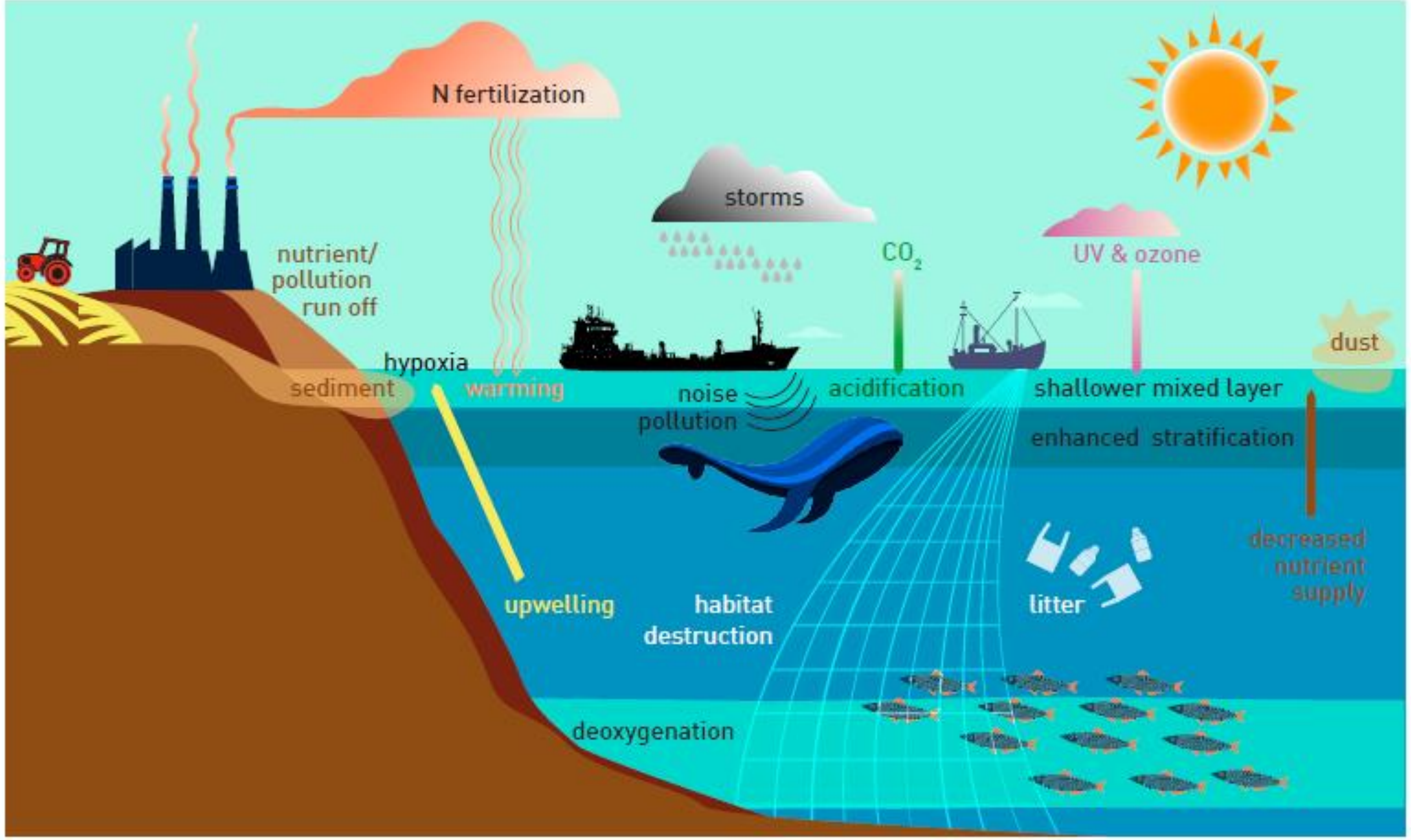
Key resource:



Goal

Healthy, resilient, productive, diverse sustianbly managed ocean, whose future we can predict

Human threats on the ocean



Multiple stressors

Different interacting categories

- ✓ *Habitat destruction (physical, pollution)*
- ✓ *Over-exploitation of resources (e.g. fishing)*
- ✓ *Movement of species (invasions, diseases)*
- ✓ *Global changes (climate change, ocean acidification, deoxygenation, etc.)*

- ✓ *Interactions*

e.g. extreme event + invasion

Local
vs
Global

Natural
vs.
Foreign

Abiotic
vs.
Biotic

What shall we do?

Healthy, resilient, productive, diverse sustianbly managed ocean, whose future we can predict

Policy action

Implementation of dadaption and mitigation strategies addressing the effects of multiple ocean stressors

Adaptation and mitigation strategies to combat the impacts of multiple stressors

Implementation of adaption and mitigation strategies addressing the effects of multiple ocean stressors

Understanding biological response

Taking into account locally specific combinations of stressors over time and space

Cataloguing stressors exposure

Identification of key stressors at all locations

Identification of temporal variability and their sources

Identify priorities


Identify priorities

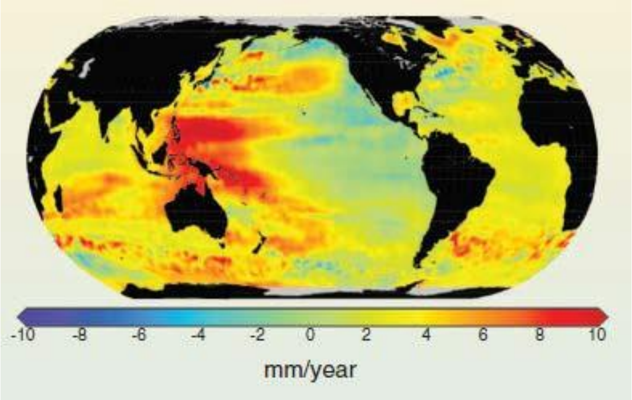
 

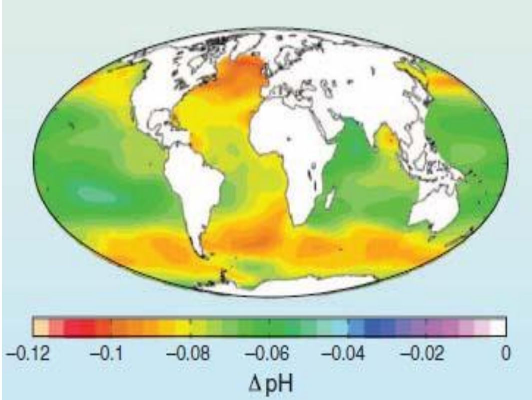
Strategy to identify priorities

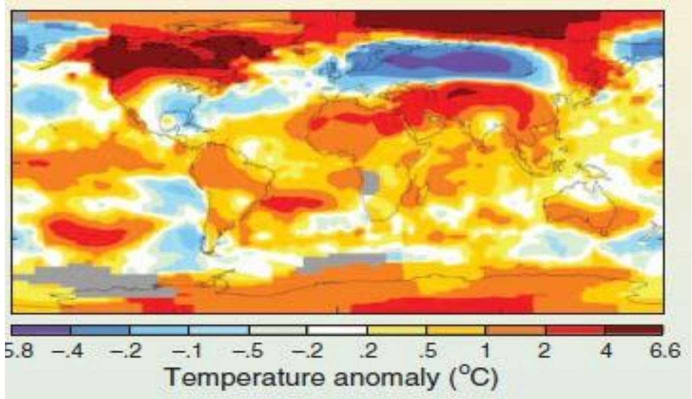
- Exposure
- Effects
- Solution availability

Different all every location

Exposure







Hoegh-Guldberg & Bruno 2010 Science

Paracelsus

« *Dosis facit venenum* »

