Department
for Environment
Food & Rural Affairs

Cefas

PLACID

Understanding Ocean Acidification: what will be the consequences for commercial species?

Silvana Birchenough, John Pinnegar, Matthew Sanders and Jeo Lee

20th March 2015

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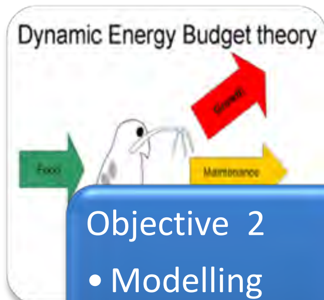
Placing Ocean Acidification into a wider fisheries Context

Objective 1

- Experiments
- Review of OA/pressures under climate change

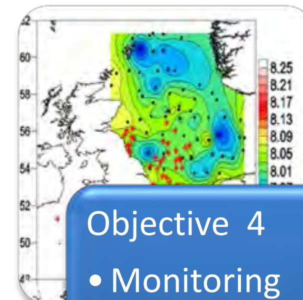


Objective 2

- Modelling studies
- Dynamic Energy Budgets (DEB)

Objective 3

- Economic quantification
- Impacts of OA on shellfish/ aquaculture



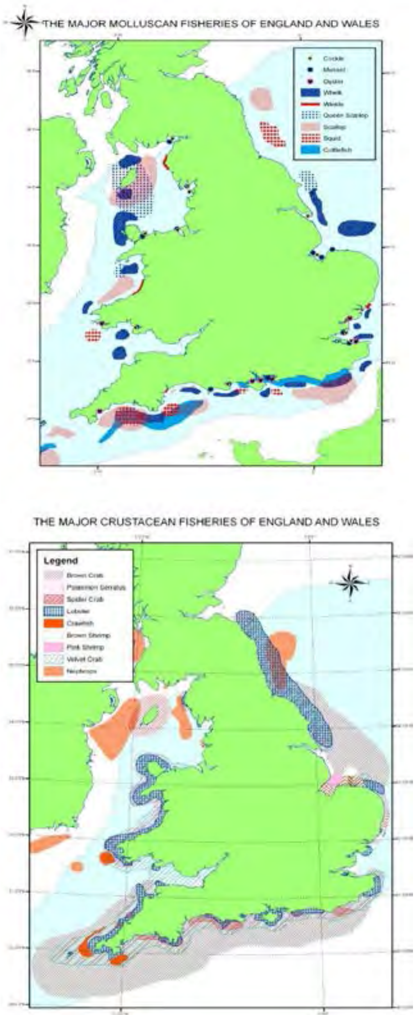
Objective 4

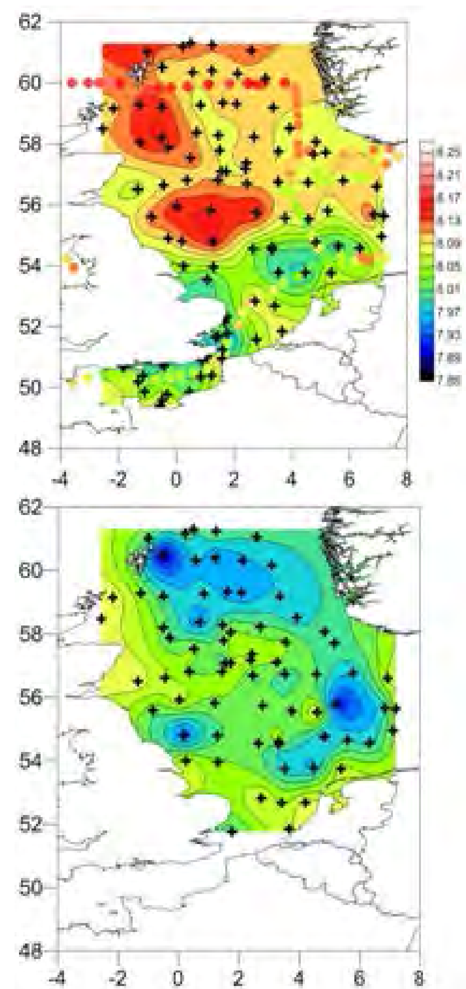
- Monitoring
- PH, TA, DIC for UK waters: inshore & offshore

This research will provide evidence of the effects of OA on commercial species and UK fisheries.

