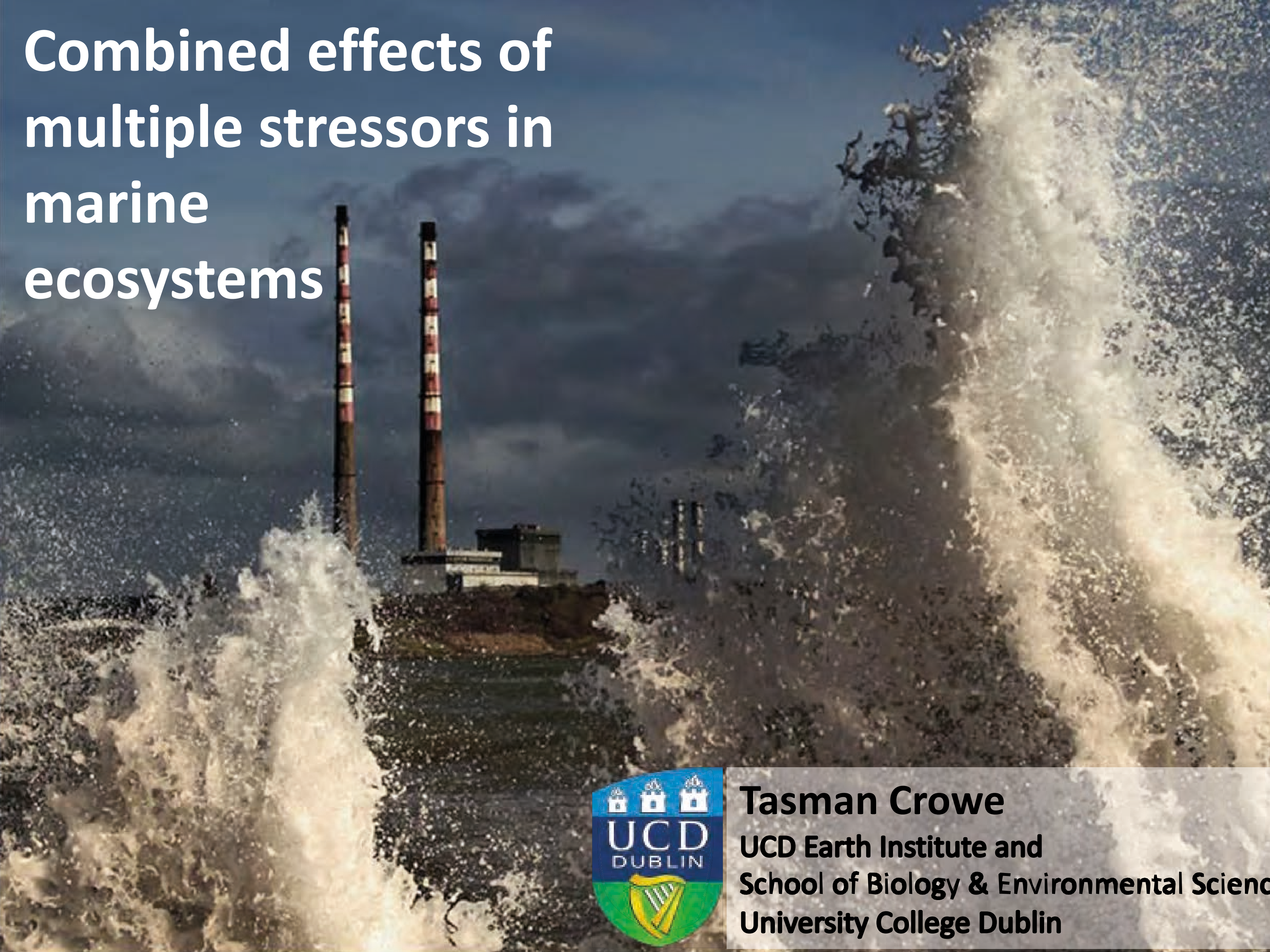
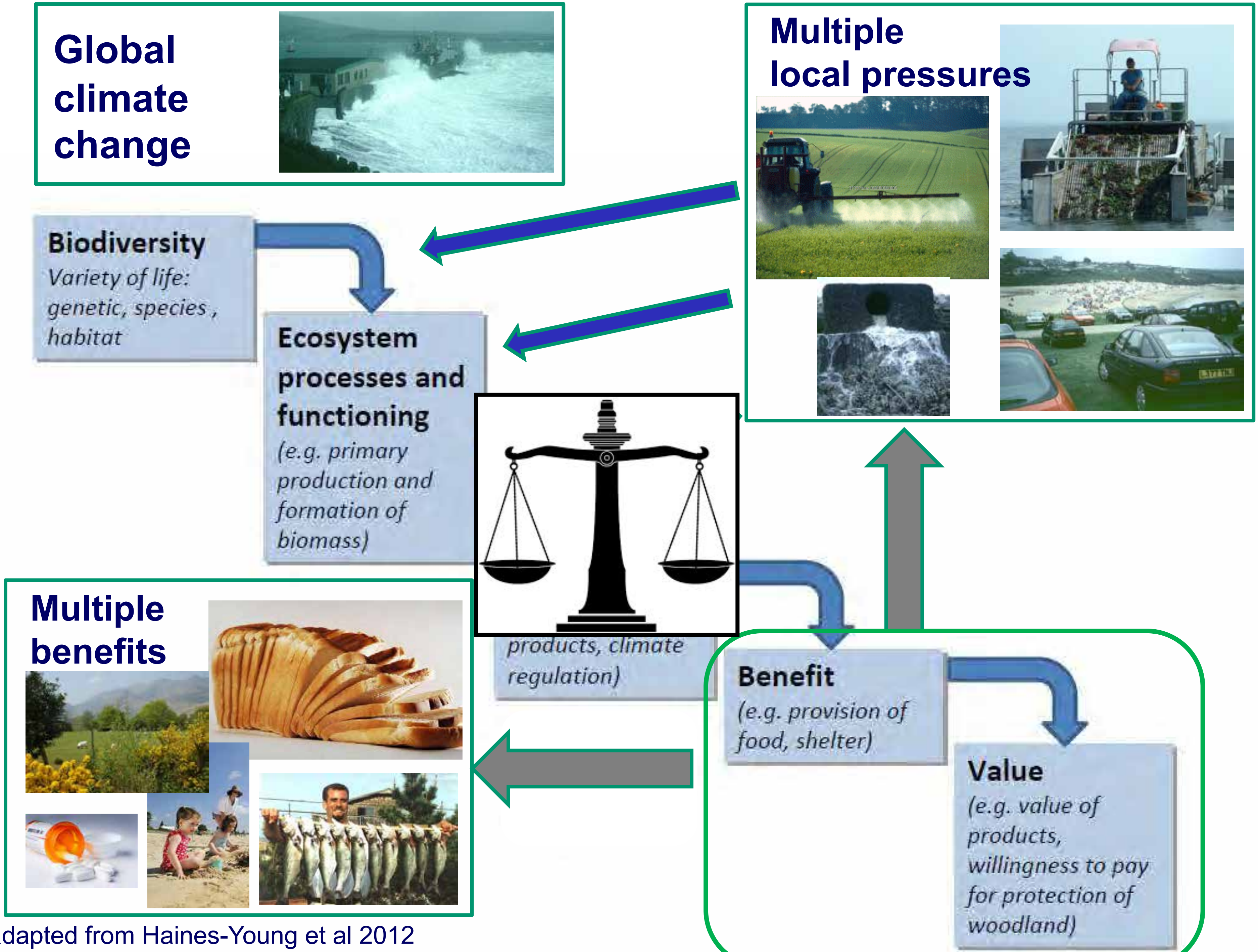
Combined effects of multiple stressors in marine ecosystems



Tasman Crowe
UCD Earth Institute and
School of Biology & Environmental Scienc
University College Dublin



adapted from Haines-Young et al 2012

EUROPEAN COMMISSION

PRESS RELEASE

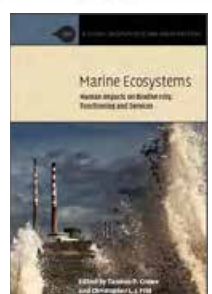
Brussels, 17 October 2013

Environment: Commission takes Bulgaria to Court for failing to protect endangered species

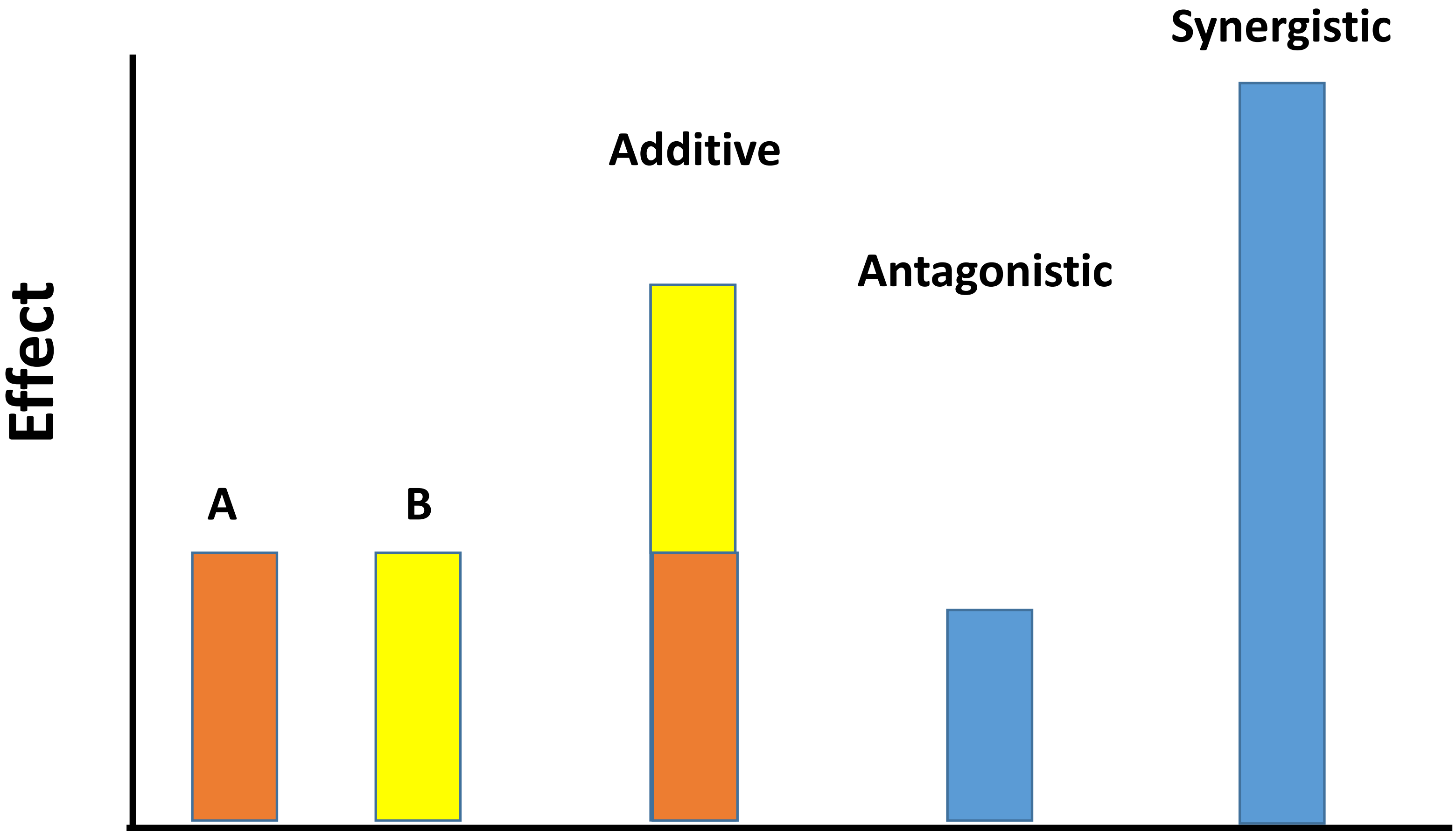
Bulgaria has authorised a high number of economic activities in the area without appropriate environmental impact assessment. Thousands of wind turbines and some 500 other projects have been authorised without adequate assessments of their effect on Kaliakra's unique habitats and species, and on the thousands of birds and bats that fly over the site each year on their way to and from Africa. Up to 100 % of the global population of the world's most endangered goose species – the red breasted goose - spends the winter in a small number of sites in and around Kaliakra. No account is being taken of the cumulative effect of the authorised projects, which is also a requirement under the Birds, Habitats and Environmental Impact Assessment Directives.