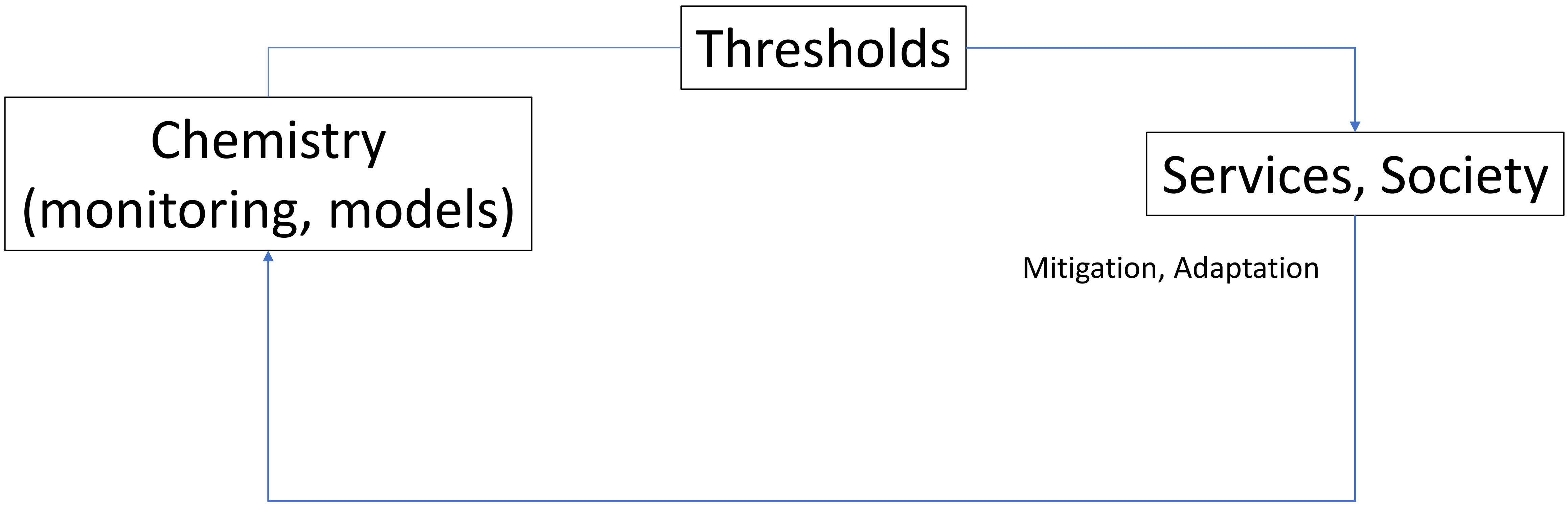
Need for local monitoring

Take home messages

- ✓ Different combination of stressors at each location

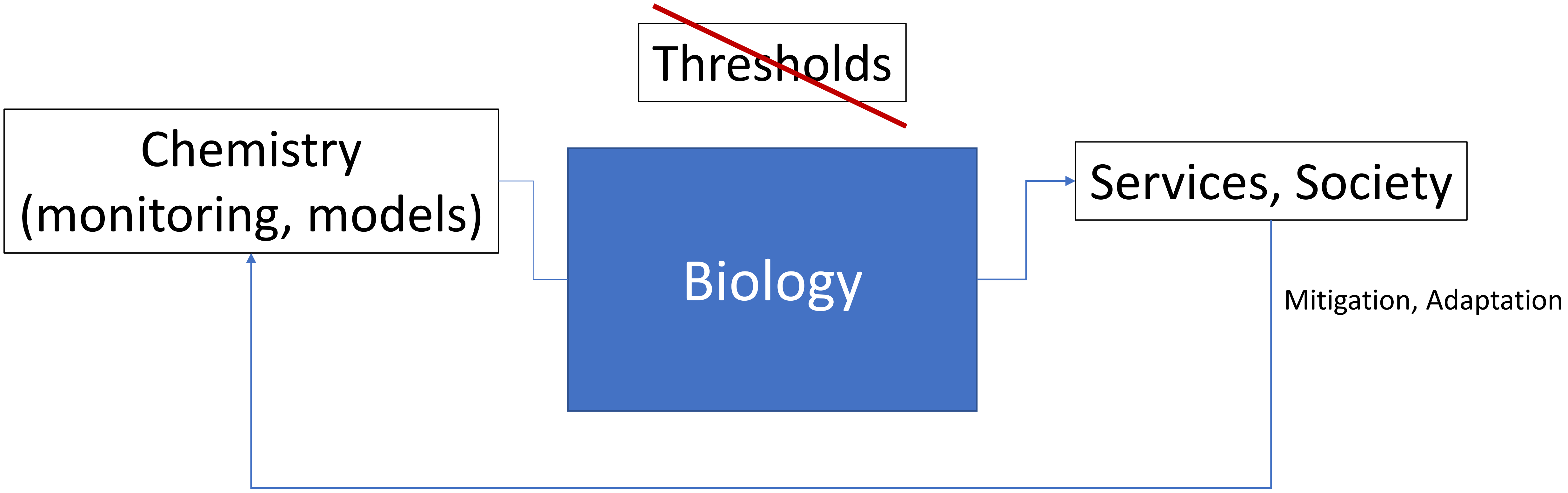
Foreign vs. Natural stressors

E.g. pollution (ecotoxicology)



Foreign vs. **Natural stressors**

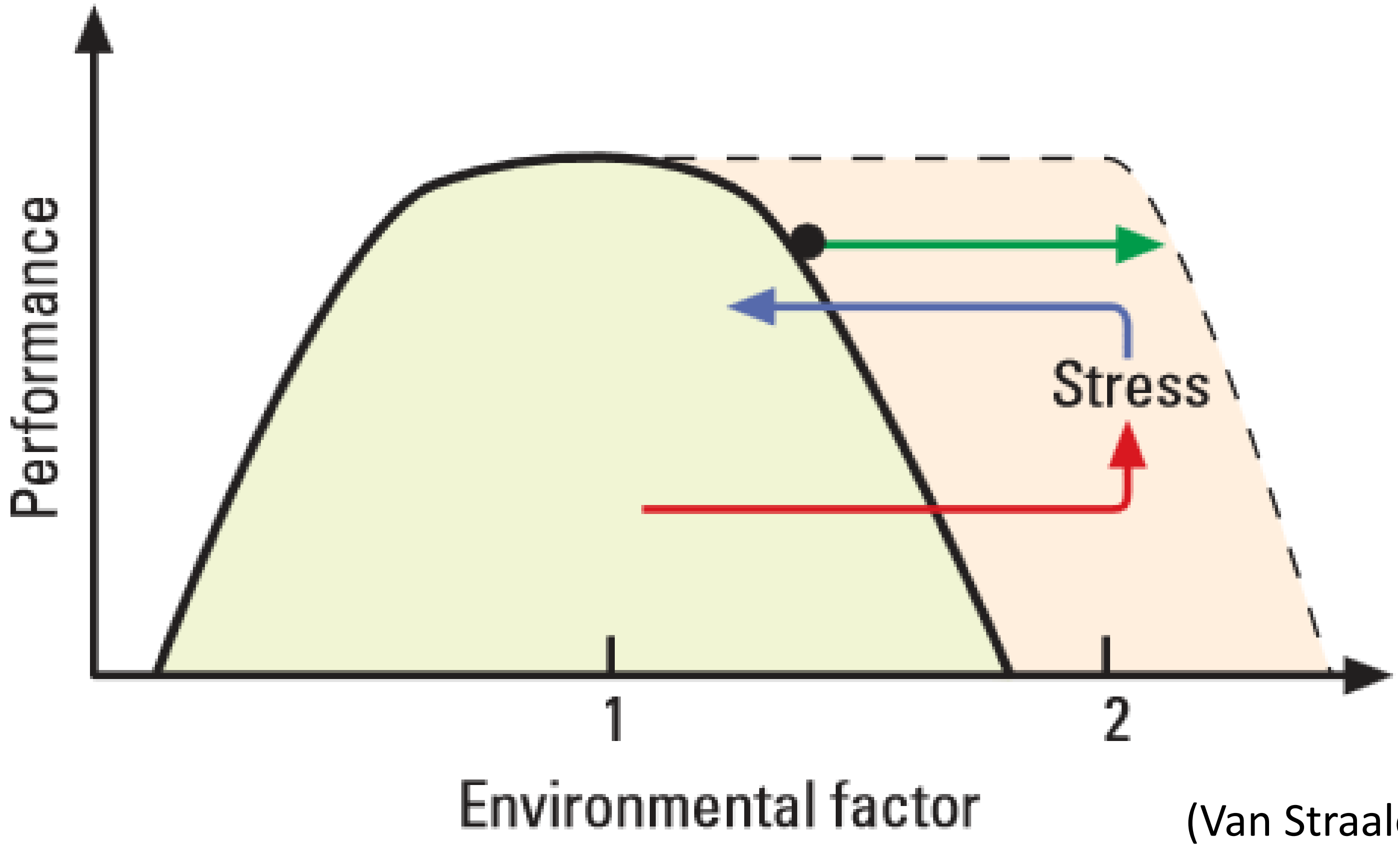
E.g. Temperature



Effects – What is a stressor?

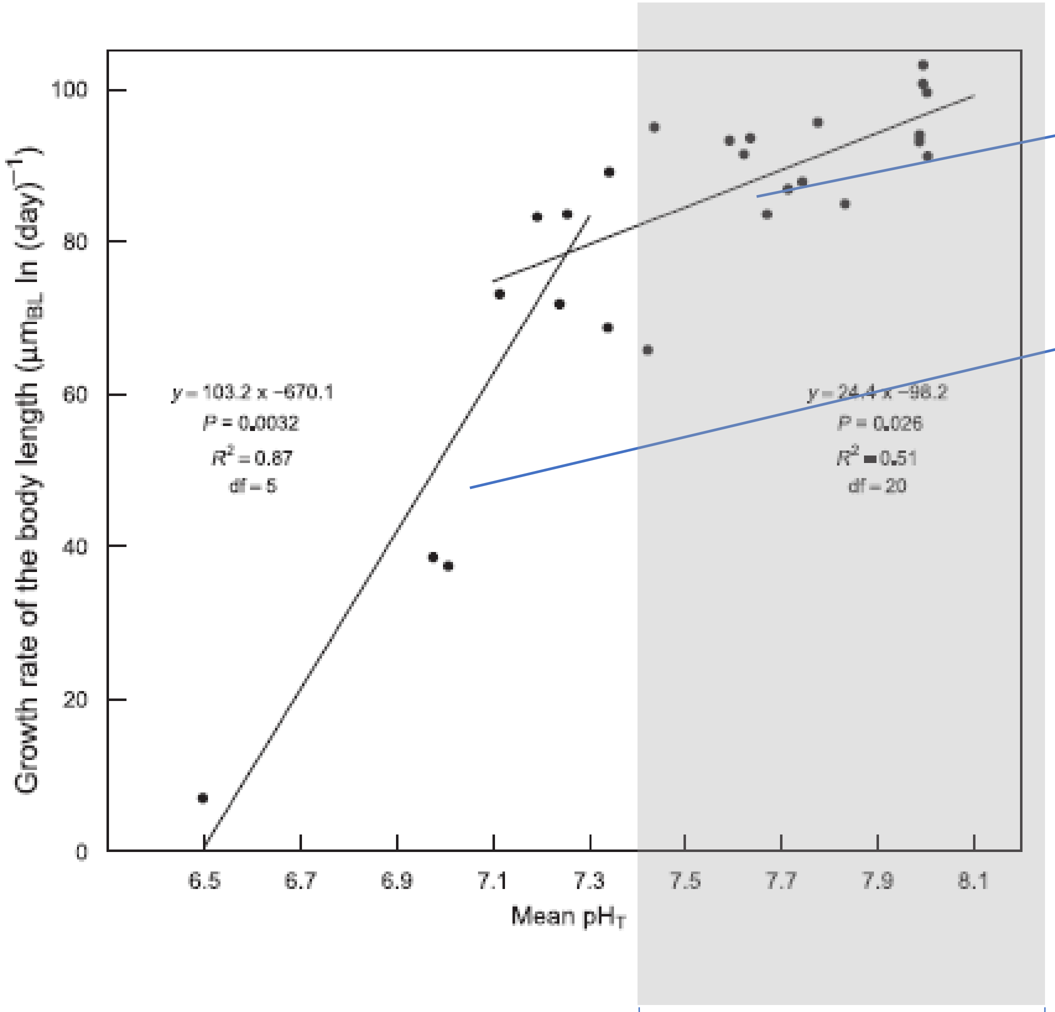
- *Stressor* — *A pressure that causes a quantifiable negative effect on an organism, process or community.*
- *Driver* — *A pressure that causes a quantifiable change (positive or negative) an organism, process or community.*
- *Stress* — *A measurable response that is deleterious to an organism, process or community.*