Distribution of commercial species

Greenwood et al.





<u>England & Welsh</u> Fisheries (MMO, 2012):

- Crab, **Landings 14,200 tonnes**, Value <u>£18.3 million</u>.
- Lobster, Landings 5,500 tonnes, Value <u>£17.8 million</u>.
- Whelk**, Landings 15,500 tonnes**, Value <u>£10.5 million</u>.
- Cockles, Landings 2,200 tonnes, Value £1.5 million.

Maps provided by Cefas Shellfish Team © (courtesy of Karen Vanstaen)

Literature review: commercial species

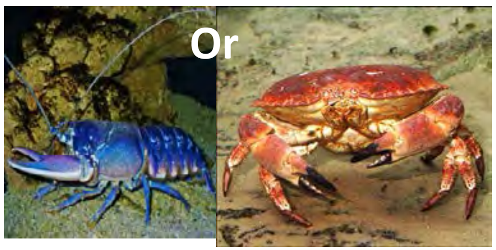
Species	Scientific name	pH tested/methods	Duration	Observations for pH decrease up to 0.4 units (effect size)	Other co-stressors	References
Molluscs						
Scallops (King)	*Pecten Maximus*	[8.18, 8.10, 7.81, 7.82] pH meter and tank	11 weeks (77 days)	*Clearance rates, respiration rates, condition index and cellular turn over (DNA:RNA)	Temperature= 15oC	Sanders et al., (2013)
Mussels	*Mytilus edulis*	[8.1, 7.6, 7.4, 7.1, 6.7]	44 days	**Shell growth was significantly affected between pHu 7.1. and 8.1 but was significantly reduced at 7.1 and 6.67pHu. From day 23 mortlaity was observed in this tre		006)
	Mytilus edulis					(2010)
	Perumytilus purpuratus					2012
Oysters	*Crassostrea gigas*	[8.07,7.55]	2hours	**Signi pH.		list
	Crassostrea gigas					(2010)
	Crassostrea virginica	[8.16,8.06,7.91, 7,76]	28 days	**Shell treatme thickness.		54-EPOCA ref. list
Clam	*Ruditapes decussatus*	[8.25,7.85, 7.67]	75 days	*No changes observed in net calcification size or weight of the clams. Mortality reduced in the acidified treatments.		Range et al.(2011)
Clam	*Macoma balthica (eggs, larvae and embrios)*	[8.1, 7.8, 8.5]		Effects observed in fertilization, embryogenesis and reduction of larval development		van Colen et al. (2012)
Cockles	*Ceratodesma edule*	[8.3, 6.7]	55 days	Direct effects: Reductions on shell length, shell weight and cockle flesh over high CO2 increased. Indirect effects: DEB but difficult to differnciate between assimilation, maintenance and growth		Klok et al (2014)
Abalone	*Concholepas concholepas*			larvae-changes		Vargas et al., 2012
Crustaceans						
Nephrops	*Nephrops norvergicus (eggs)*	[control and -0.4 units]	4 months	Embryo rate anc comsun		)
	Hyas araneus (larvae)	[8.01, 7.71]		Zoea I l affecte		013)
Crabs	*Necora puber*	[8.05, 7.8. 7.6, 7.4, 7.2, 6.8 and 6.0]	30 days			0)
	Cancer magister					
Shrimps	*Palaemon pacificus (egg, juvenile)*	[7.9, 7.6]	30, 15 wk	**Decreased survival, growth, egg production		Kurihara et al. (2008)
Prawns	*Palamon elegans*		30 days			Kurihara (2008)
	Palamon serratus		30 days			
Lobster (European)	*Hommarus gammarus (larvae)*	[8.10, 7.84] pH meter	5 months (140 days)	**Growth was slow at 10oC and after 5 weeks none of the larvae moulted into Stage 4.Deformities were observed in the larvae (curled carapace, damaged in the tail and bend rostrum)	10- and 18oC	Agnalt et al. (2013)
	Hommarus gammarus (juvenile)	[7.95, 7.96] pH meter	5 months (140 days)	**Deformities were observed in juveniles ~40 in total (mainly claws, twisted legs and puffy carapace)	14oC	Agnalt et al. (2013)