	Sector/Pressure	Fisheries		Aquaculture		Sewage discharge	Agricultural discharge	Industrial discharge	Construction/ development	Shipping	Leisure and tourism	Energy
		Active	Passive	Fin	Shellfish							
P	Habitat loss (to land)						■		■		■	
P	Habitat change (to another marine habitat)	■		■	■	■		■	■			
P	Physical disturbance	■	■	■	■	■			■	■	■	■
P	Siltation rate changes	■	■	■	■	■	■	■	■			■
P	Temperature change					■		■				■
P	Salinity change					■		■				■
P	Water flow			■	■			■	■	■		■
P	Emergence regime											
P	Wave exposure changes-local			■	■				■	■	■	
P	Litter	■	■	■	■	■		■	■	■	■	
C	Non-synthetic compounds	■		■	■	■		■	■	■		■
C	Synthetic compounds	■		■		■	■	■	■	■	■	■
C	De-oxygenation			■	■	■	■	■				
C	Inorganic nutrients			■	■	■	■	■				
C	Organic enrichment			■	■	■	■	■				
B	Introduction of microbial pathogens			■	■	■	■			■	■	
B	Introduction/spread of non-indigenous species			■	■					■		■
B	Removal of target and non-target species	■	■		■				■		■	■

□ - no association between sector and pressure ■ - potential association between sector and pressure



from Crowe and Frid 2015, adapted from Robinson et al 2008


Synergistic
Additive
Antagonistic
Effect
A
B

Ecology Letters, (2008) 11: 1304–1315 doi: 10.1111/j.1461-0248.2008.01253.x

LETTER

Interactive and cumulative effects of multiple human stressors in marine systems

Caitlin Mullan Crain,[1,*] Kristy Kroeker[2] and Benjamin S. Halpern[3]

Abstract
Humans impact natural systems
multiple stressors on ecologic
synthesized 171 studies that ma

Global Change Biology (2014) 20, 3300–3312, doi: 10.1111/gcb.12619

RESEARCH REVIEW

Identifying the interacting roles of stressors in driving the global loss of canopy-forming to mat-forming algae in marine ecosystems

ELISABETH M. A. STRAIN[1,2], RUSSELL J. THOMSON[2], FIORENZA MICHELI[3], FRANCESCO P. MANCUSO[1] and LAURA AIROLDI[1]

Global Change Biology (2009) 15, 2153–2162, doi: 10.1111/j.1365-2486.2009.01886.x

Synergistic effects of climate change and local stressors: CO_2 and nutrient-driven change in subtidal rocky habitats

BAYDEN D. RUSSELL, JO-ANNE I. THOMPSON, LAURA J. FALKENBERG and SEAN D. CONNELL

Ecology, 93(3), 2012, pp. 441–448

Multiple anthropogenic stressors and the structural properties of food webs

EOIN J. O'GORMAN,[1,2,3] JAYNE E. FITCH,[1] AND TASMAN P. CROWE[1]

Journal of Applied Ecology 2013, **50**, 51–58 doi: 10.1111/1365-2664.12019

Disrupting the effects of synergies between stressors: improved water quality dampens the effects of future CO_2 on a marine habitat

Laura J. Falkenberg[1], Sean D. Connell[1*] and Bayden D. Russell[1]

Contents lists available at ScienceDirect
Marine Pollution Bulletin
journal homepage: www.elsevier.com/locate/marpolbul

Impacts of multiple stressors during the establishment of fouling assemblages

Silvia Saloni *, Tasman P. Crowe
School of Biology and Environmental Science, Science Centre West, University College of Dublin, Belfield, Dublin 4, Ireland

	Hl	Hc	Pd	Sr	Tc	Sa	Wf	Er	We	Li	Nc	Sc	Do	Ne	Oe	Pa	In	Rs
Habitat loss (to land) (Hl)	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
Habitat change (to another marine habitat) (Hc)	X	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
Physical disturbance (Pd)	X	X	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
Siltation rate changes (Sr)	X	X	X	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
Temperature change (Tc)	X	↑	↑	X	_	_	_	_	_	_	_	_	_	_	_	_	_	_
Salinity change (Sa)	X	X	X	X	↑	_	_	_	_	_	_	_	_	_	_	_	_	_
Water flow (Wf)	X	X	X	X	X	X	_	_	_	_	_	_	_	_	_	_	_	_
Emergence regime (Er)	X	X	X	X	X	↕	X	_	_	_	_	_	_	_	_	_	_	_
Wave exposure changes-local (We)	X	X	X	X	X	X	X	X	_	_	_	_	_	_	_	_	_	_
Litter (Li)	X	X	X	X	X	X	X	X	X	_	_	_	_	_	_	_	_	_
Non-synthetic compounds (Nc)	↑	↑	↑	X	↕	↓	X	X	X	X	_	_	_	_	_	_	_	_
Synthetic compounds (Sc)	X	X	X	X	↕	↓	X	X	X	X	X	_	_	_	_	_	_	_
De-oxygenation (Do)	↑	↑	↑	X	X	X	X	X	X	X	X	X	_	_	_	_	_	_
Inorganic nutrient enrichment (Ne)	↕	X	X	↑	+	+	X	↑	X	X	↓	↓	X	_	_	_	_	_
Organic enrichment (Oe)	X	X	X	X	X	X	X	X	X	X	X	X	↑	↕	_	_	_	_
Introduction of microbial pathogens (Pa)	X	+	+	X	X	↑	X	X	X	X	↕	X	X	X	X	_	_	_
Introduction/spread of non-indigenous species (In)	X	X	X	↕	X	X	X	X	X	X	X	X	X	X	X	X	_	_
Removal of target and non-target species (Rs)	X	X	X	X	X	X	X	X	X	X	X	X	X	↕	X	X	X	_

(+) additive; (↑) synergistic; (↓) antagonistic; (↕) complex; (x) insufficient evidence (--) not applicable.

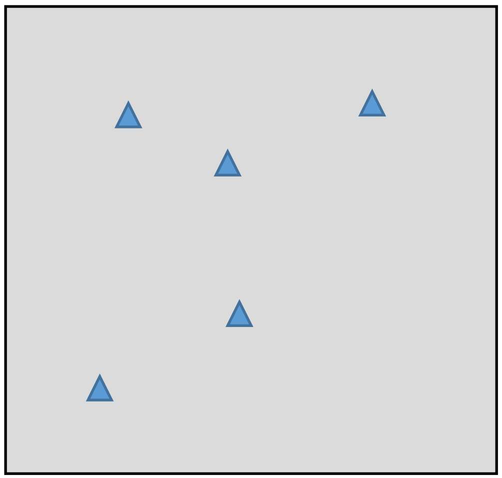
from Crowe, Fitch et al. 2011

Modifiers of effects

1. Characteristics of biota & receiving environment
2. Stressor regimes
   - intensity, frequency, timing, etc.

1. Receiving environment

e.g. different effects of copper and freshwater in establishing and mature fouling assemblages



Effect of copper, not freshwater

Weak interactive effects

No effect on functioning

Saloni and Crowe 2015

Effect of copper after 3 months

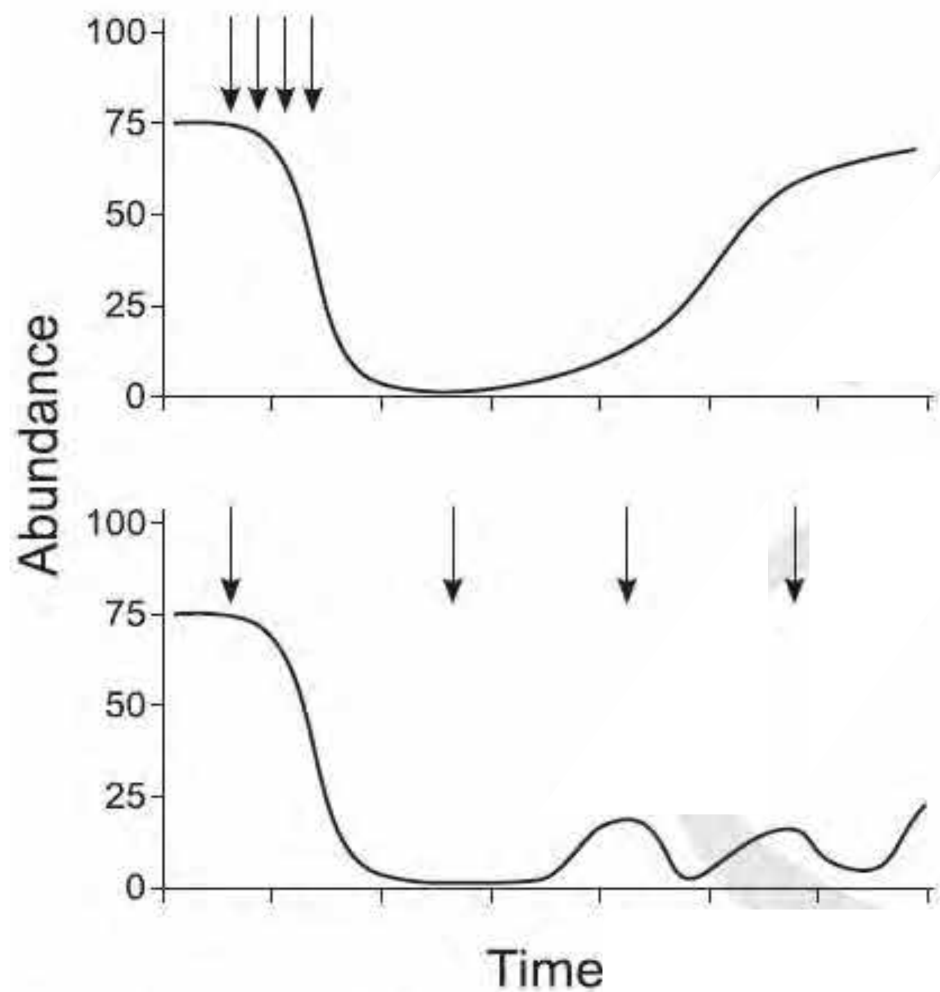
No interactive effects

Functioning affected

Kinsella and Crowe 2016

2. Stressor regimes

- Effects of stressors modified by variation in
  - Intensity
  - Extent
  - Frequency
  - Duration
  - Timing
  - Temporal pattern

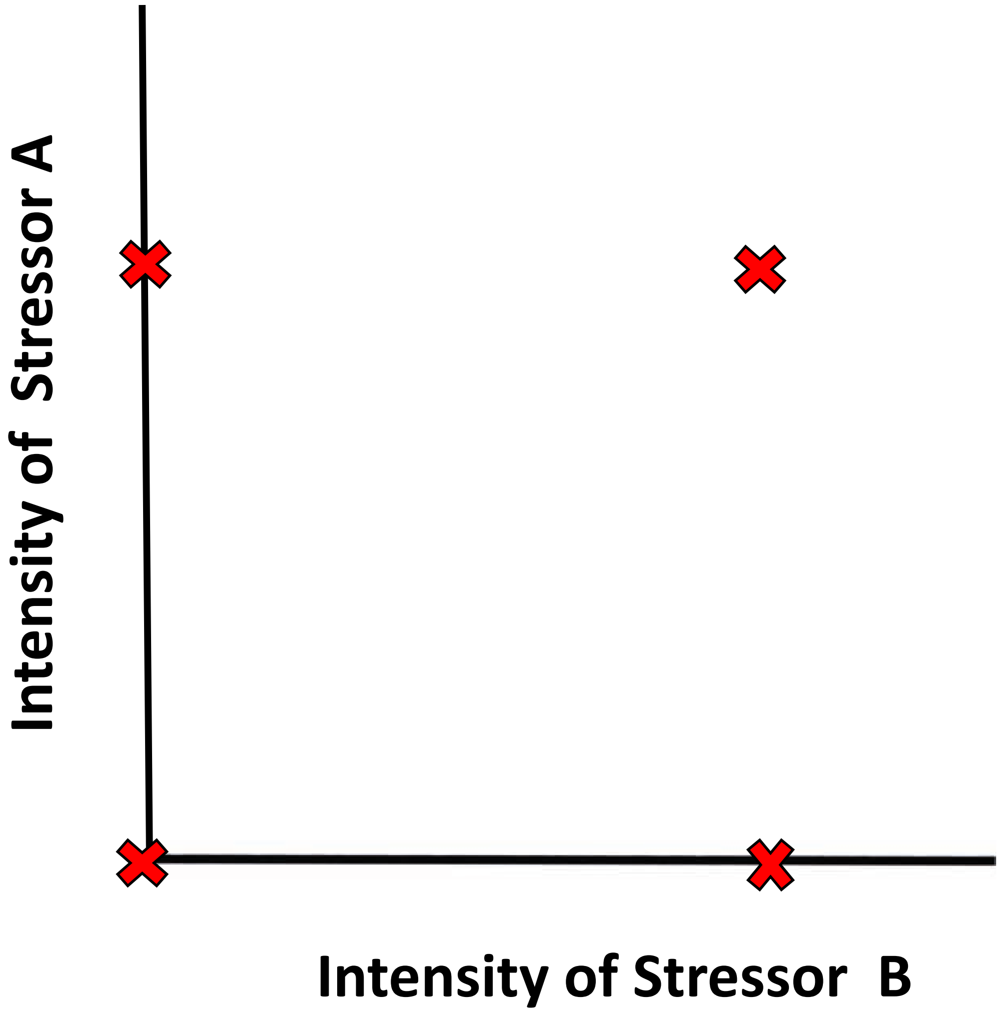


from Lyons, Benedetti-Cecchi, et al. 2015

2a. Variation in intensity

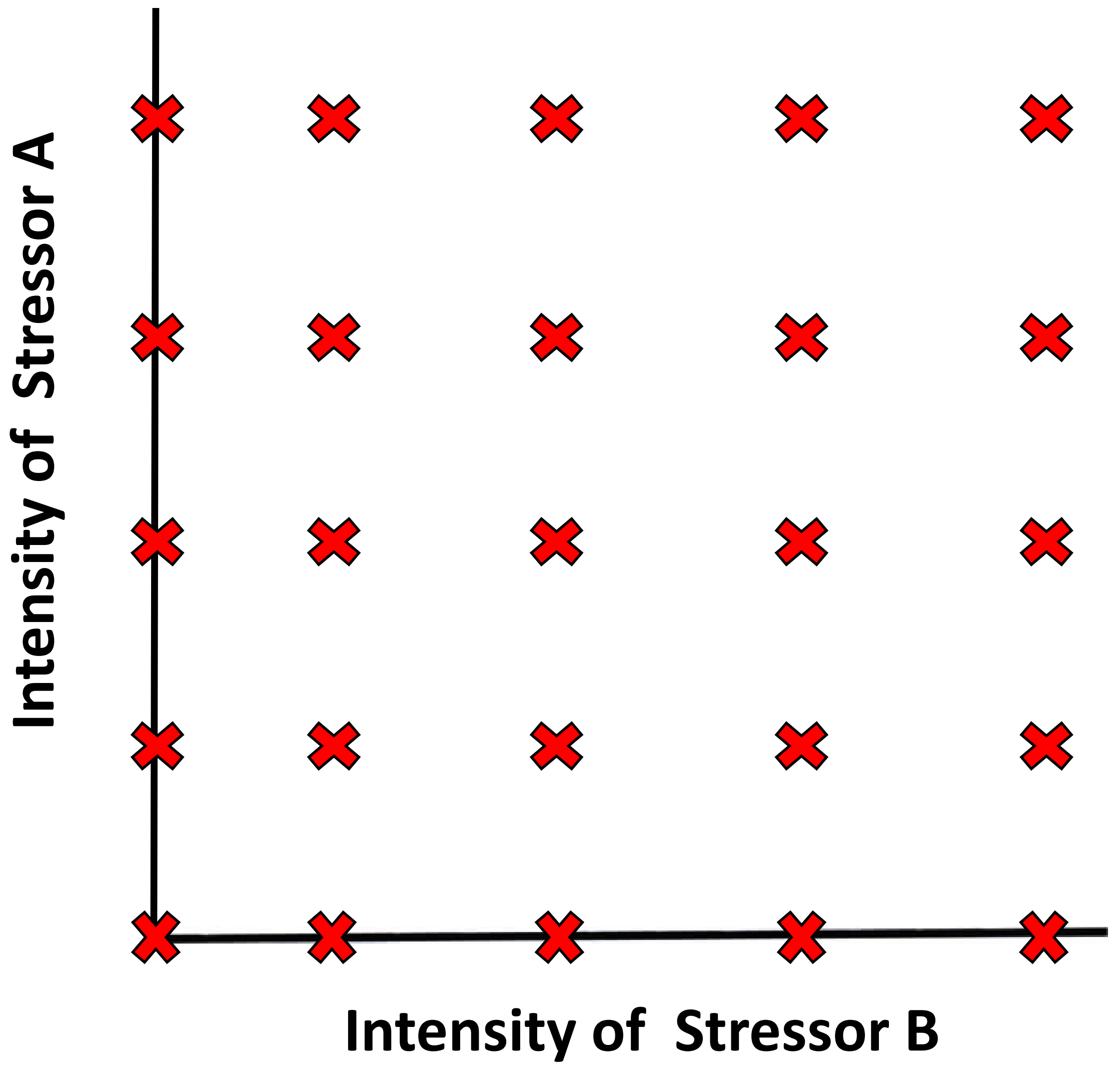
Brooks, Browne, Benedetti-Cecchi, Lyons and Crowe, in prep