Biological thresholds different from chemical thresholds



(Van Straalen 2007)

A driver can become a stressor



Today

Within the present range of variability
NOT ocean acidification
NOT stressor / No stress (plasticity)

Outside the present range of variability
ocean acidification
stressor / stress

Global Change Biology

Global Change Biology (2013), doi: 10.1111/gcb.12276

Assessing physiological tipping point of sea urchin larvae exposed to a broad range of pH

NARIMANE DOREY*, PAULINE LANÇON*, MIKE THORNDYKE† and SAM DUPONT*
*Department of Biological and Environmental Sciences, The Sven Lovén Centre for Marine Sciences – Kristineberg, University of Gothenburg, Fiskebäckskil 45178, Sweden, †The Royal Swedish Academy of Sciences, The Sven Lovén Centre for Marine Sciences – Kristineberg, Fiskebäckskil 45178, Sweden

Biological response is locally dependent


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 Ibáñez, Santiago, Chile
6 Laboratorio de Bioingeniería, Facultad de Ingeniería y Ciencias, Center of Applied Ecology and Sustainability (CAPES), Universidad Adolfo Ibañez, Santiago, Chile

Keywords
Adaptive variability; copepods; low pH; ocean acidification; river discharges.

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Accepted: 8 February 2015

doi: 10.1111/maec.12282

Abstract

Environmental transitions leading to spatial physical–chemical gradients are of ecological and evolutionary interest because they are able to induce variations in phenotypic plasticity. Thus, the adaptive variability to low-pH river discharges may drive divergent stress responses [ingestion rates (IR) and expression of stress-related genes such as *Heat shock protein 70* (*Hsp70*) and *Ferritin*] in the neritic copepod *Acartia tonsa* facing changes in the marine chemistry associated to ocean acidification (OA). These responses were tested in copepod populations inhabiting two environments with contrasting carbonate system parameters (an estuarine *versus* coastal area) in the Southern Pacific Ocean, and assessing an *in situ* and 96-h experimental incubation under conditions of high pressure of CO_2 ($_pCO_2$ 1200 ppm). Adaptive variability was a determining factor in driving variability of copepods' responses. Thus, the food-rich but colder and corrosive estuary induced a traits trade-off expressed as depressed IR under *in situ* conditions. However, this experience allowed these copepods to tolerate further exposure to high $_pCO_2$ levels better, as their IRs were on average 43% higher than those of the coastal individuals. Indeed, expression of both the *Hsp70* and *Ferritin* genes in coastal copepods was significantly higher after acclimation to high $_pCO_2$ conditions. Along with other recent evidence, our findings confirm that adaptation to local fluctuations in seawater pH seems to play a significant role in the response of planktonic populations to OA-associated conditions. Facing the environmental threat represented by the inter-play between multiple drivers of climate change, this biological feature should be examined in detail as a potential tool for risk mitigation policies in coastal management arrangements.

Introduction

Geographically widespread species must cope with environmental differences among habitats. This ability can, in principle, be achieved by genetic differentiation and/or phenotypic flexibility (Blanckenhorn 1997; Lardies *et al.* 2008). Information concerning geographic variations in response to ocean acidification (OA; Feely *et al.* 2004; Caldeira & Wickett 2003) is critical because many morphologic, life-history and metabolic traits show variation

Population 1

Population 2

–––

+

Same species, different responses

Biological response is locally dependent

marine ecology

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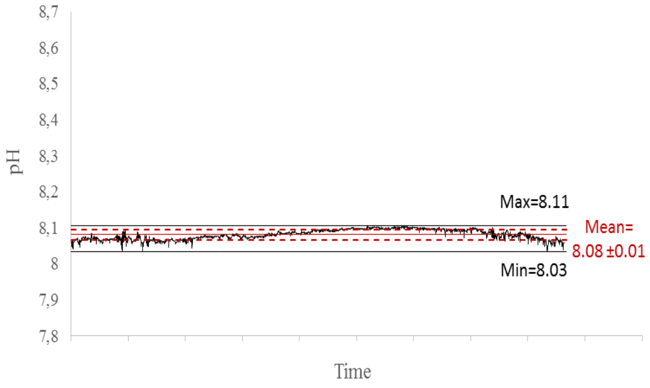
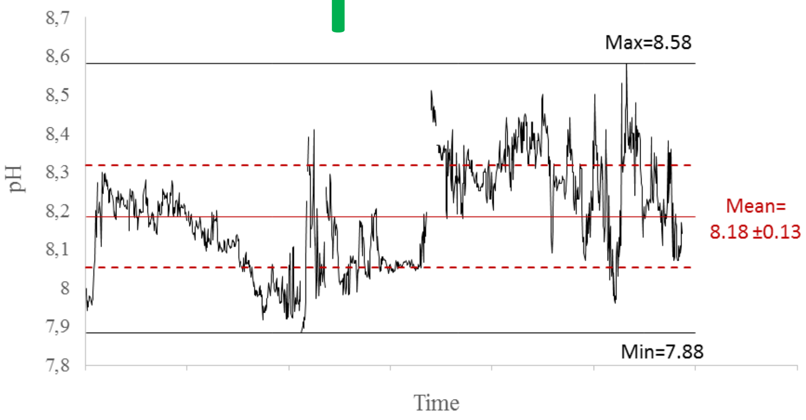
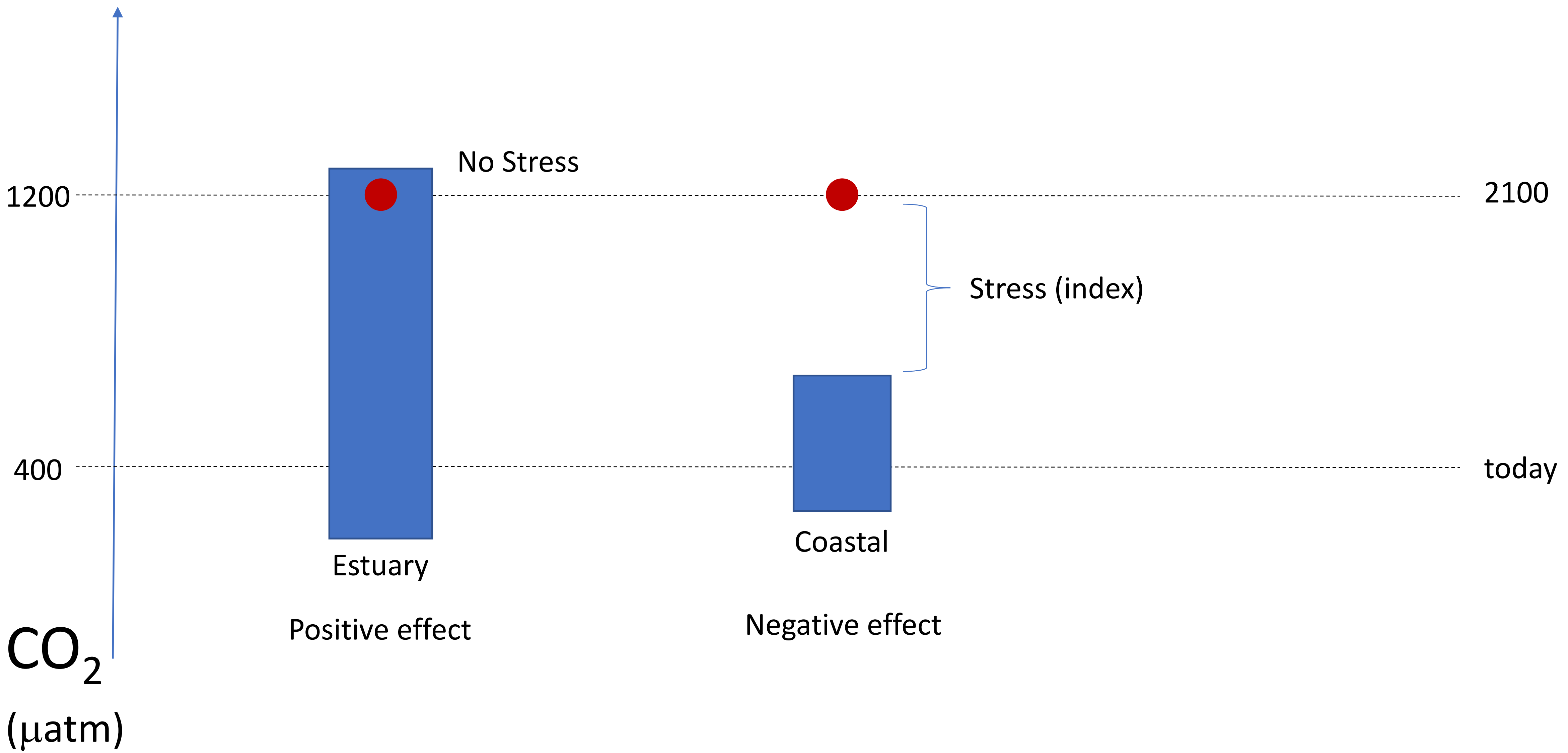