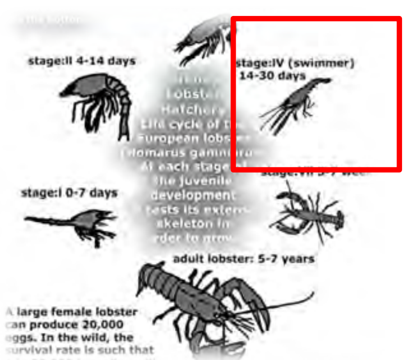
Molluscs:
Changes in shape, shell morphology, growth

Crustaceans:
Decrease in growth, reproduction some deformities

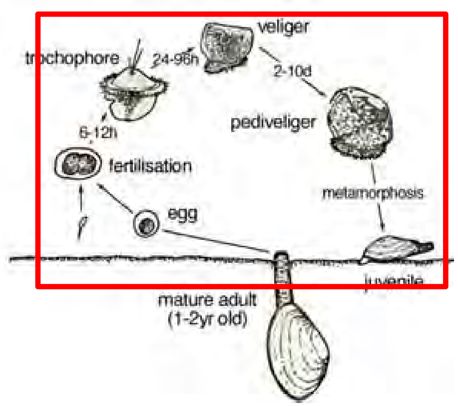
Our stars species!

Year 1: 2013-14





Year 2:2014



Year 3

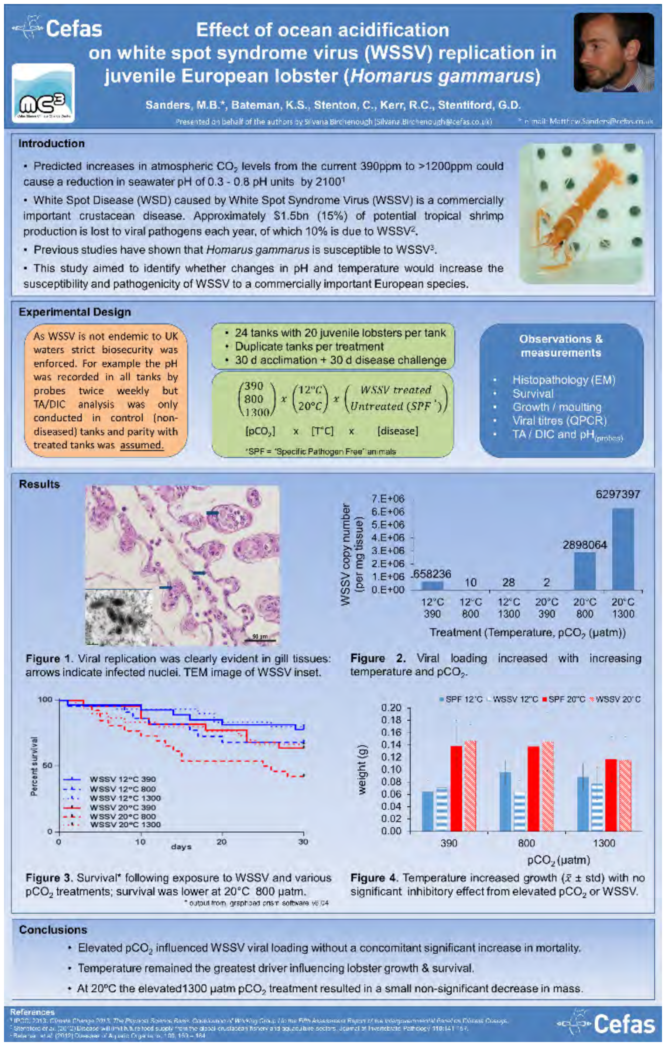
Tips:

Understand the biology and ecology of the species (feeding regimes, habits, other)

Acclimation in the laboratory

Co-stressors (understand the natural variability in the systems: What are they used to already?)

Lobster: pH changes, temperature and disease

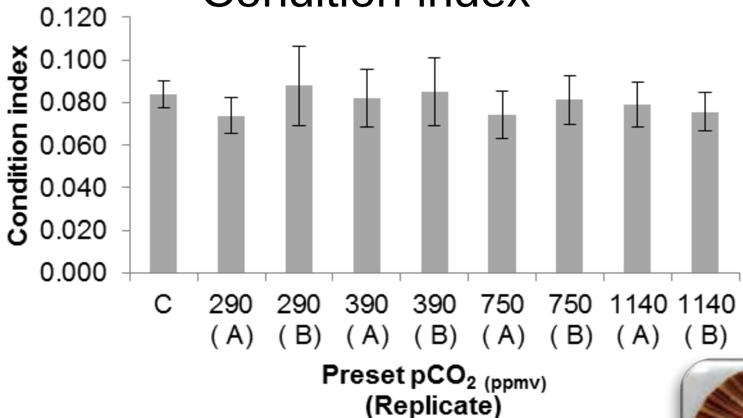


Effect of ocean acidification on white spot syndrome virus (WSSV) replication in juvenile European lobster (*Homarus gammarus*)

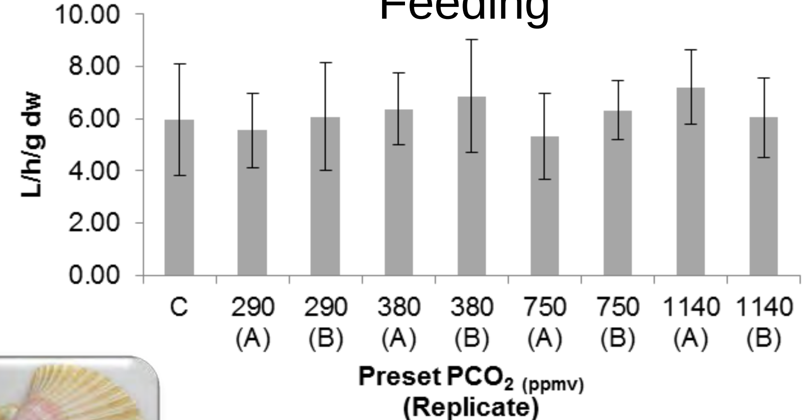
- Elevated pCO_2 influenced WSSV viral loading without a concomitant significant increase in mortality;
- Temperature remained the greatest driver influencing lobster growth & survival;
- At 20ºC the elevated1300 µatm pCO_2 treatment resulted in a small non-significant decrease in mass.