Previous work – binary designs



Adapted from Inouye 2001

Response-surface designs



Adapted from Inouye 2001

Mark Browne

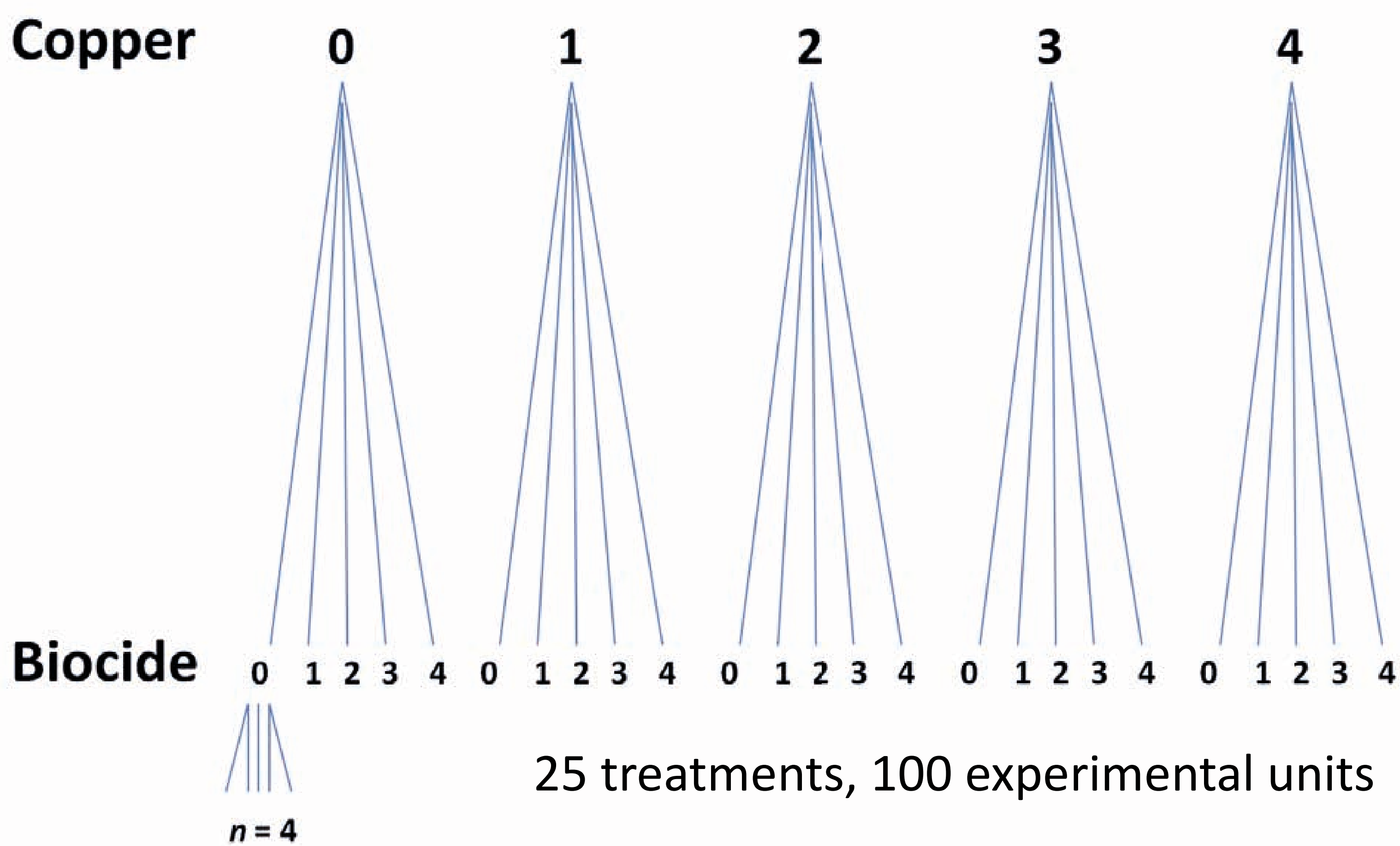
Paul Brooks

Methods in Ecology and Evolution

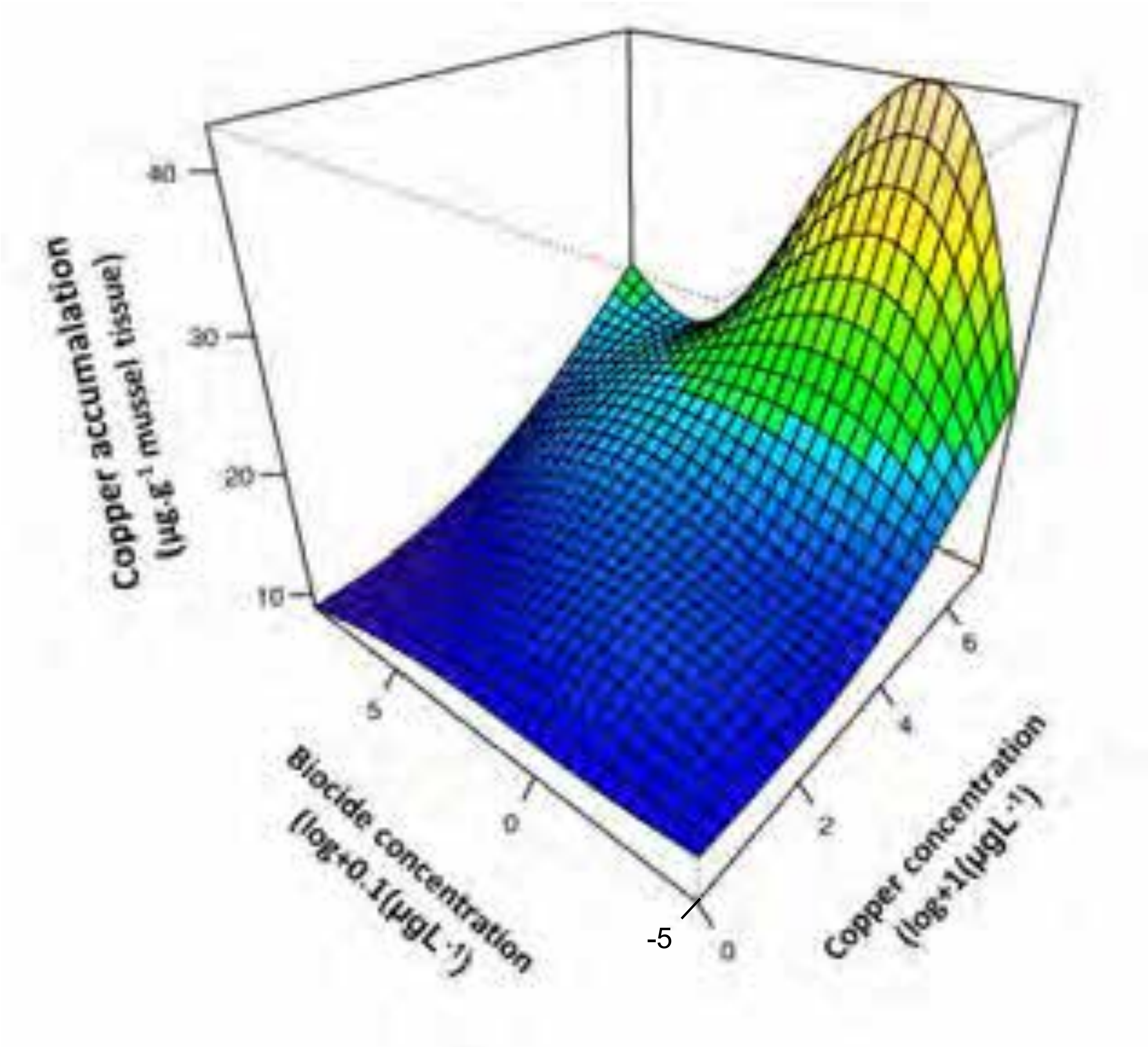
Methods in Ecology and Evolution 2015 doi: 10.1111/2041-210X.12521

Simulating regimes of chemical disturbance and testing impacts in the ecosystem using a novel programmable dosing system

Mark Anthony Browne[1,2,3,4*], Paul R. Brooks[1], Robert Clough[5], Andrew S. Fisher[5], Mariana Mayer Pinto[2,3] and Tasman P. Crowe[1]


Copper
0
1
2
3
4
Biocide
0 1 2 3 4 0 1 2 3 4 0 1 2 3 4 0 1 2 3 4 0 1 2 3 4
$n = 4$
25 treatments, 100 experimental units

Copper accumulation in tissue



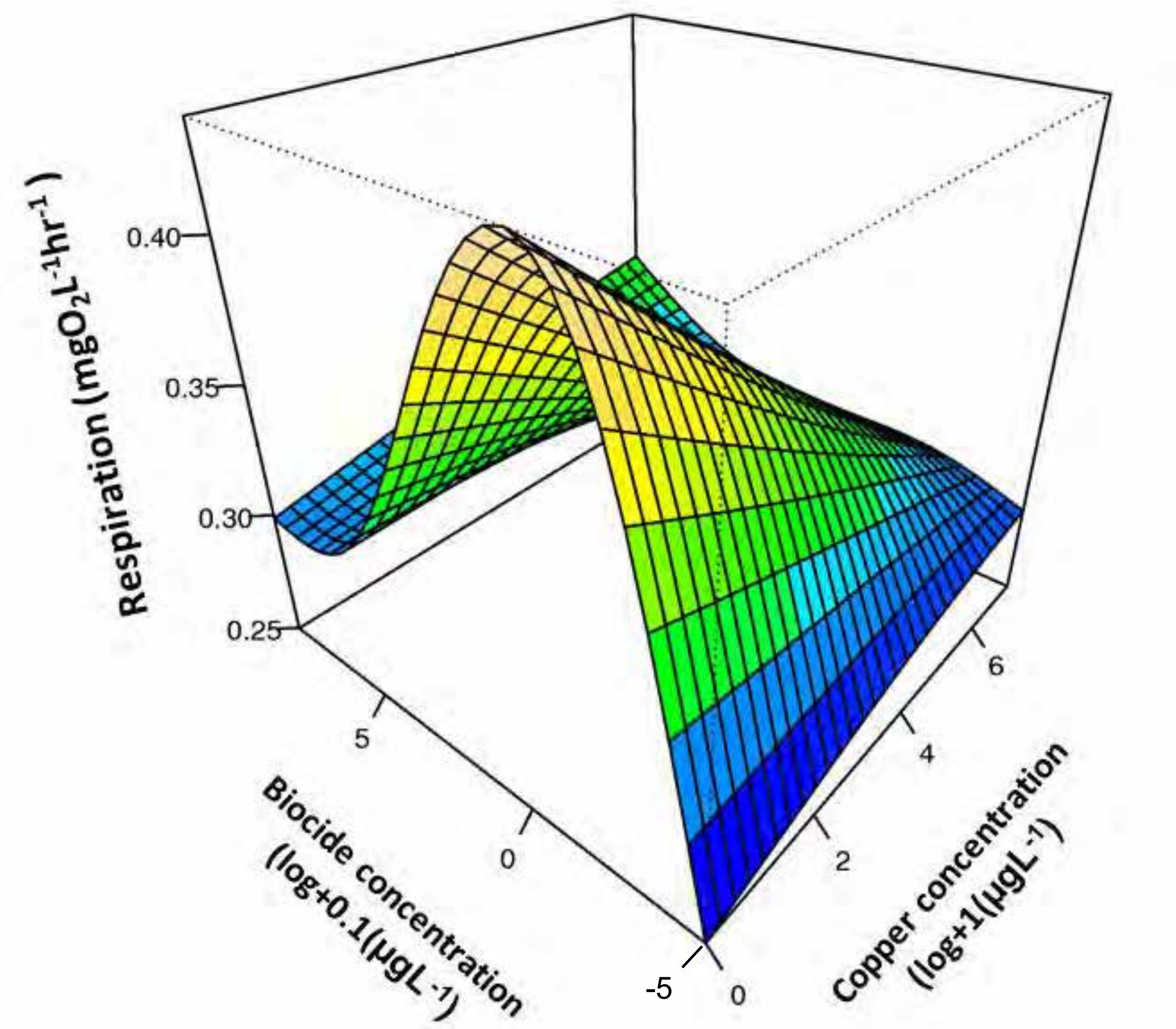
Single stressors

- As expected

Multiple stressors

- Synergistic interaction
- Peak uptake at intermediate conc. of biocide and high conc. of copper