Population 2

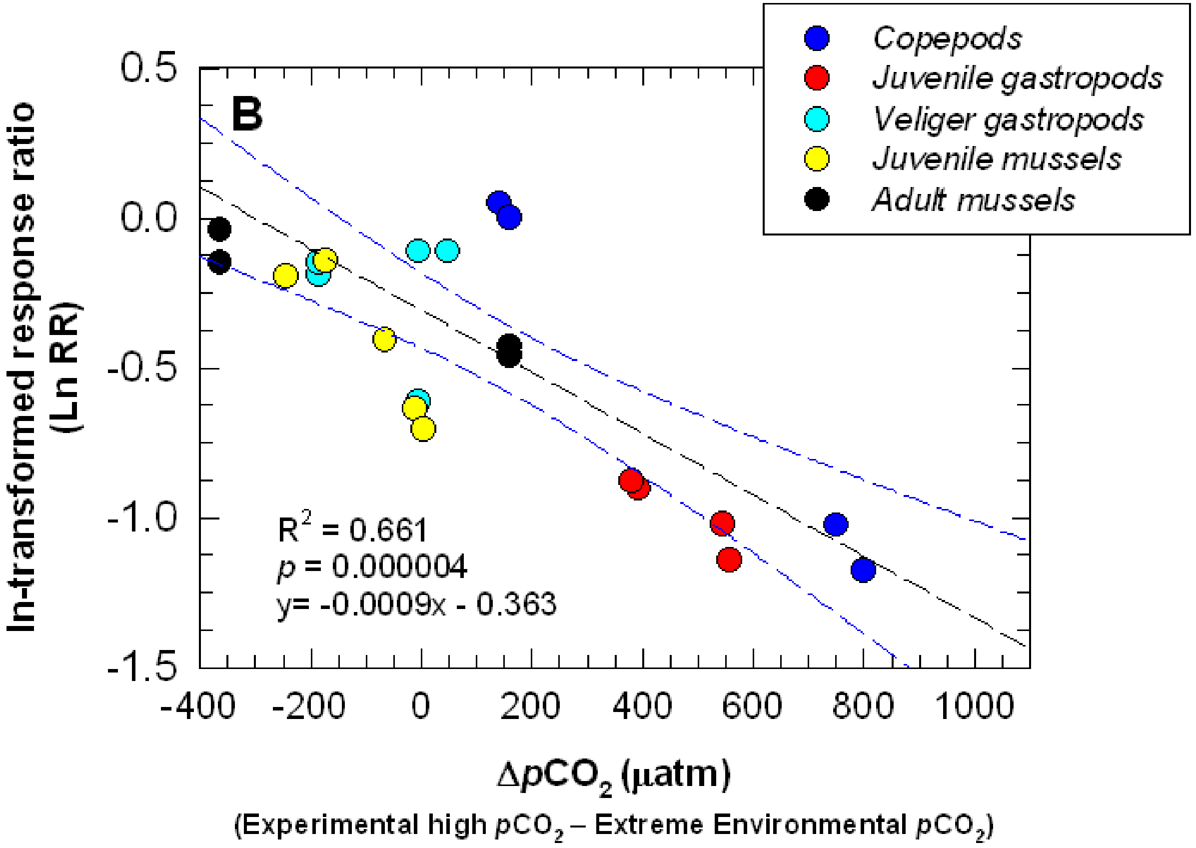


Same species, different responses

Theory: adaptation drives sensitivity



Local adaptation



nature ecology & evolution

ANALYSIS

PUBLISHED: 13 MARCH 2017 | VOLUME: 1 | ARTICLE NUMBER: 0084

Species-specific responses to ocean acidification should account for local adaptation and adaptive plasticity

Cristian A. Vargas[1,2,3]*, Nelson A. Lagos[3,4], Marco A. Lardies[3,5], Cristian Duarte[3,6], Patricio H. Manríquez[7], Victor M. Aguilera[2,8], Bernardo Broitman[3,7], Steve Widdicombe[9] and Sam Dupont[10]

nature climate change

ANALYSIS

https://doi.org/10.1038/s41558-021-01269-2

Check for updates

Upper environmental pCO_2 drives sensitivity to ocean acidification in marine invertebrates

Cristian A. Vargas[1,2,3], L. Antonio Cuevas[1,3], Bernardo R. Broitman[3,4], Valeska A. San Martin[3], Nelson A. Lagos[3,5], Juan Diego Gaitán-Espitia[6] and Sam Dupont[7,8]

The more you **deviate from today**, the more negative impact (stress is relative)

Take home messages

- ✓ Different combination of stressors at each location

- ✓ What defines a stressor is relative and depends also on each location

THE question

Multiple drivers/stressors
(A, B, C, D, etc.)

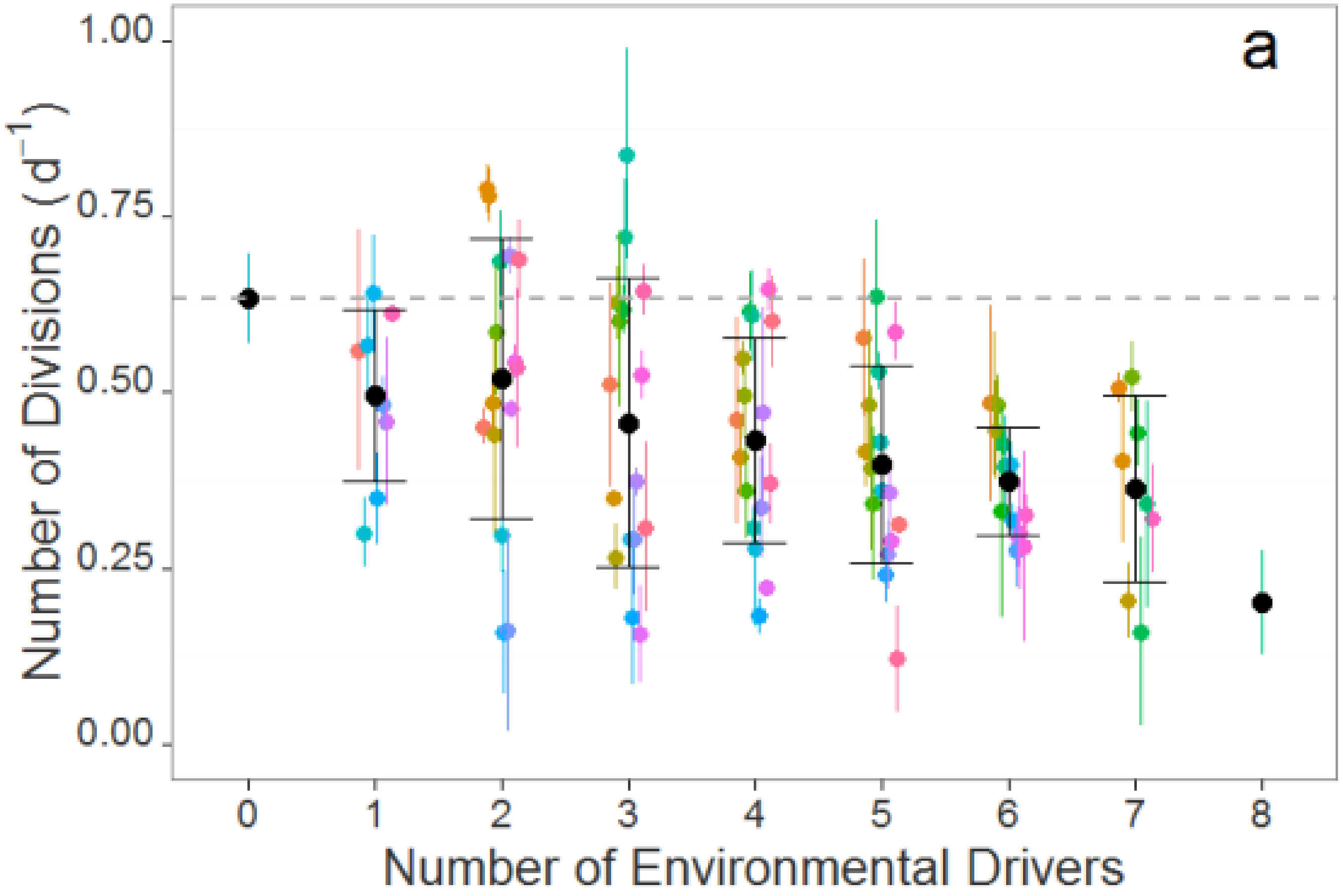
What is the effect of A+B+C+D+etc.

Increased drivers = increased stress


ARTICLES
PUBLISHED ONLINE: 15 JUNE 2015 | DOI: 10.1038/NCLIMATE2682
nature climate change

Growth responses of a green alga to multiple environmental drivers

Georgina Brennan and Sinéad Collins*



Combined effects can change priority

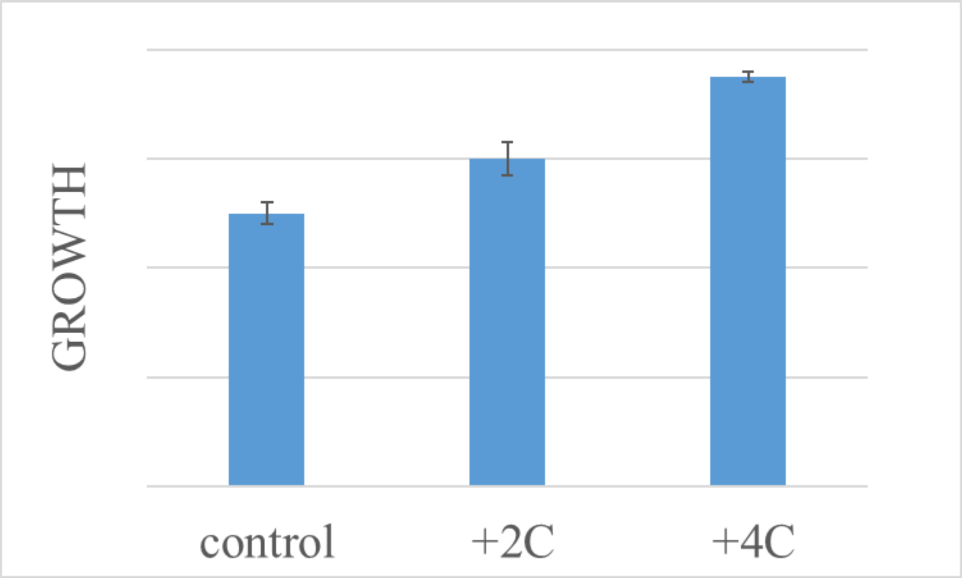
Combined effects are complex

Additive

Synergism/Synergistic

Antagonistic

E.g. impact of temperature on mussels



Effect on growth:

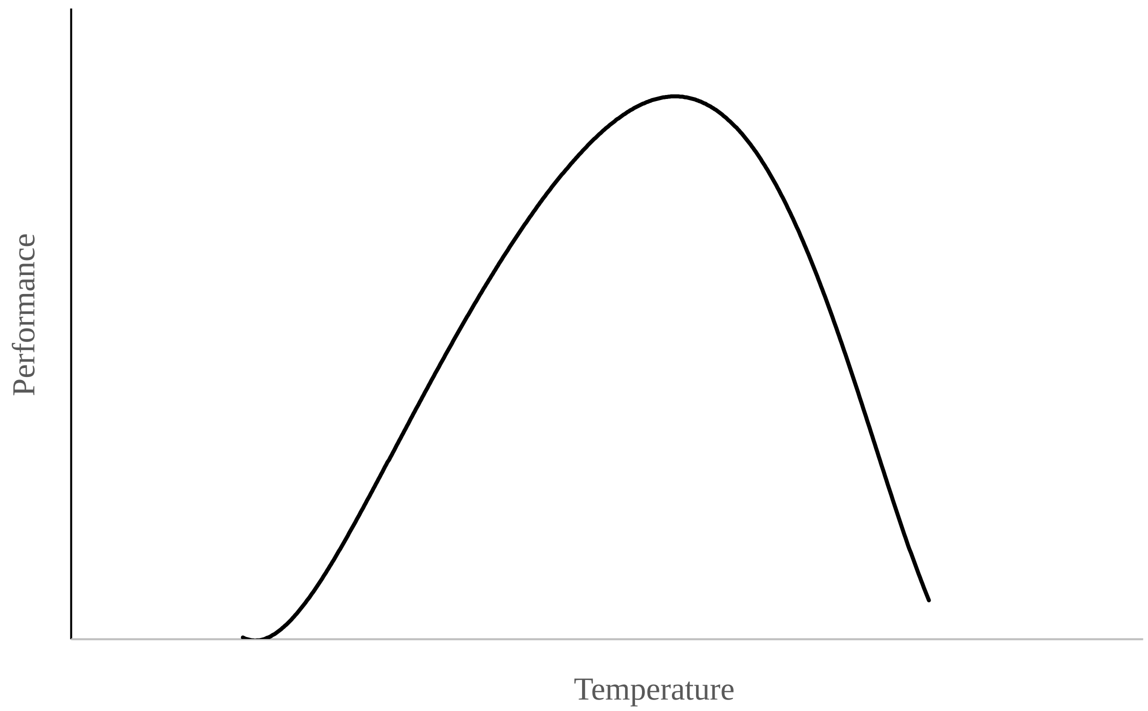
+2C (A): +10%
+4C (B): +15%
+6C (A+B): ?

E.g. impact of temperature on mussels

An increase by 2C = 10% increase in growth
An increase by 4C = 25% increase in growth
What is the % of increase in growth after a 6C increase in temperature?

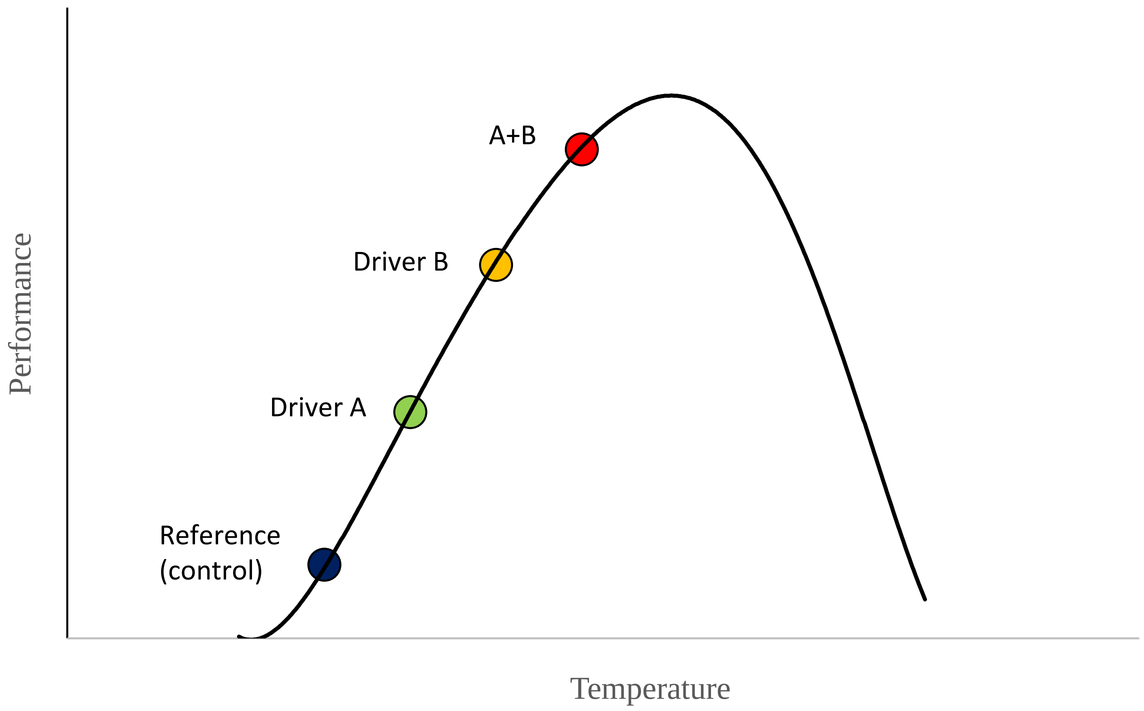
- 35%
- <35%
- >35%
- It depends

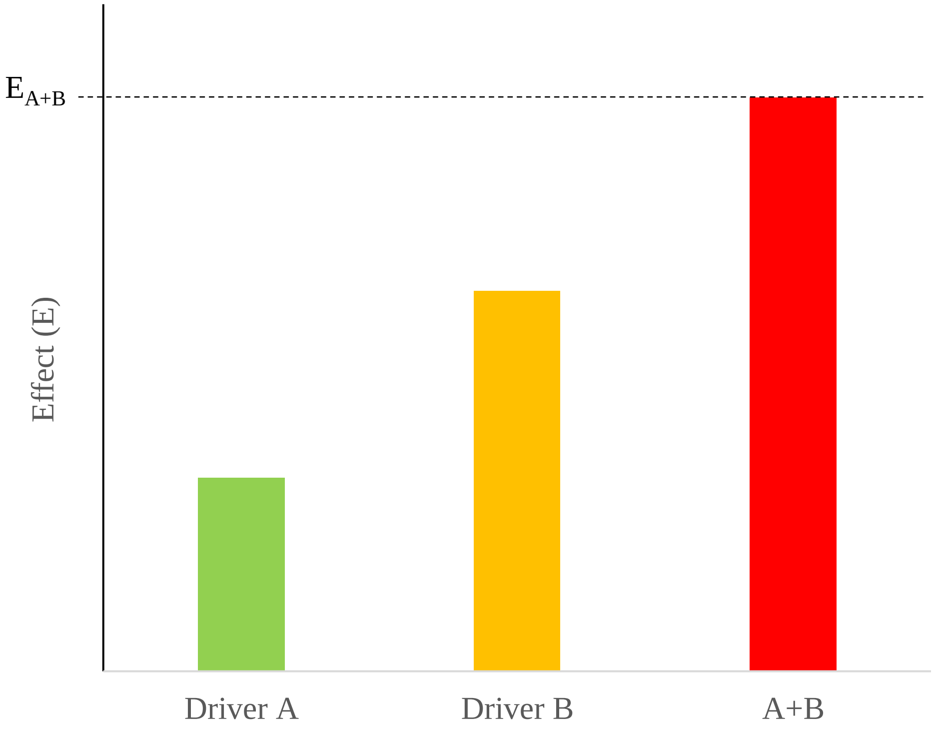
Why does it depend?



Performance curves are not linear

For additive driver, the effect depends on the shape of the curve and starting point