Scallop: Pecten Maximum

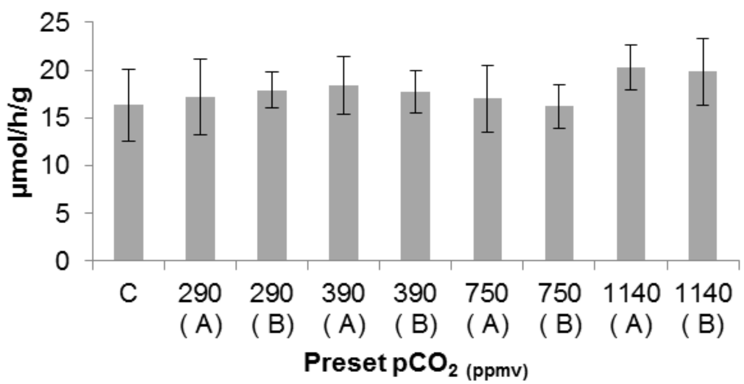
Condition index



Feeding

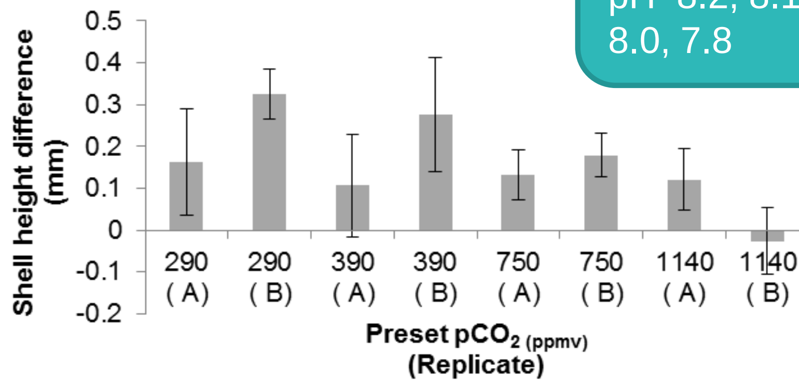


Respiration



Growth

2 months exposure to: pH 8.2, 8.1, 8.0, 7.8



Sanders, M.B., et al. 2013. Juvenile king scallop, Pecten maximus, is potentially tolerant to low levels of ocean acidification when food is unrestricted. PLOS ONE 8: e74118.

Cockles Background

Journal of the Marine Biological Association of the United Kingdom, 2012, 92(7), 1563–1577.
doi:10.1017/S0025315412000355

A review of the biology of European cockles (*Cerastoderma* spp.)

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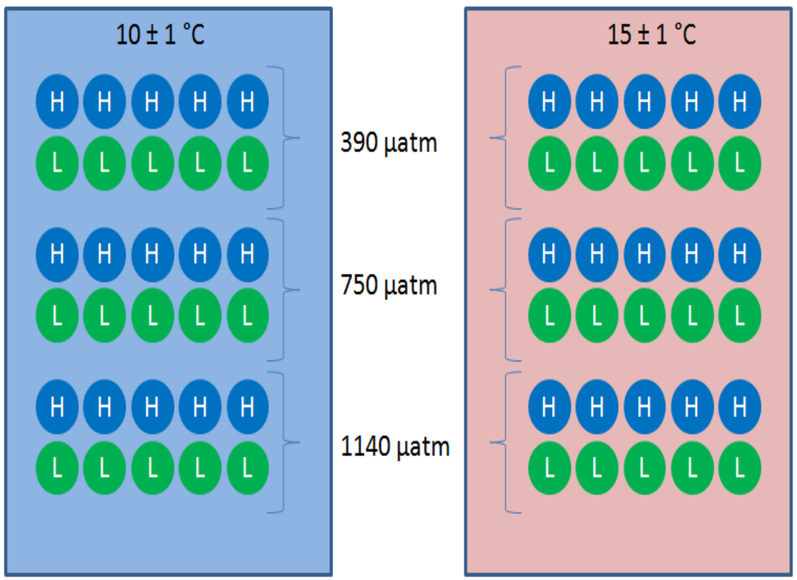
This review examines the biology of the two main cockle species Cerastoderma edule *and* C. glaucum *found in coastal areas around the north-east Atlantic from Norway to Morocco and through the Baltic, Mediterranean and Black Sea. It considers those factors in particular that impact on the overall health and survival of individuals as well as populations. Methods for the discrimination of the species are reviewed as well as the approaches being taken to delineate different populations, which is crucial to appropriately manage individual fisheries. Cockle populations generally undergo sexual maturation during their second summer and sexes are separate. Eggs are pelagic, with larvae being both benthic and pelagic before settling on the sediment and becoming benthic adults. However, data are lacking on basic larval biology and dispersal mechanisms. Data are provided on predator–prey relationships including information on types of food of importance to cockles. Main predators of cockles include brown shrimp, shore crabs, gastropods, polychaetes, fish and a variety of birds and these can be important in structuring cockle populations. Predation of larval cockles by adult cockles through larviphagy can lead to reductions of up to 40% of the population. Cockles are sensitive to a wide range of chemical contaminants but few data are published on impacts on cockles, in particular larval stages. The review concludes with an assessment of future climate change scenarios on cockles and considers some areas of future research required to preserve this ecologically and economically important species.*