Community respiration

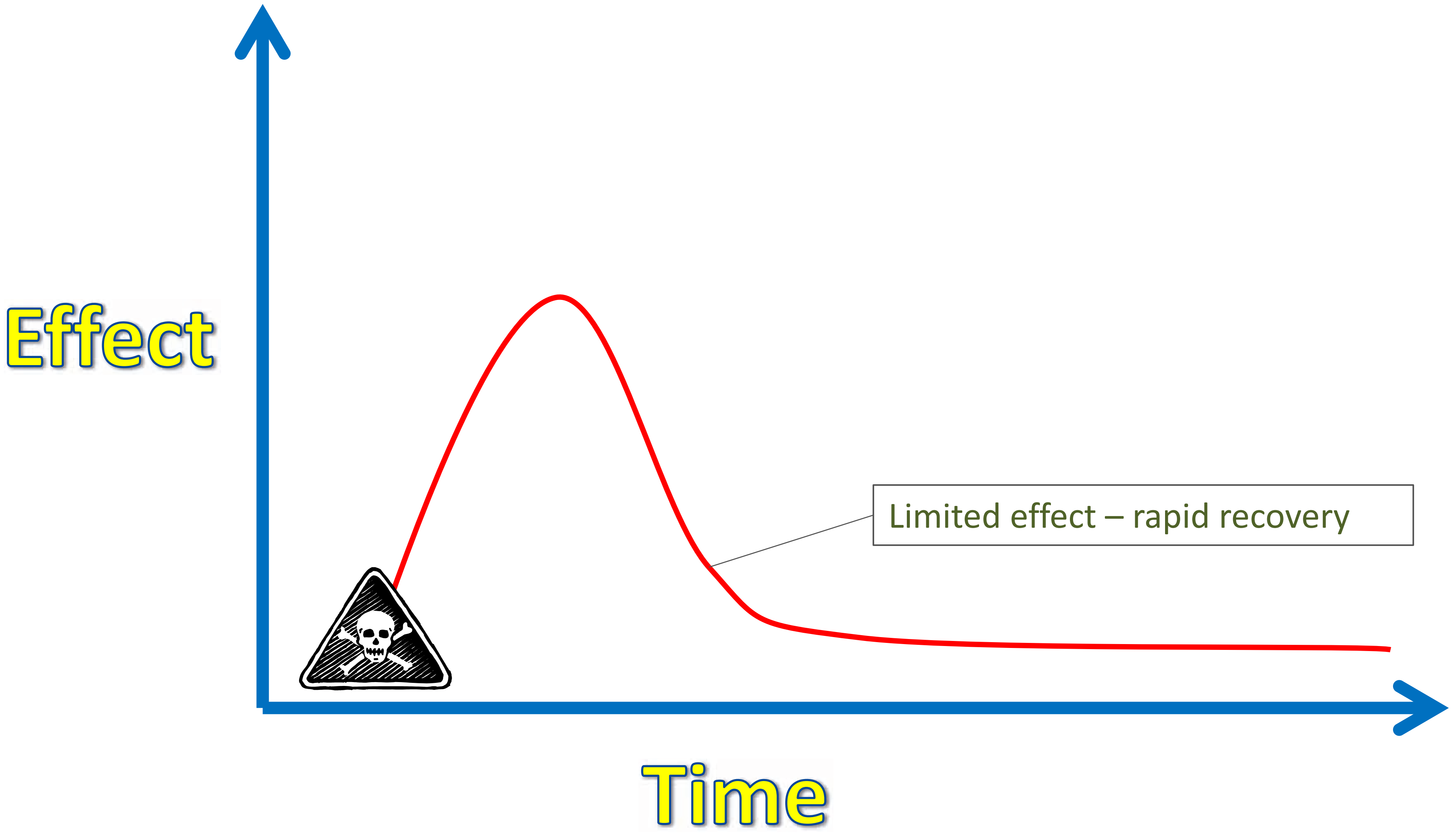


- Single stressors
  - Copper: little effect
  - Biocide: large effect peaks at intermediate conc.
- Multiple stressors
  - Antagonistic interaction – copper reduced effect of biocide