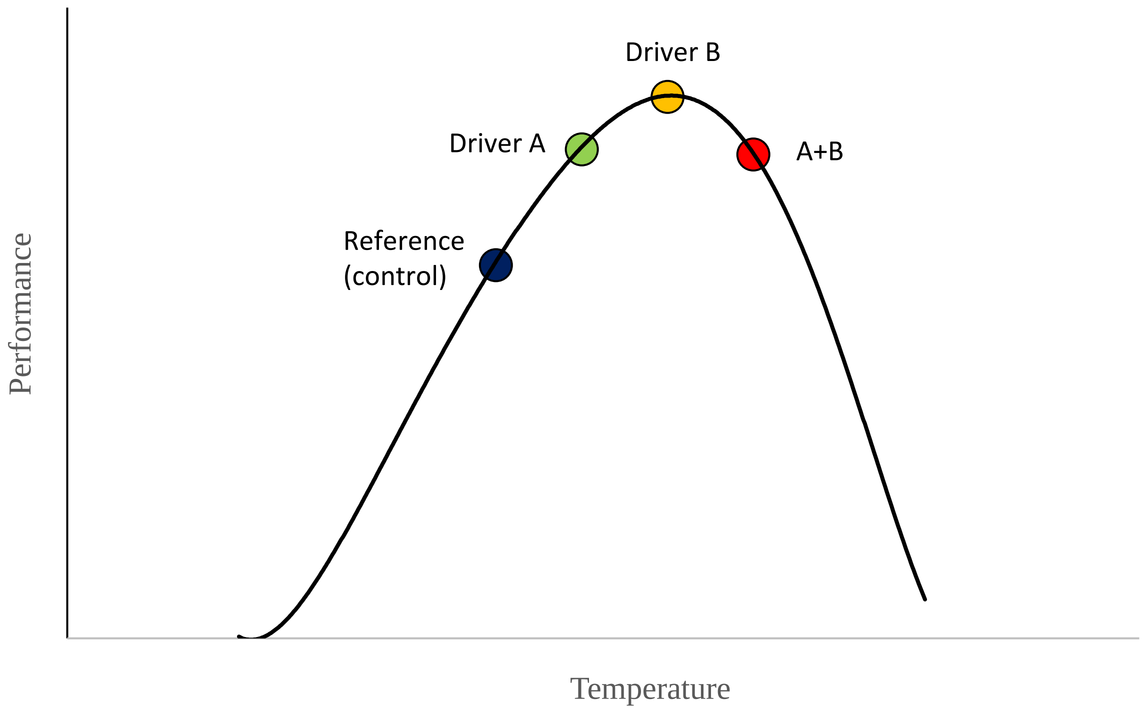


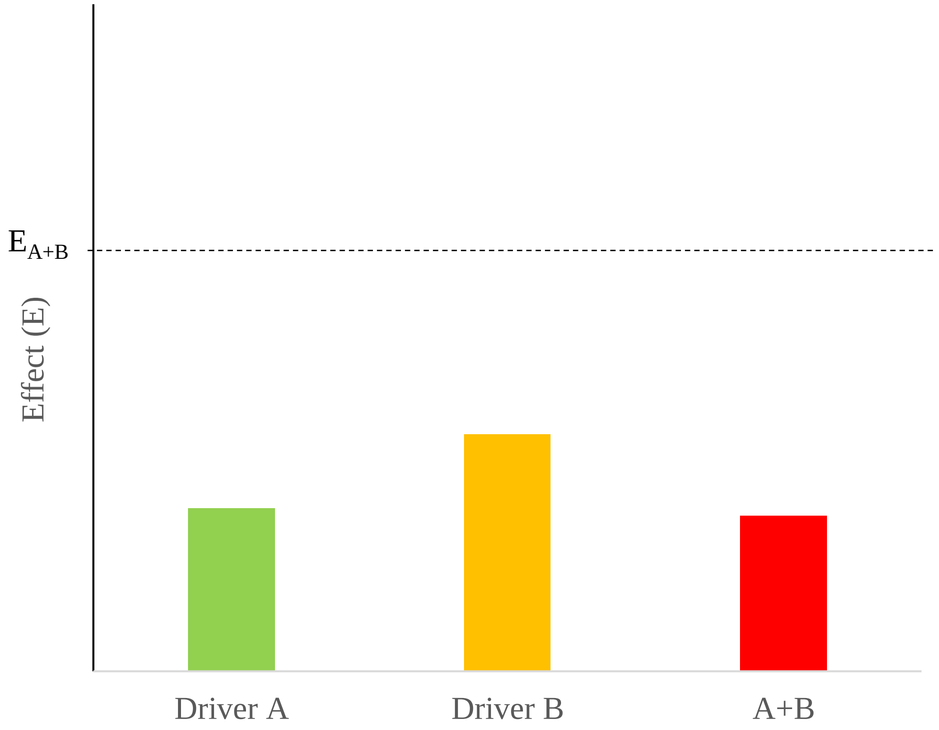


Additive drivers
Additive effect

$$Ea+b = Ea + Eb$$

For additive driver, the effect depends on the shape of the curve and starting point

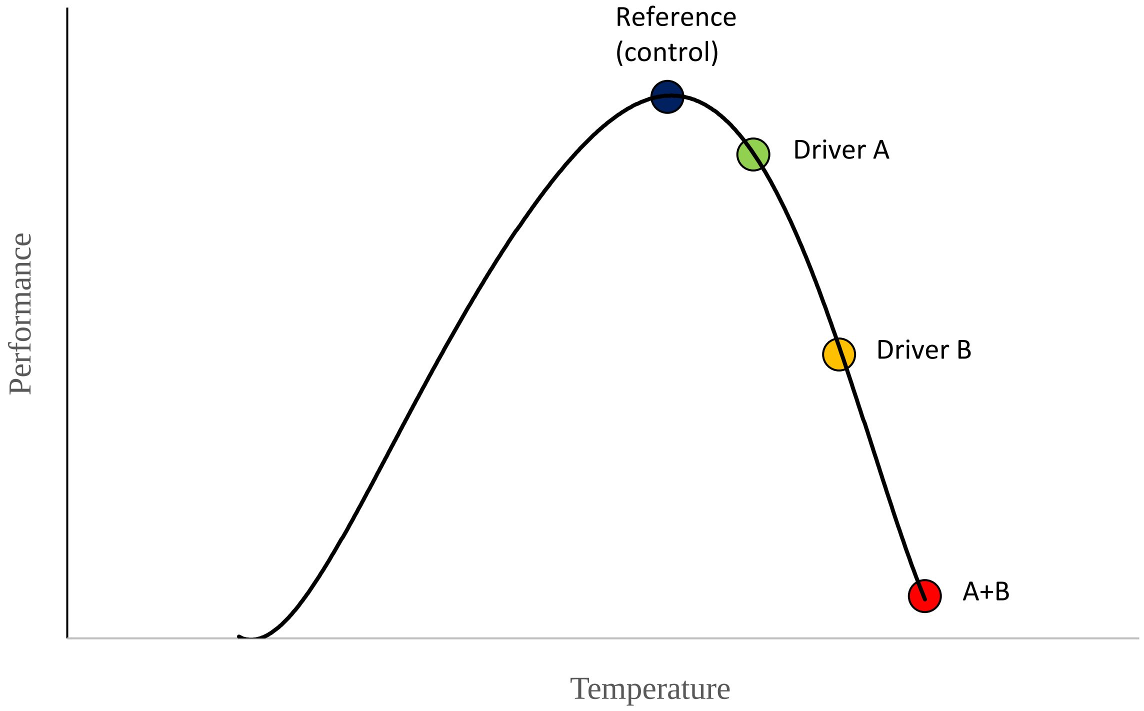


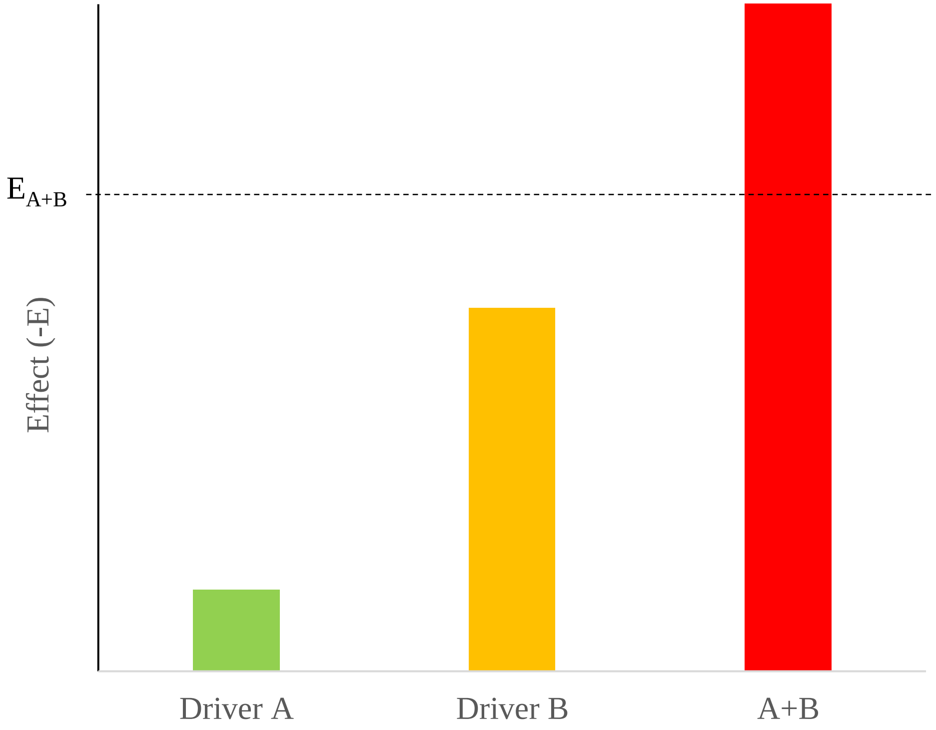


Additive drivers
Antagonistic effects

$$Ea+b < Ea + Eb$$

For additive driver, the effect depends on the shape of the curve and starting point





Additive drivers
Synergistic effects

$$Ea+b > Ea + Eb$$

Additive stressors add in a non-linear way (depends on the shape of the curve) so it does not translate into an arythmetic mathematical addition at the effect level

As a consequence:

1. What you see at the effect level does not say anything on the additivity of stressors

2. Multiple stressors experiments have limited potential to resolve how stressors work in combination

Take home messages

- ✓ Different combination of stressors at each location
- ✓ What defines a stressor is relative and depends also on each location
- ✓ Combined effects are complex and cannot easily be understood from classic effect studies

To understand how two stressors work in combination you need the mode of action

Mode of action and interactions

Driver 1 = beer

No interaction / Additive

Driver 1 = wine

Interaction

Driver 1 = drugs

Mechanistic studies

Definitions

- *Additive* — ***Absence of interaction*** *between drivers/stressors (dose-addition)*
- *Synergism/Synergistic*
- *Antagonistic*

(Synergism/Synergistic and Antagonistic:) ***Interactions*** *between drivers/stressors*

Four options

- *Same or different mode of action*
- *Interactions or no interactions*

Mode of action		**Interaction**	
		Yes	No (additive)
	Same		
	Different		

Case study: warming and over-fishing

Global warming (A): kills 50% of fish

Fishing (B): kills 50% of fish

A+B?

Different mode of action and no interactions

		Interaction	
		Yes	No (additive)
Mode of action	Same		
	Different		●

Different mode of action and no interactions

Stressor 1 = overfishing (50%)

Stressor 2 = Global warming (50%)

Stressor 1 + Stressor 2 = ???

Different mode of action and no interactions

Stressor 1 = overfishing (50%)

Stressor 2 = Global warming (50%)

Stressor 1 + Stressor 2 = ???

Different mode of action and no interactions

Stressor 1 = overfishing (50%)

Stressor 2 = Global warming (50%)

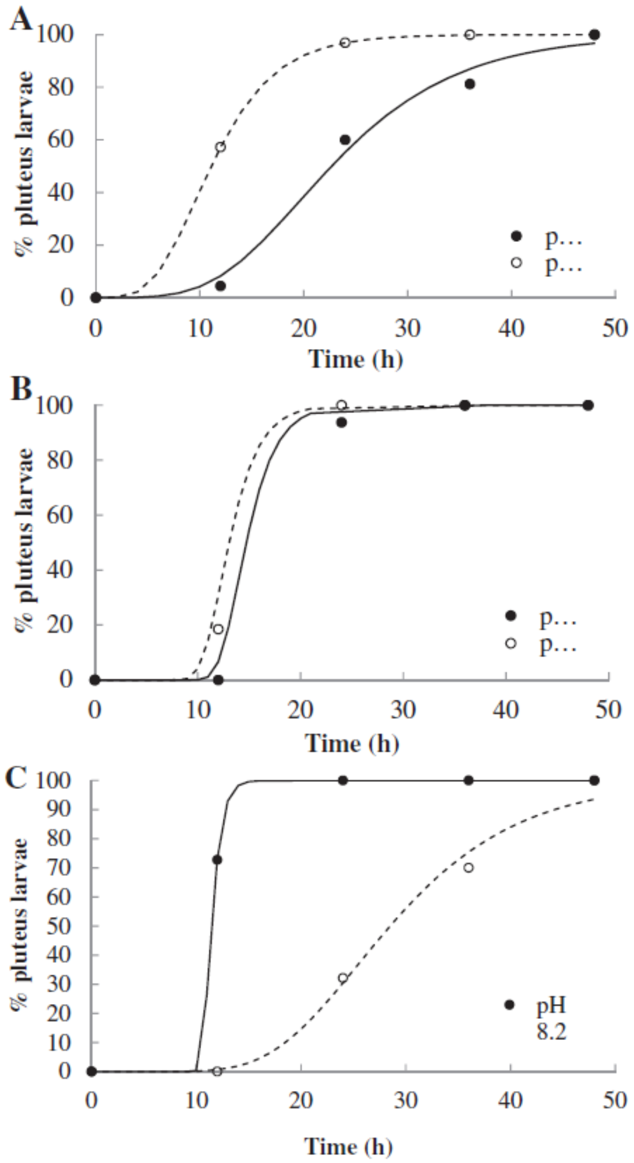
Stressor 1 + Stressor 2 = ???

$$R_{A+B} = R_A + R_B - R_A x R_B = 75\%$$

Same mode of action and no interactions

		Interaction	
		Yes	No (additive)
Mode of action	Same		●
	Different		

OA + temperature



Low temperature
Positive effect of OA

Mid temperature
No effect of OA

High temperature
Negative effect of OA

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ELSEVIER

Temperature modulates the response of the thermophilous sea urchin *Arbacia lixula* early life stages to CO_2-driven acidification

Paola Gianguzza[a], Giulia Visconti[a,*], Fabrizio Gianguzza[b], Salvatrice Vizzini[a], Gianluca Sarà[a], Sam Dupont[c]

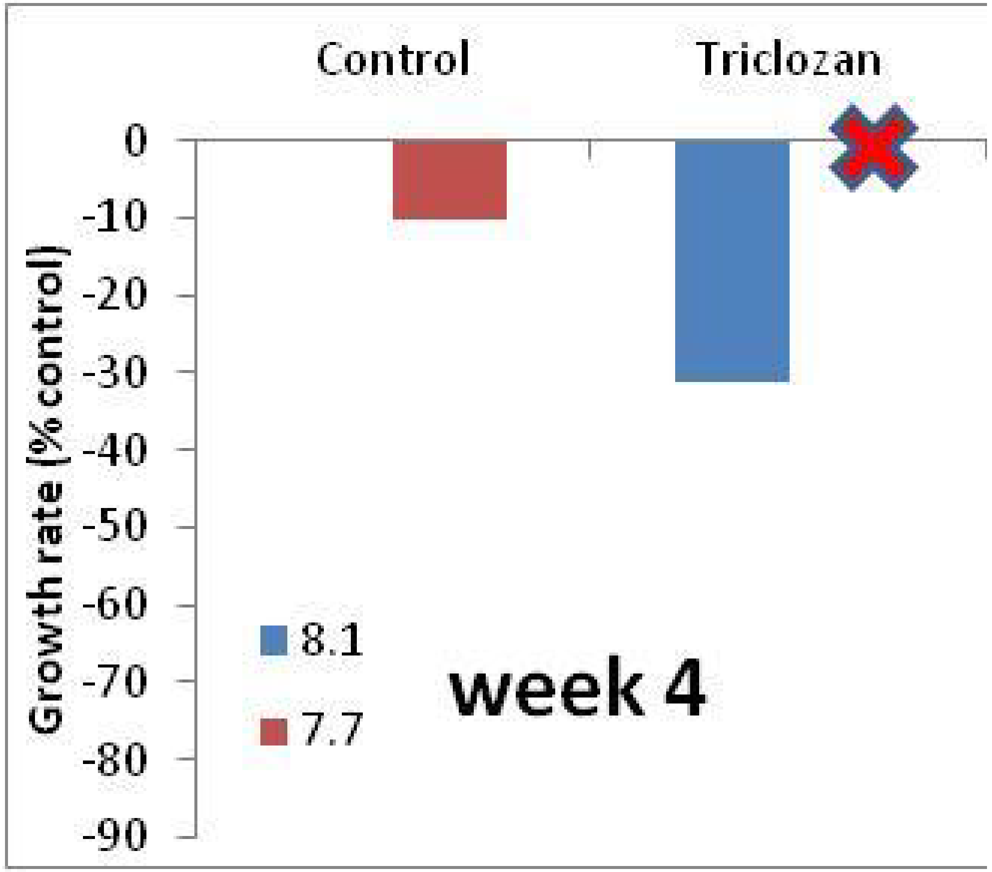
[a] Dipartimento di Scienze della Terra e del Mare (DiSTeM), Università di Palermo, Via Archirafi, 22, I-90123 Palermo, Italy
[b] Department of Molecular and Biomolecular Technologies Sciences (STEMBIO), University of Palermo, 90128 Palermo, Italy
[c] Department of Biological and Environmental Sciences, University of Gothenburg, The Sven Lovén Centre for Marine Sciences, 45178 Fiskebäckskil, Sweden

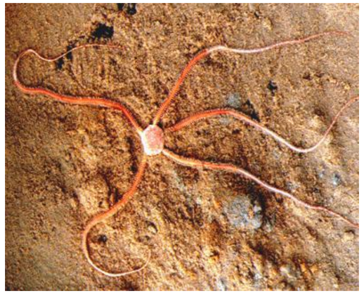
Additive stressor,
Depends on effects

Different modes of action and interactions

		Interaction	
		Yes	No (additive)
Mode of action	Same		
	Different	●	

Ocean acidification with toxicants





Complex interactions

Need a deeper mechanistic understanding

Take home messages

- ✓ Different combination of stressors at each location
- ✓ What defines a stressor is relative and depends also on each location
- ✓ Combined effects are complex and cannot easily be understood from classic effect studies
- ✓ Mechanistic studies are needed to understand multiple stressors

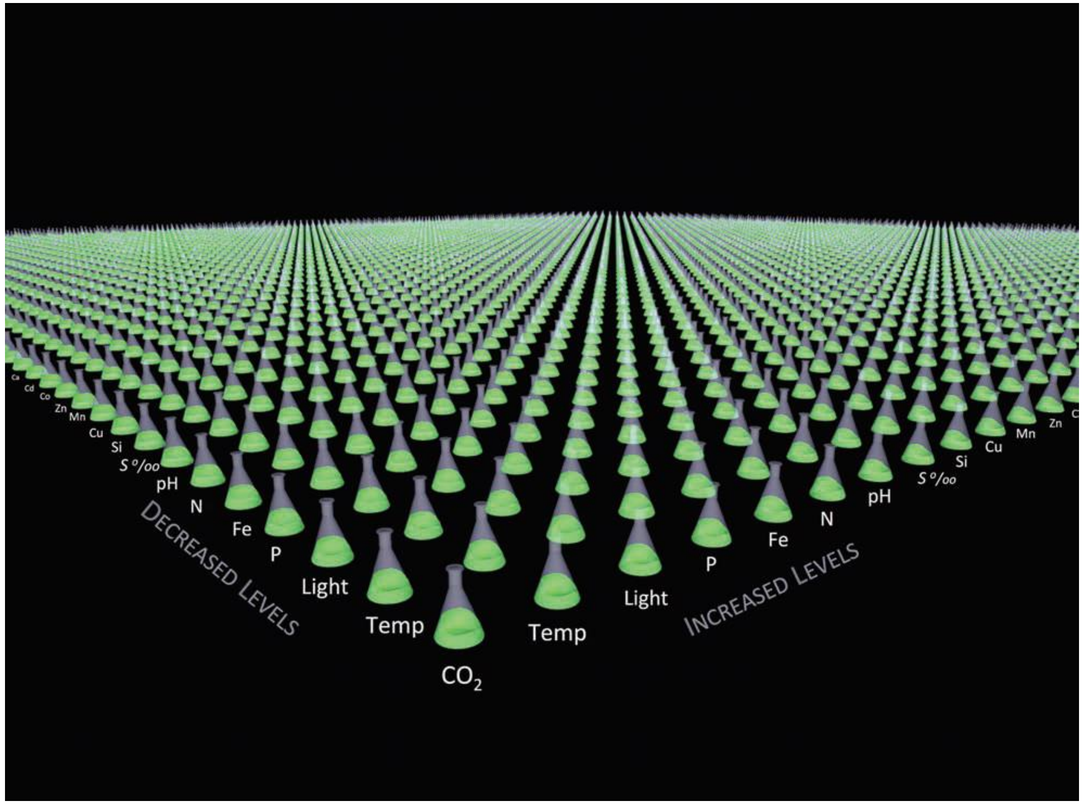
THE question

Multiple drivers/stressors
(A, B, C, D, etc.)