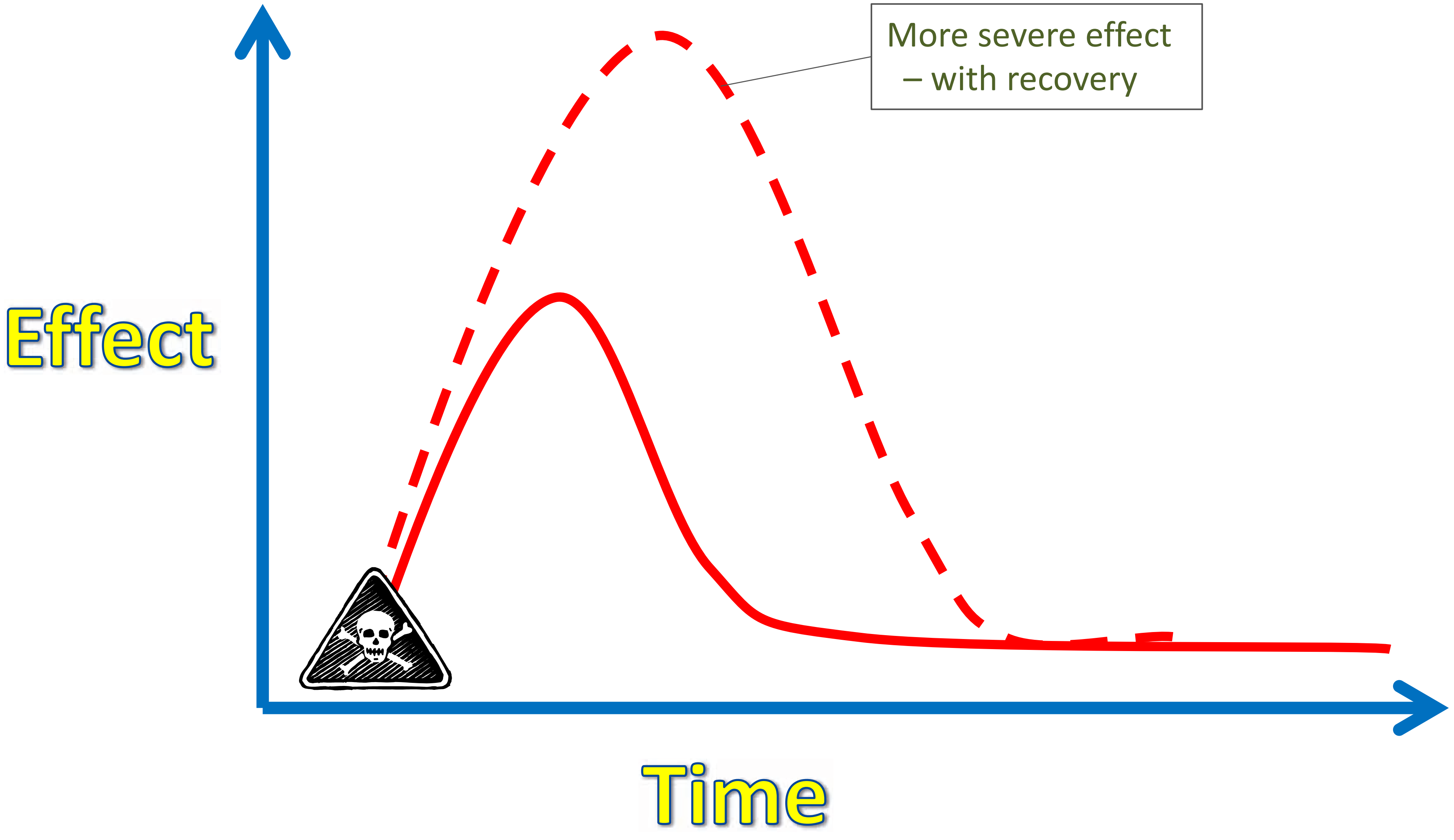
2b. Variation in timing and sequence

Brooks and Crowe, in review

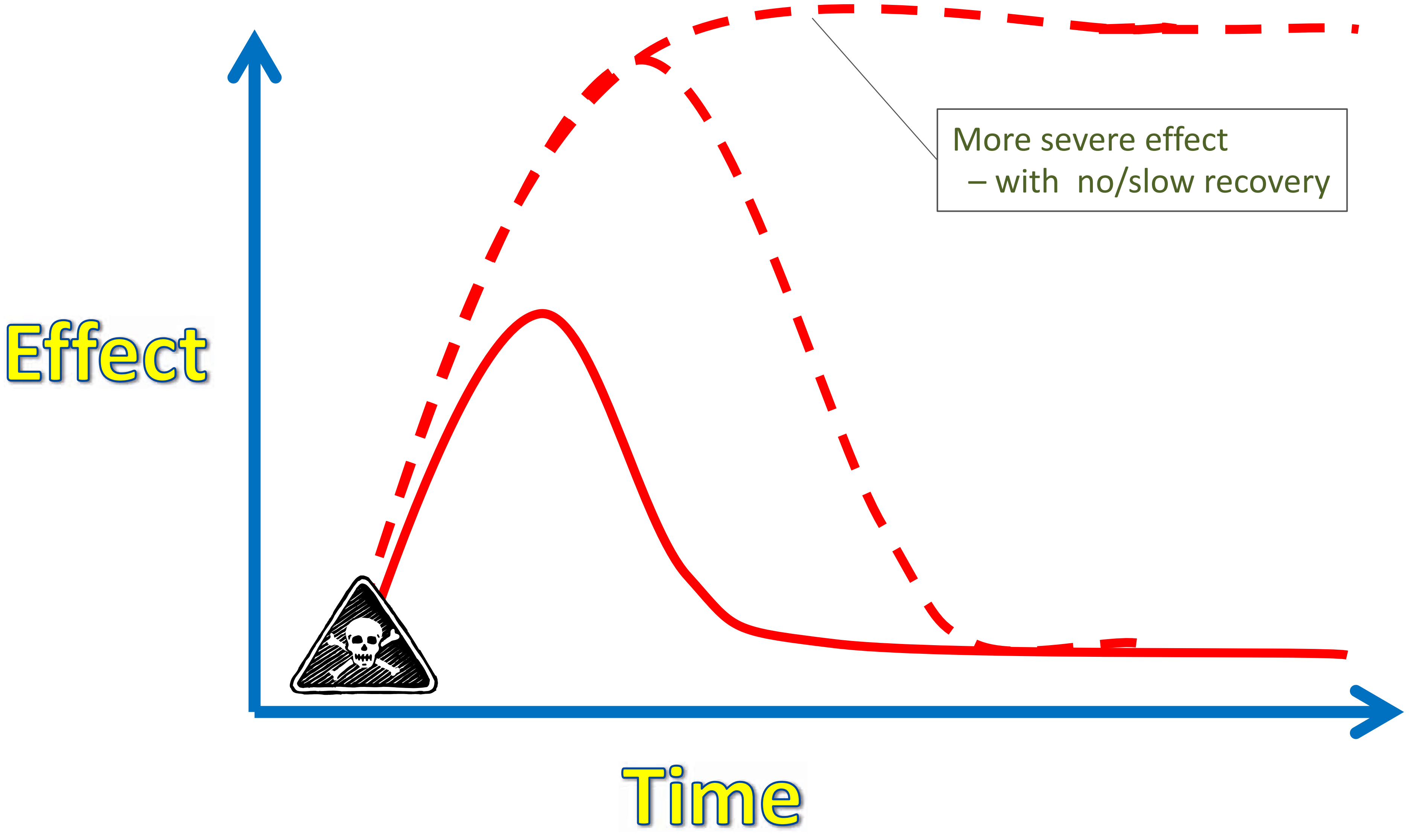
Hypothetical effects of stressors



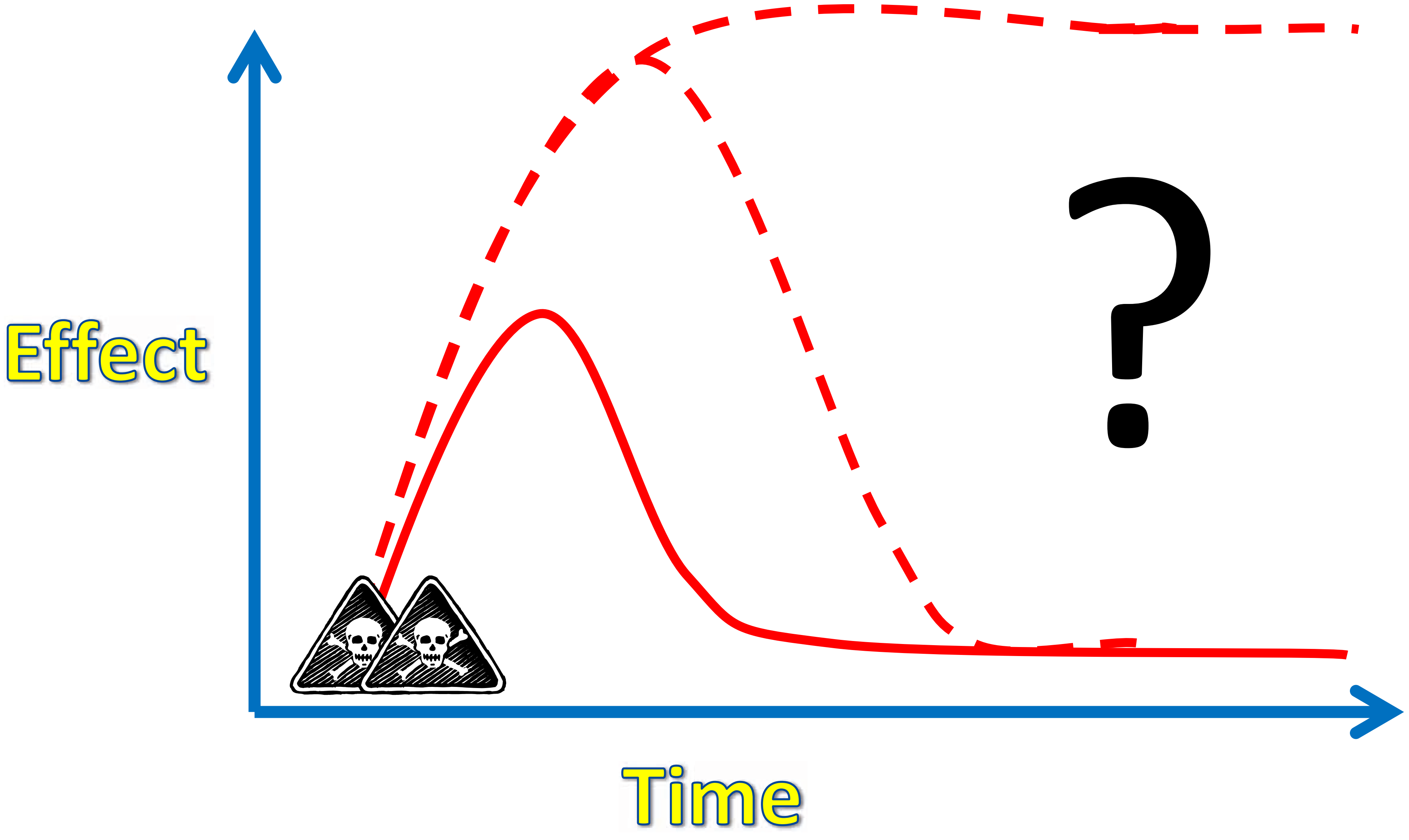
Hypothetical effects of stressors



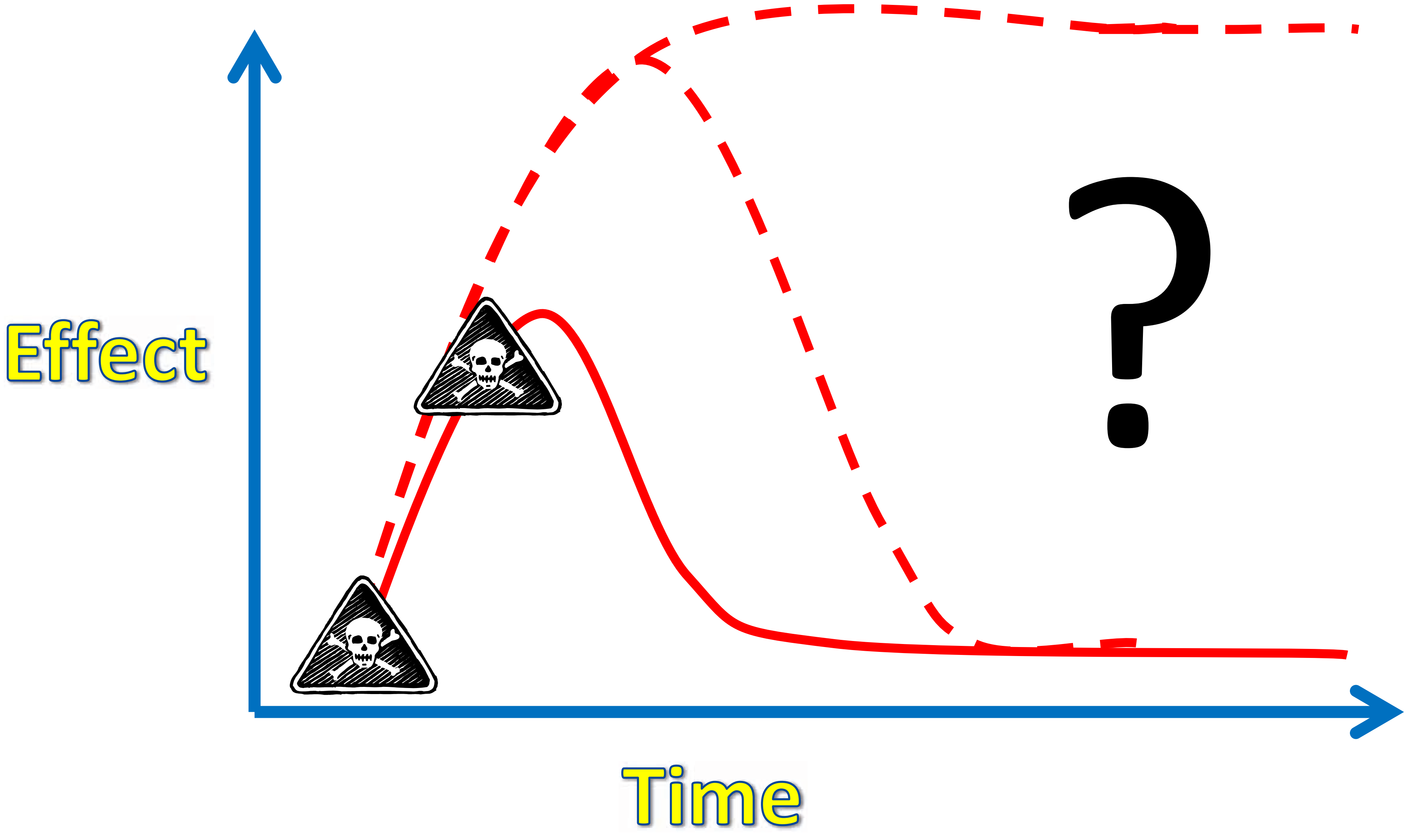
Hypothetical effects of stressors



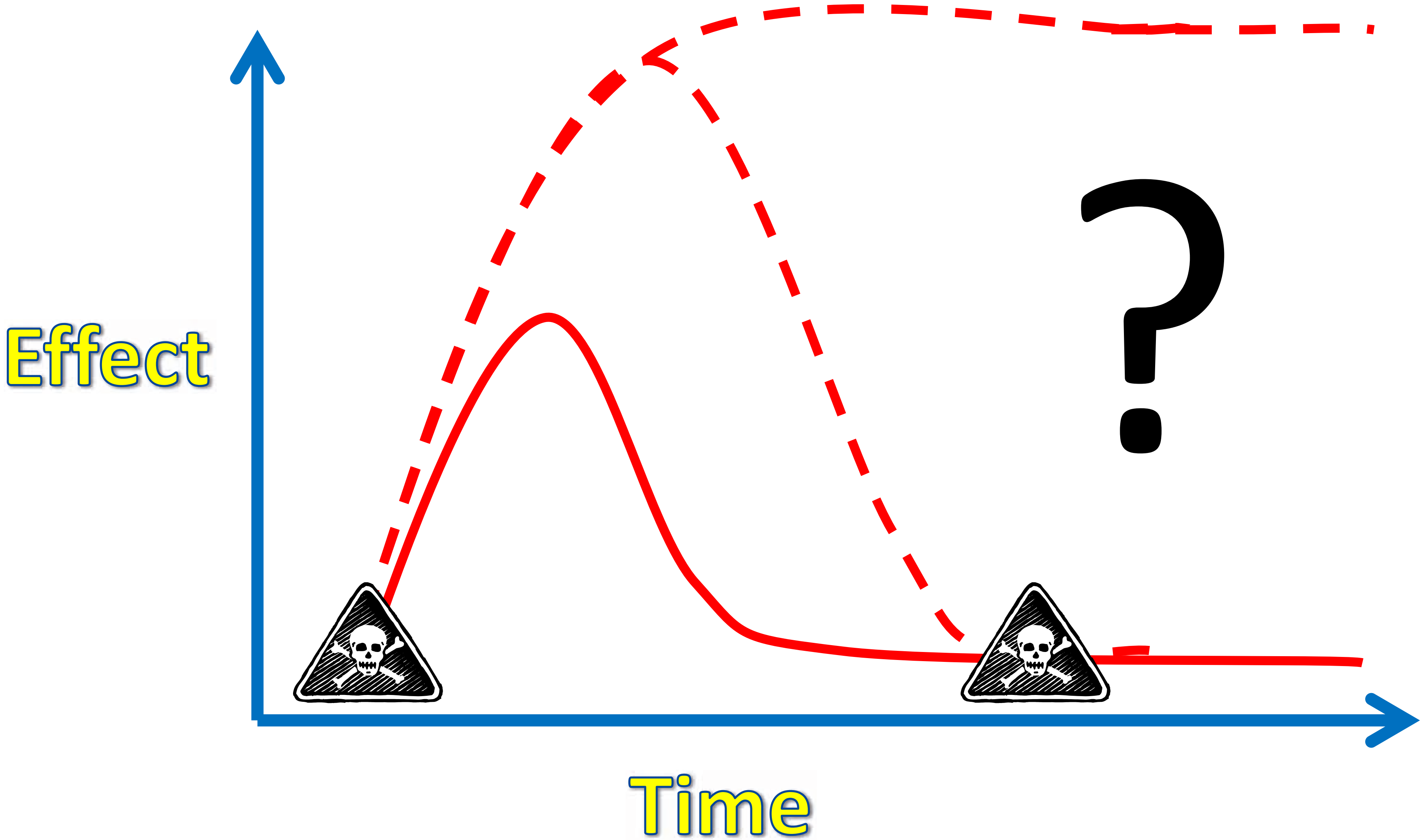
Second stress event – no time lag



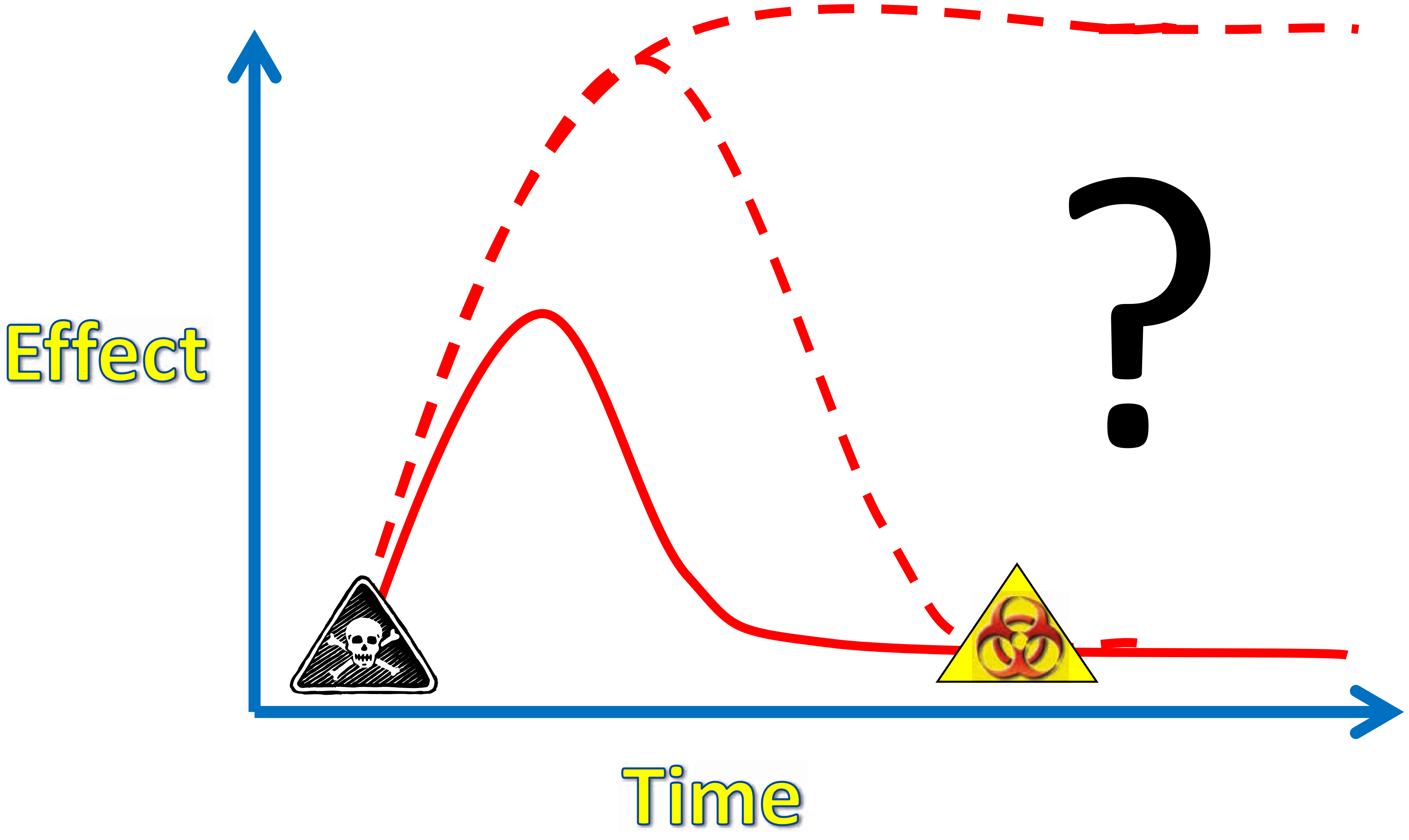
Second stress event – short time lag



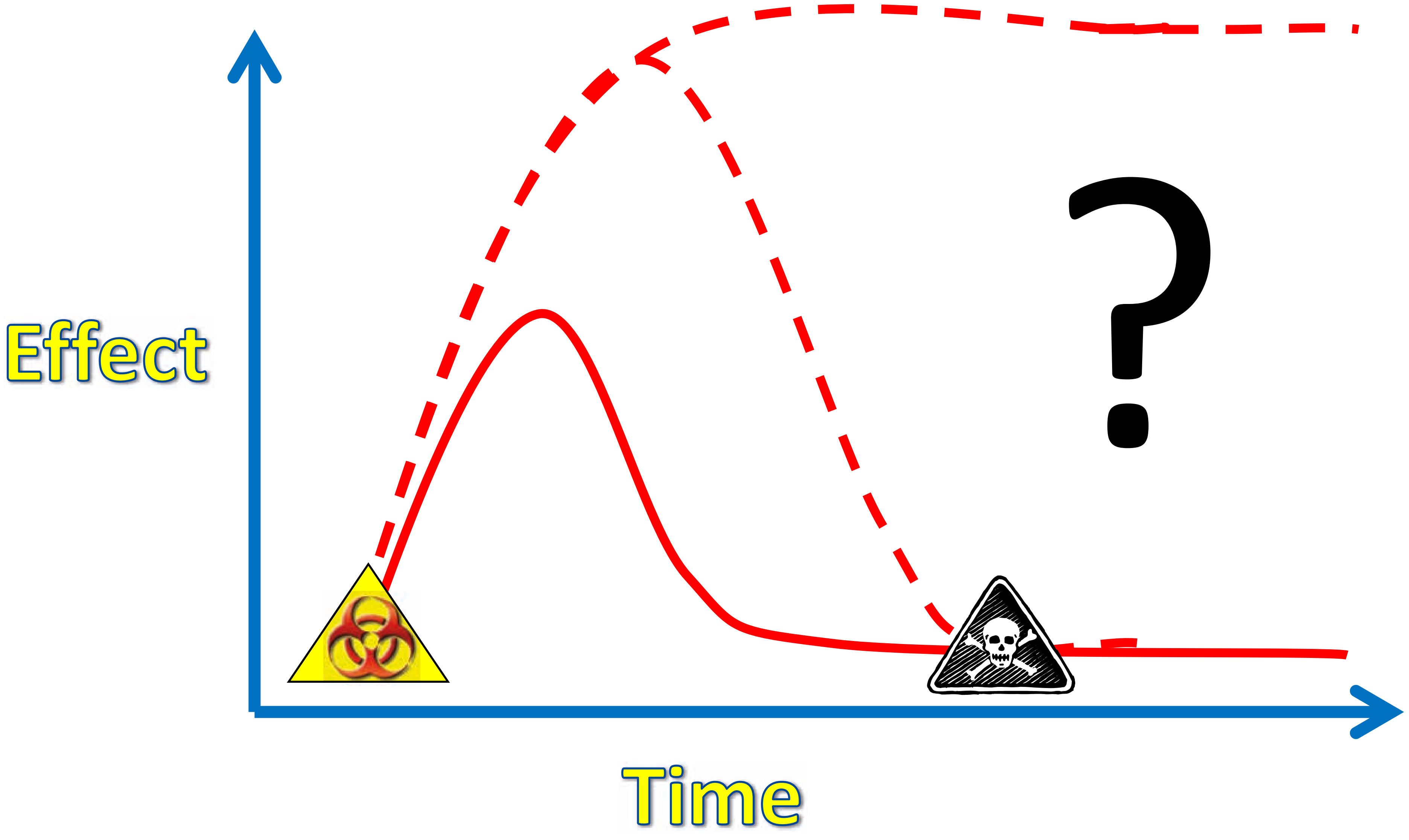