What is the effect of A+B+C+D+etc.

How to answer this question

Multiple stressors experiments



- ✓ Many stressors
- ✓ Many scenarios

Complex to perform

Complex to interpret !

Research strategy

1. List your drivers/stressors
(intensity, duration, thresholds, etc.)
2. Understand the mode of action and interactions
3. Understand your performance curves
4. Model
5. Test your model

Monitoring

Single stressor experiments

Modeling

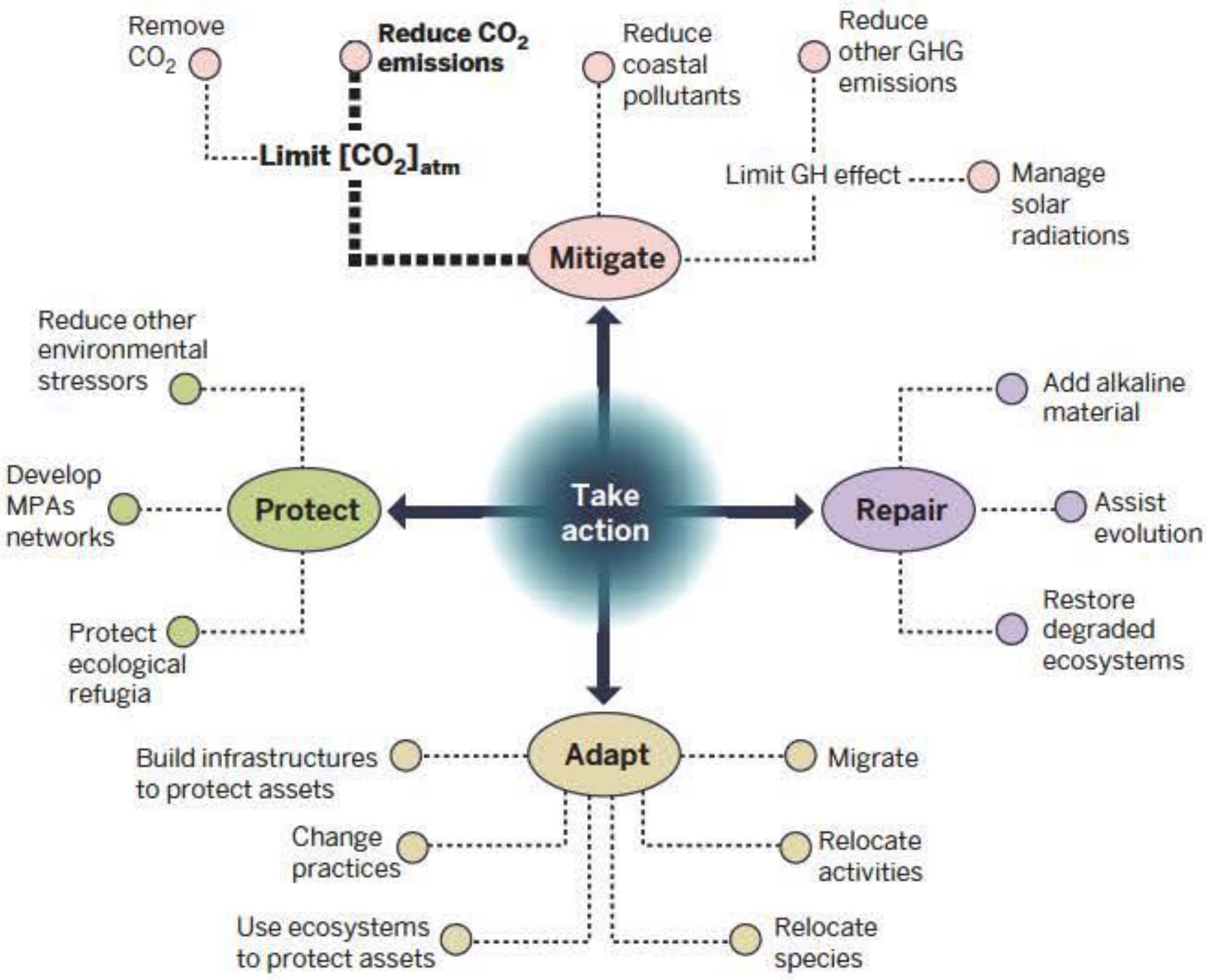
Multiple stressors experiments

Take home messages

- ✓ Different combination of stressors at each location
- ✓ What defines a stressor is relative and depends also on each location
- ✓ Combined effects are complex and cannot easily be understood from classic effect studies
- ✓ Mechanistic studies are needed to understand multiple stressors

To build a local priority list of stressors, you need a **good understanding of the local conditions** (monitoring) as well as a **mechanistic understanding of each stressors** and their **combined effects** (mode of action)

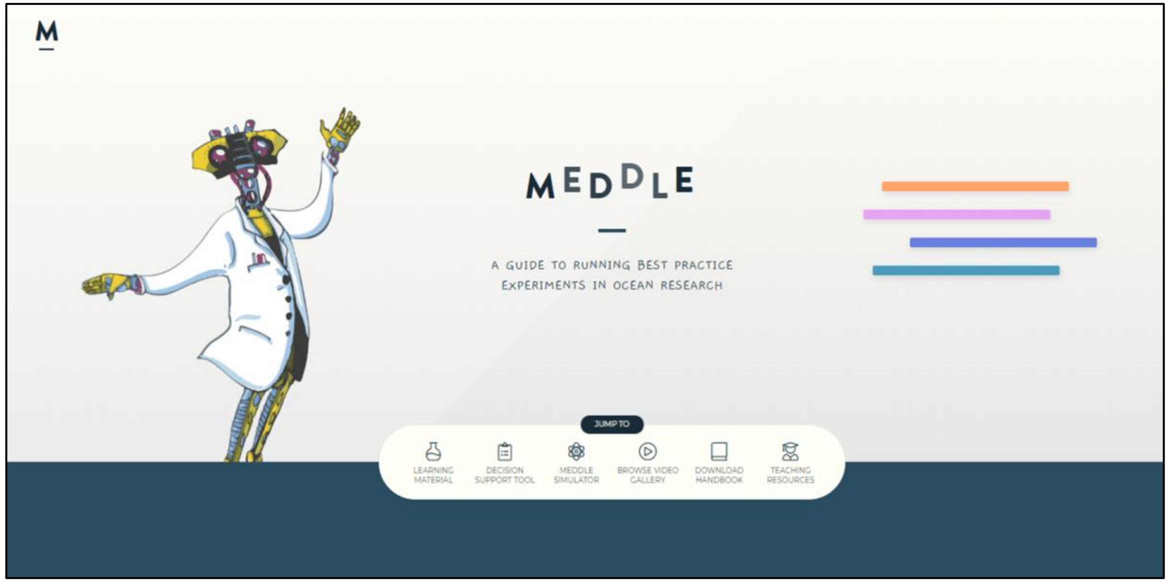
+ Solutions – The science we need

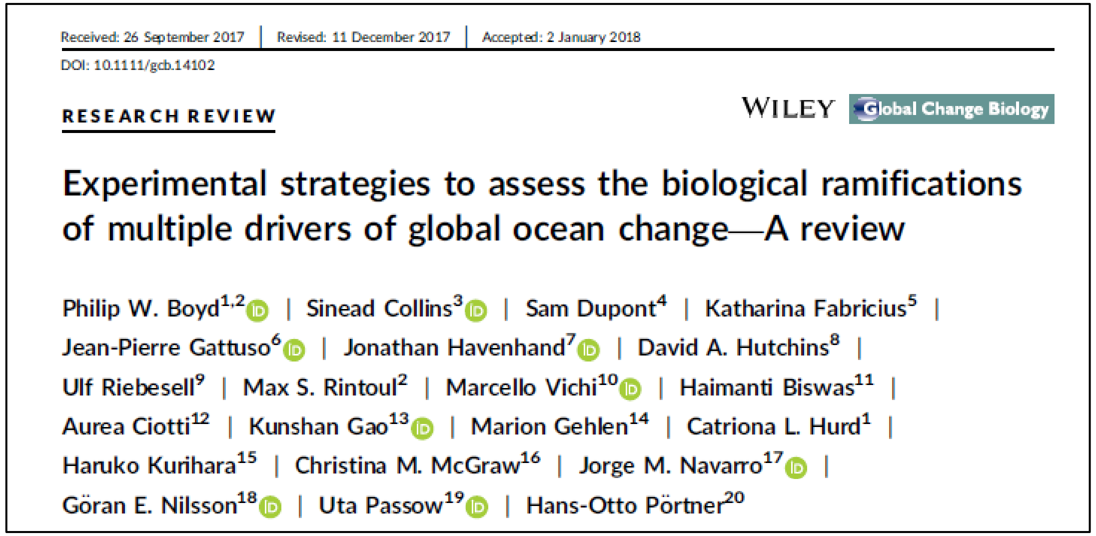


Science priority based on development and implementation of solutions

- ✓ General vs. Specific?
- ✓ Already available
- ✓ Timeline
- ✓ Science needs

Other resources: SCOR WG 149




Received: 26 September 2017 | Revised: 11 December 2017 | Accepted: 2 January 2018
DOI: 10.1111/gcb.14102

RESEARCH REVIEW

WILEY Global Change Biology

Experimental strategies to assess the biological ramifications of multiple drivers of global ocean change—A review

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https://meddle-scor149.org/

Other resources: Training

Basic Training Course on Multiple Stressors

May 2022 (2 weeks)

Monaco (IAEA), Villefranche-sur-Mer (LOV)

IAEA | Ocean Acidification International Coordination Centre OA-ICC

FONDATION PRINCE ALBERT II DE MONACO

Check: https://news-oceanacidification-icc.org/

Thanks a lot for your attention !