Second stress event – long time lag

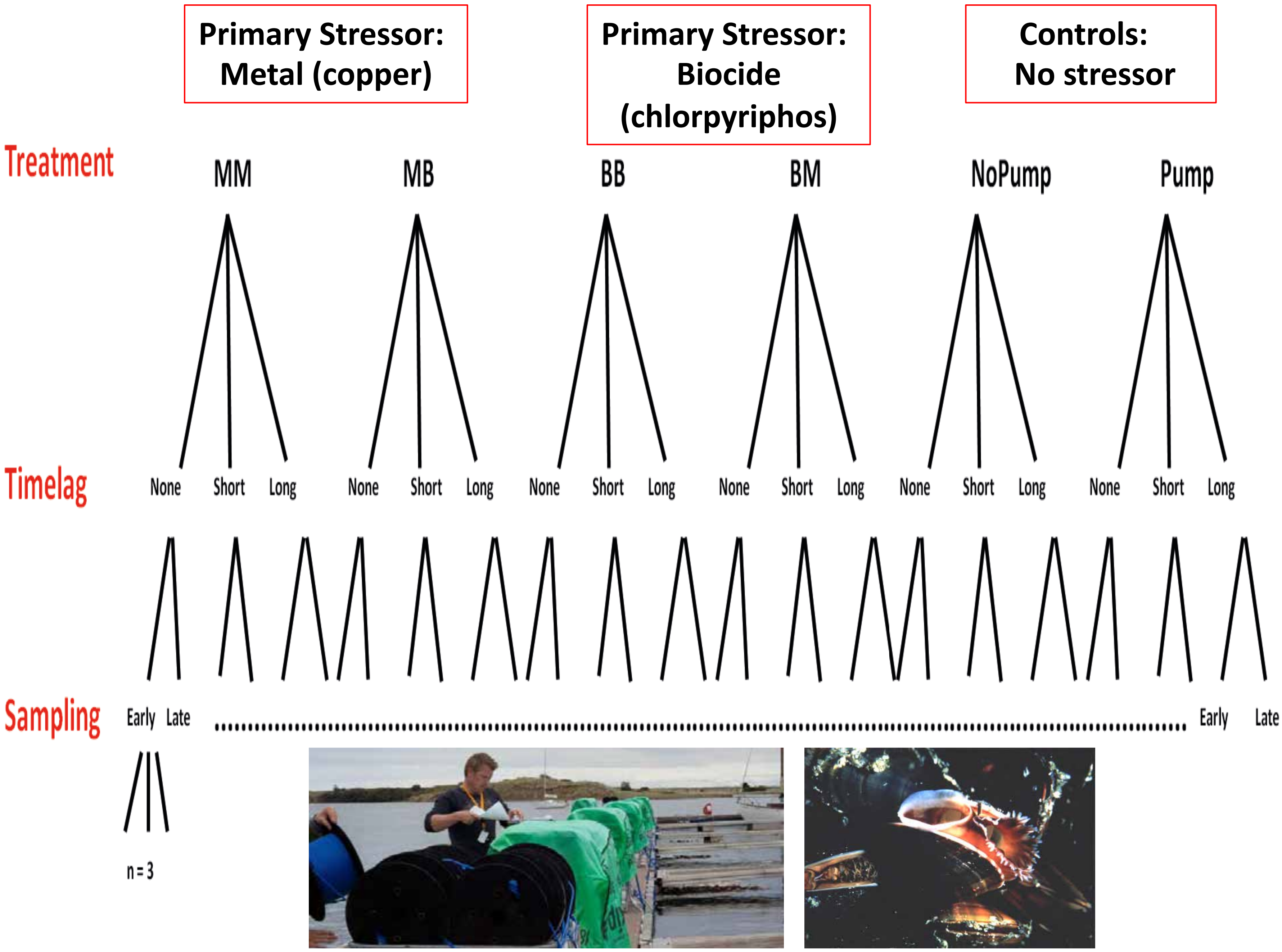


Second stress event – different stressor

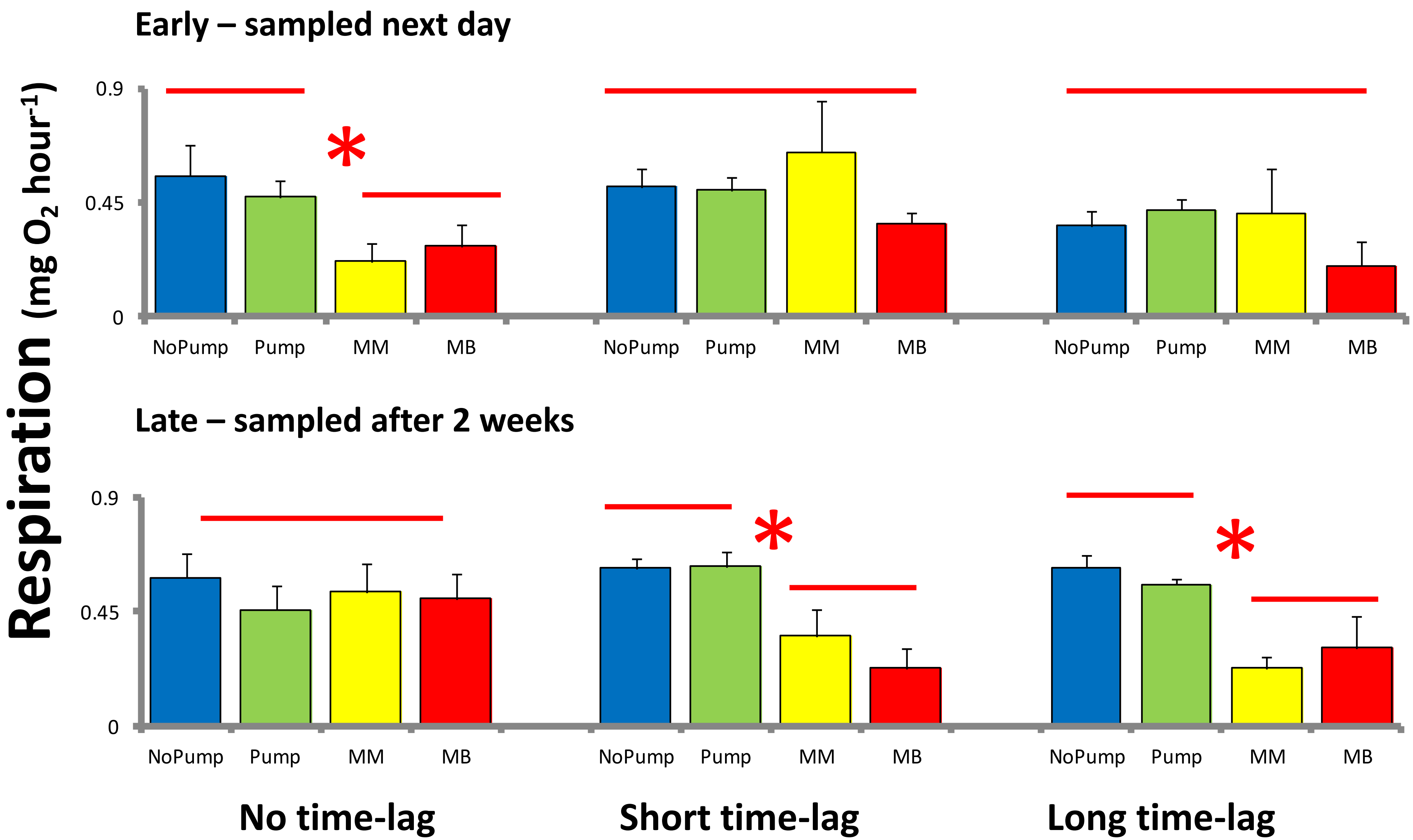


Second stress event – different sequence

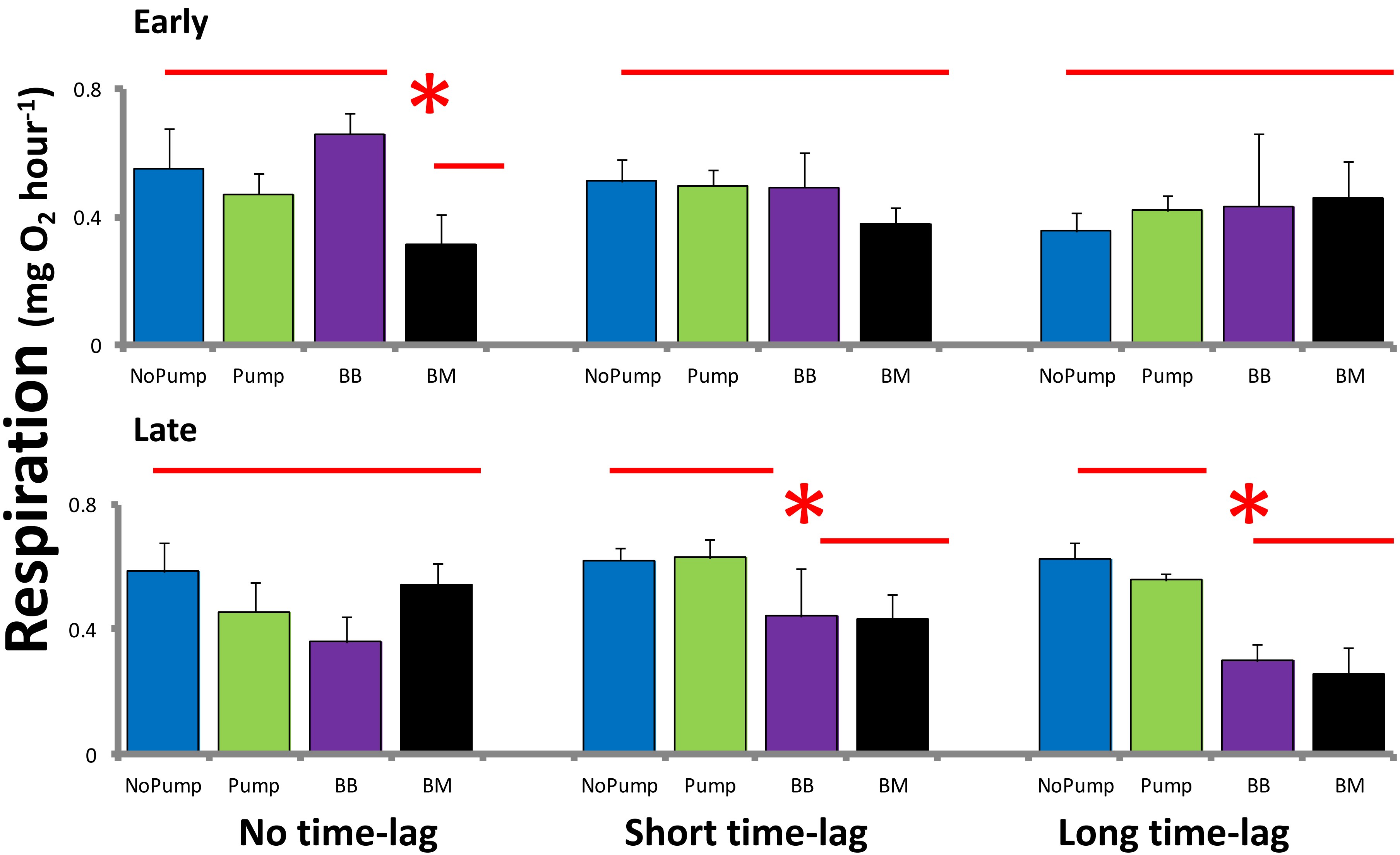



Primary Stressor: Metal (copper)
Primary Stressor: Biocide (chlorpyriphos)
Controls: No stressor
Treatment
MM
MB
BB
BM
NoPump
Pump
Timelag
None Short Long
None Short Long
None Short Long
None Short Long
None Short Long
None Short Long
Sampling
Early Late
Early Late
n = 3

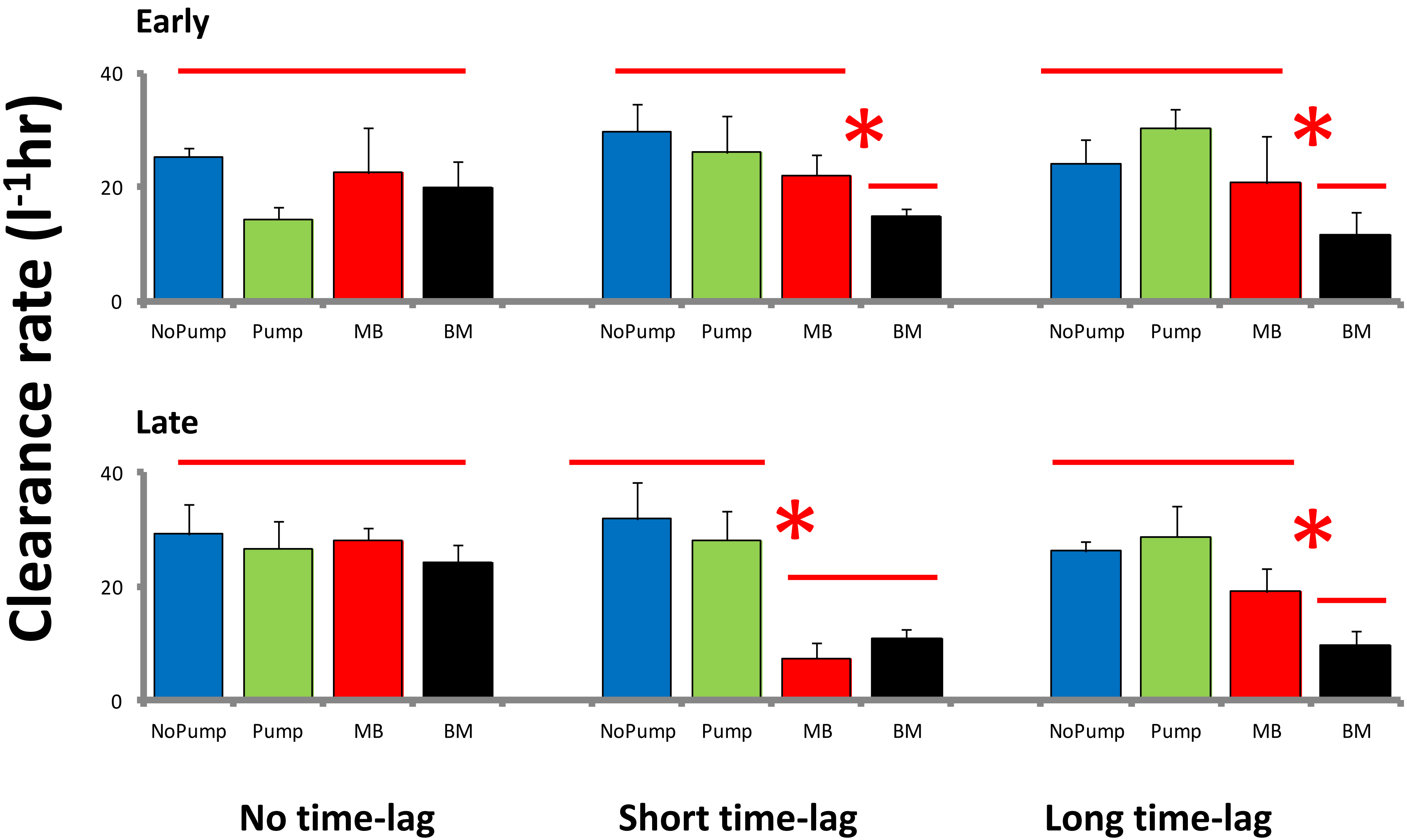
Primary stressor: metal

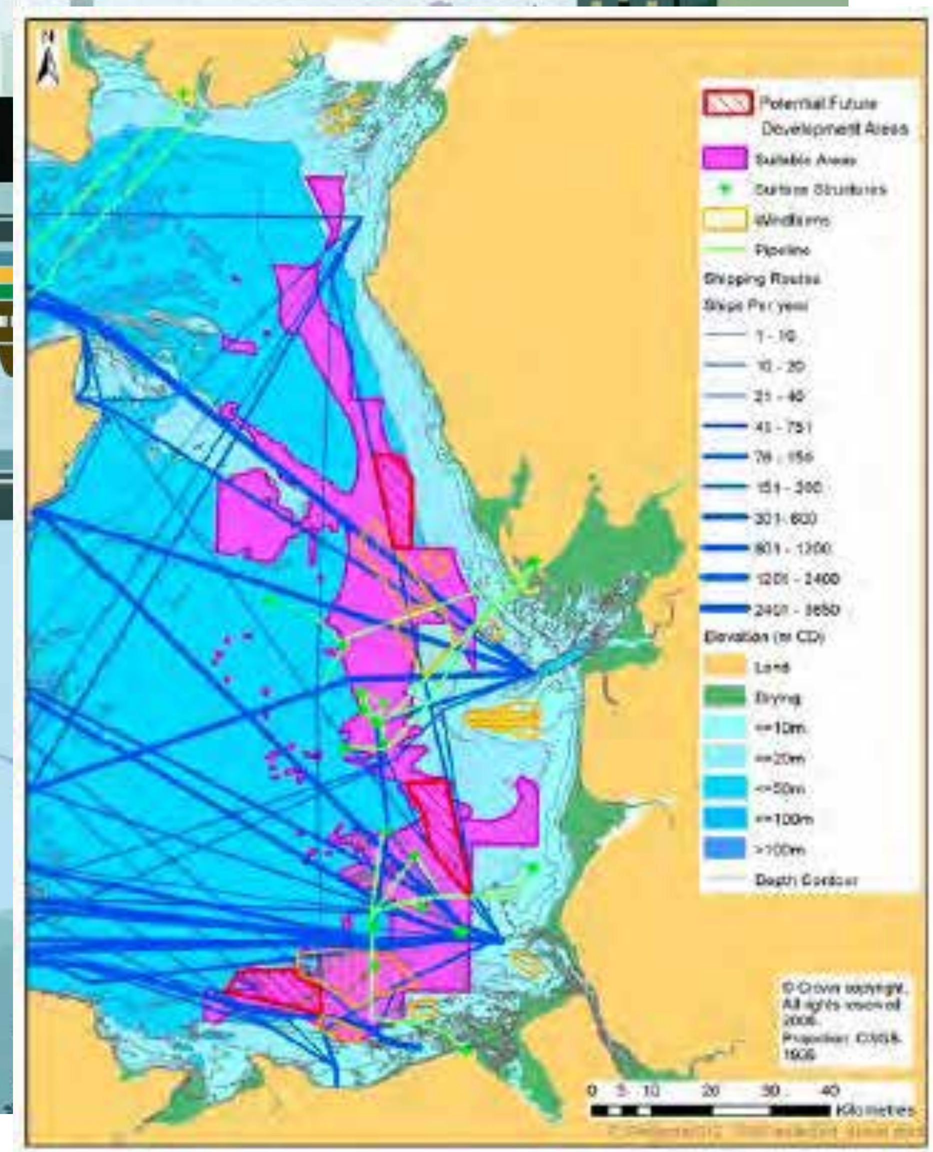


Primary stressor: biocide



Sequential order of stressors




Potential Future Development Areas
Suitable Areas
Pipeline
Shipping Routes
Land
Drying
Depth Contour
0 5 10 20 30 40
Kilometres

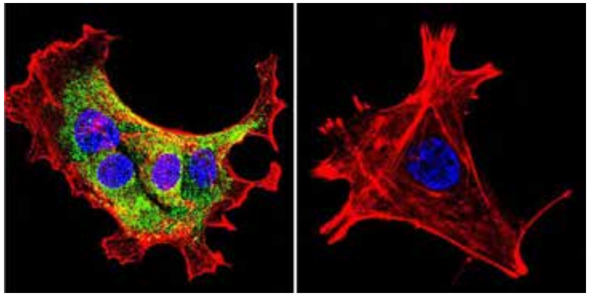
Ways forward

1. Focus on priority combinations of stressors, biota and receiving environments
2. Characterise mechanisms of interaction
3. Explore co-tolerance and other trait-based approaches

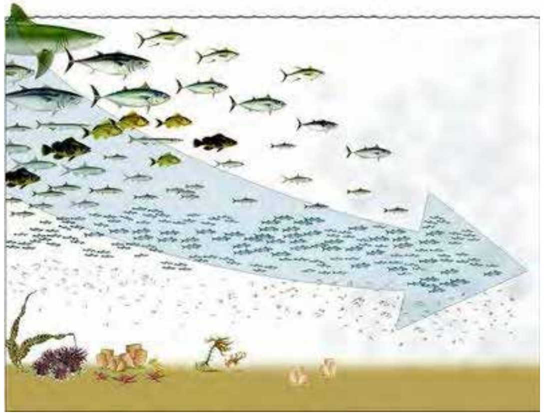
2. Mechanisms of interaction between stressors

Exogenous

Endogenous

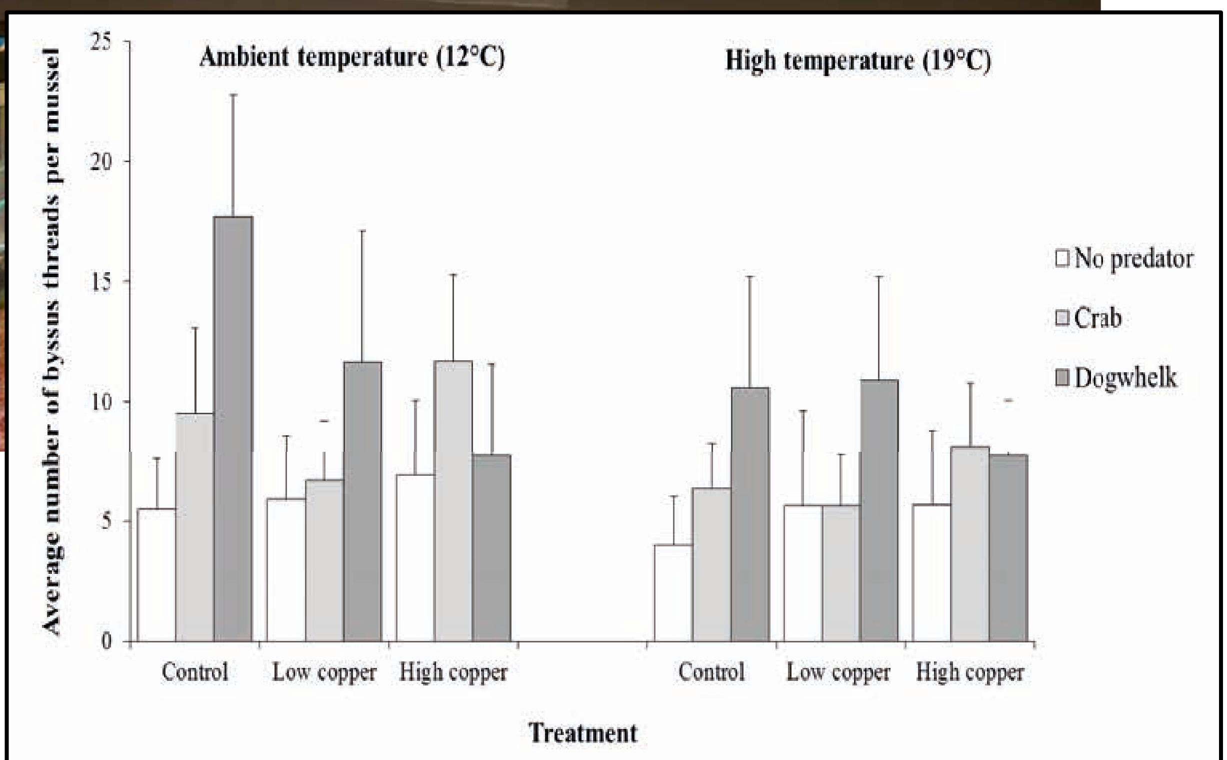


Ecological



from Lyons, Benedetti-Cecchi, et al. 2015

Côté 1995
Davenport et al 1996
Farrell & Crowe 2008

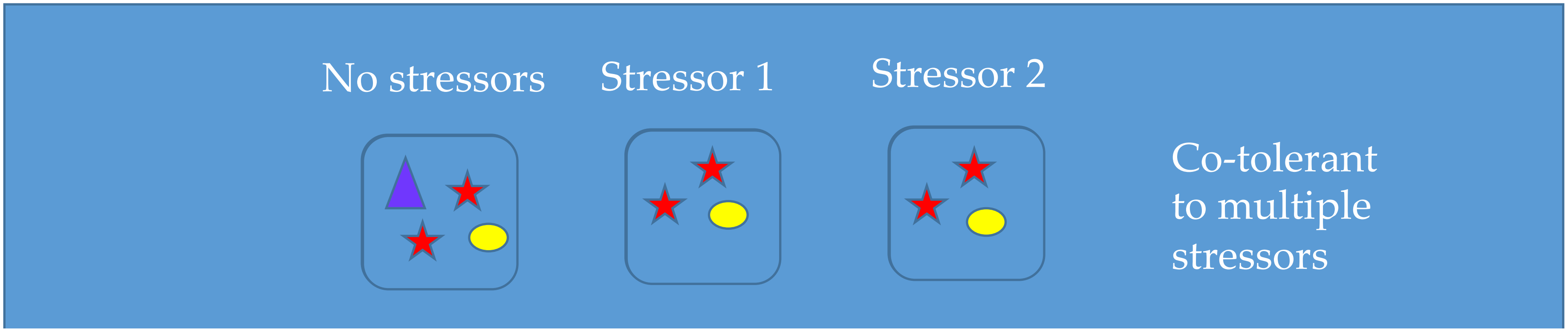


Caroline Kerrigan

Valeria Palmeri

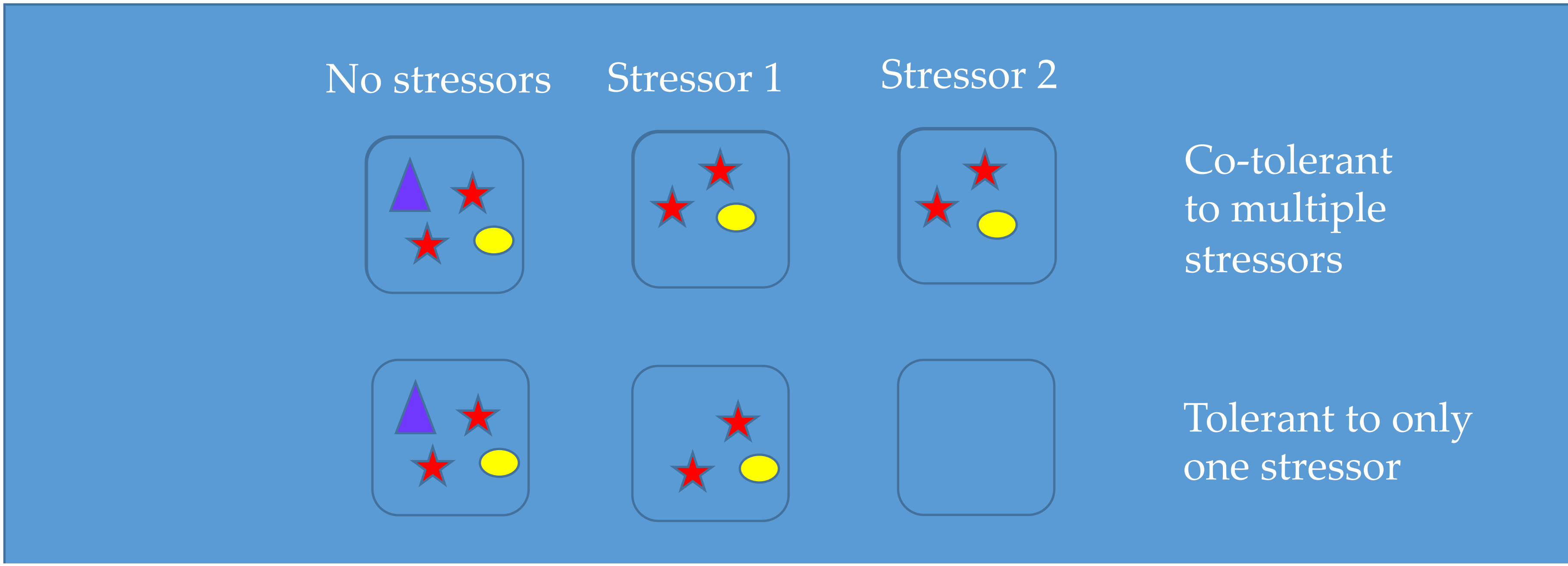
and see Wang et al. 2012

3. Co- tolerance & other trait based approaches



Based on Vinebrook et al. 2004

3. Co- tolerance & other trait based approaches

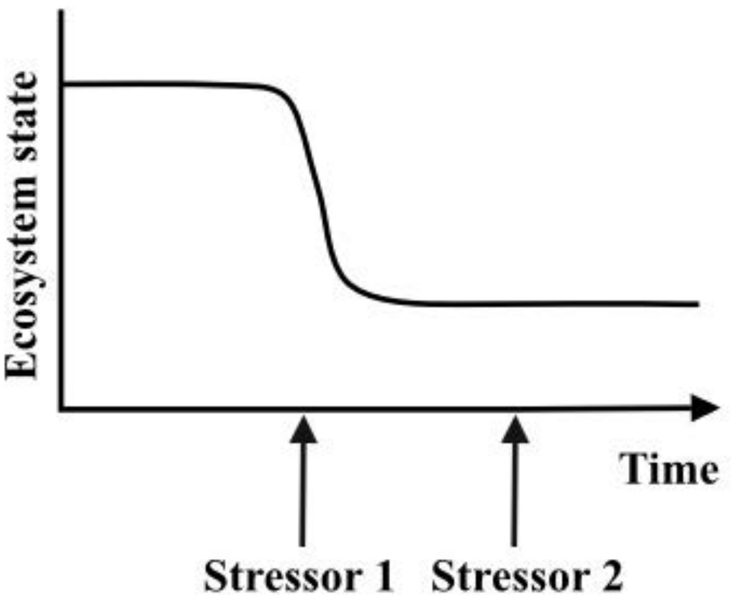


Based on Vinebrook et al. 2004

Most species co-tolerant

Adding stressors to a degraded system will NOT cause further change

- Partially degraded systems contain tolerant species which will also tolerate future stressors

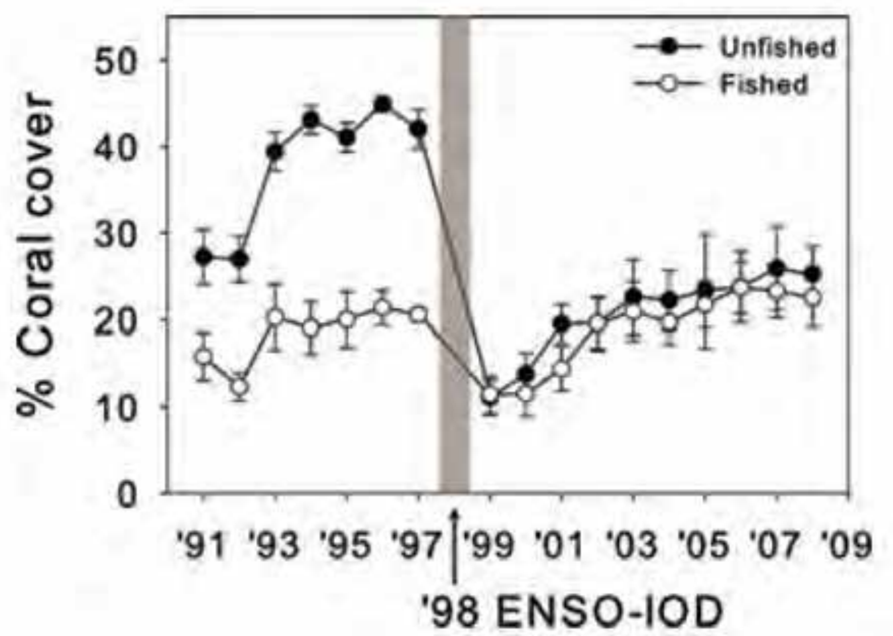


Côté & Darling (2010)

Most species co-tolerant

Adding stressors to a degraded system will NOT cause further change

- Partially degraded systems contain tolerant species which will also tolerate future stressors

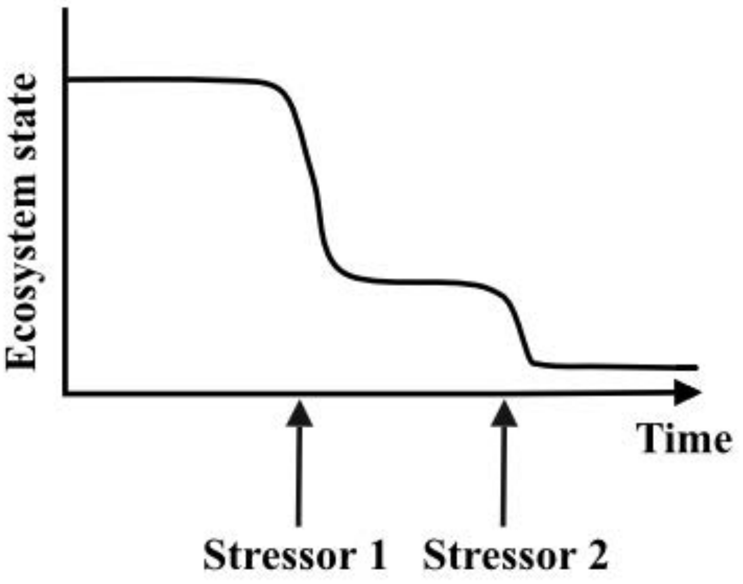


Darling *et al.* (2010)

Most species not co-tolerant

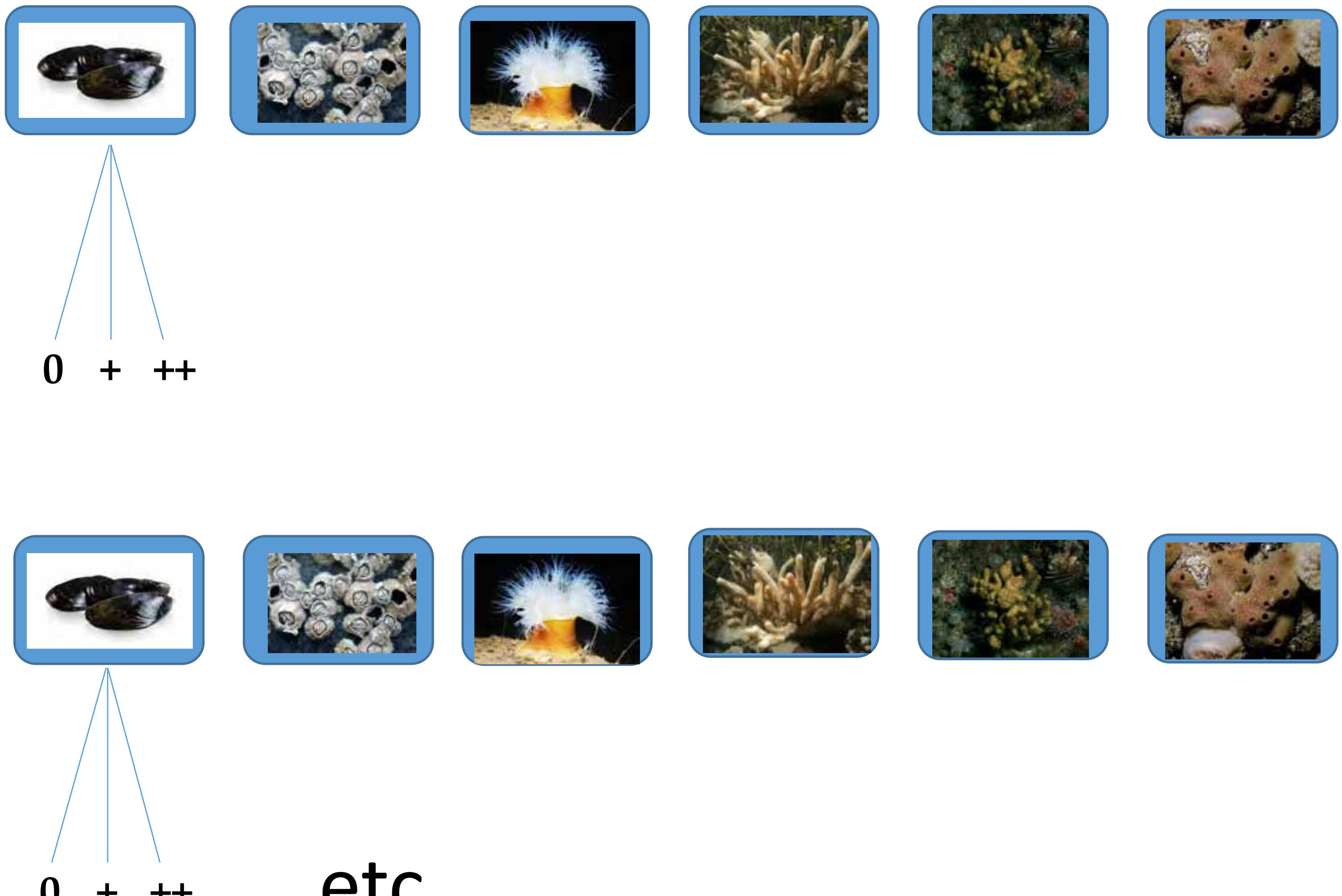
Adding stressors to a degraded system will cause further change

- Partially degraded systems contain species tolerant to one stressor but sensitive to others



Allison (2004)

Would need to improve knowledge of co-tolerances of individual species & test effectiveness



Stressor 1

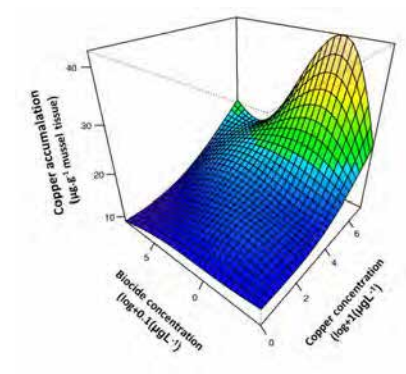
Stressor 2

etc.

Gastaldi Blanco et al, current research

Overall conclusions

- Effects of multiple stressors vary with biota, context, stressor regime
- Interactive effects varied at different concentrations of stressors & levels of organisation



- Timing and sequence altered effects

➢ **Non-additive effects of multiple stressors may be more complex and common than expected**

Ways forward

- Focus on priority combinations of stressors and contexts
- Use more complex designs and tools to characterise range of possible effects

- Characterise mechanisms of interaction
  - Exogenous, endogenous, ecological
- Explore co-tolerance and other trait-based approaches; collate and generate relevant trait information

Acknowledgements

- **Funding:** Irish Research Council, Environmental Protection Agency
- **Co-authors**: Paul Brooks, Mark Browne, Lisandro Benedetti-Cecchi, Jayne Fitch, Chris Frid, Chloe Kinsella, Devin Lyons, Caroline Kerrigan, Martina O’Brien, Valeria Palmeri, Silvia Saloni, Paul Somerfield
- **Malahide Marina staff**, particularly Damian Offer
- **Field and technical assistance:** Jen Coughlan, Paul O’Callaghan, Ciara Murphy, Conor McGee, et al.

IRISH RESEARCH COUNCIL
An Chomhairle um Thaighde in Éirinn

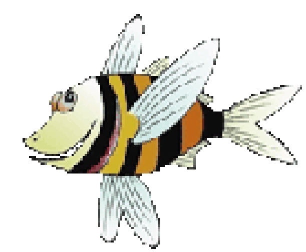
epa Environmental Protection Agency

NDP

SSTI Funded as part of the Strategy for Science, Technology and Innovation

UCD DUBLIN

malahide marina
dublin, ireland
...welcome...
...fáilte...
...bienvenue...
...willkommen...



EMBS
EUROPEAN
MARINE BIOLOGY
SYMPOSIUM
54 DUBLIN
25-29 August 2019

54^{th}
EUROPEAN MARINE BIOLOGY SYMPOSIUM

25-29 August 2019
Dublin

JOIN US IN DUBLIN IN 2019 FOR EMBS54!

THEMES

BLUE GROWTH
In this session, we will explore the potential of marine organisms and ecosystems to underpin economic and societal benefits and examine potential risks and emerging approaches to sustainability.

RAPID CHANGE
Organisms, communities and ecosystems change daily, seasonally, annually and over decades, centuries and millennia. This session focuses on temporal change and explores how and why it is accelerating during the Anthropocene.

FUNDAMENTAL BIOLOGICAL TRAITS
We still lack knowledge of the basic biology and ecological traits of many species. This session aims to capture recent research and synthesis of the fundamental biology of marine organisms.

MOVEMENT AND REDISTRIBUTION OF SPECIES
Seas and oceans are filled with species on the move over short and long distances to feed, breed or disperse. Research on any aspect of movement biology or species distribution will be captured in this session.

There will also be a **General Session** covering any aspect of marine biology.

2019 is the International Year of the Salmon, a fish that has a special place in the mythology of Ireland – look out for the salmon throughout the scientific and social programme!

EMBS54 · 25-29 August 2019 · www.embs54.org · info@embs54.org