- *Cerastoderma edule* and *C. galucum*
- *Factors influencing survival*
- *Considers parasites, reproduction and other factors*
- *Climate change (including OA) are included in the gaps!*



Vessels: 5L plastic buckets
Total at each temp = 30
Density: 1 per ml = 4000 per vessel (120 000 per temperature)
Water exchange = 3 -4-3-4 days
Water volume at each exchange : 4L * 30 = 120L
Larval duration at 16°C : ~ 21d

Algae: Isochrysis: Pavlova: Chaetocerous:
High dose: 100 cells µl^{-1} (60:20:20)
In 4L; 240 x 10^{6} cells Isochrysis, 80x 10^{6} Pav and 80 x 10^{6} Chaetocerous

Low: 60 cells µl^{-1} (30:10:10)
In 4L; 120 x 10^{6} cells Isochrysis, 40 x 10^{6} Pav and 40 x 10^{6} Chaetocerous

Sample dates: 3, 7, 10, 14, 17.
Measurements: 1) surface area, 2) CEA Shell composition, 3) survival, 4) development time, 5) settlement success. 6) Post settlement growth.

Experiment design

Acclimation period (2 weeks)

End May, June: feeding, observing: behaviour, density, survival

Short term experiment

10 &15oC, pH: 380, 750, 1140 ppm---------------------14days

Long-term experiment (larvae->settled in sediment)

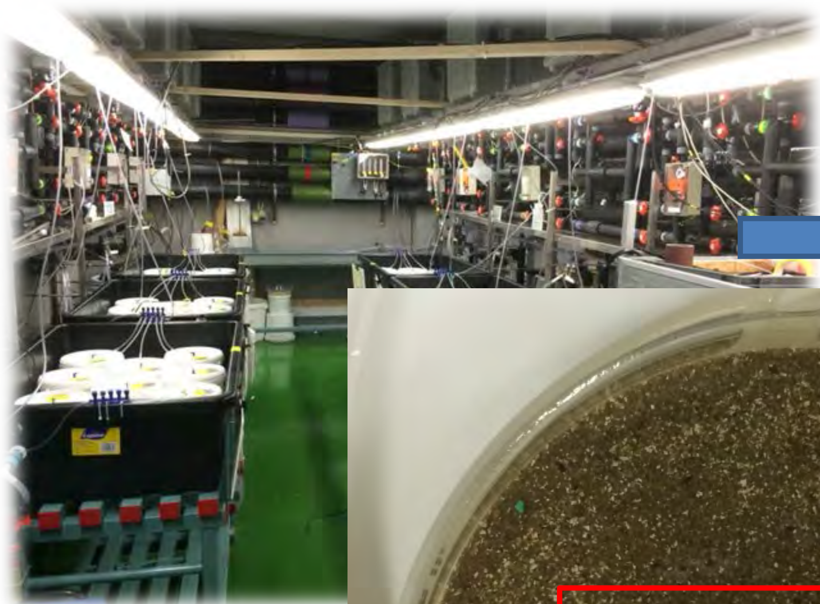
15oC, pH: 380, 750, 1140ppm---55days

Sample, image and data analysis

January /February 2015

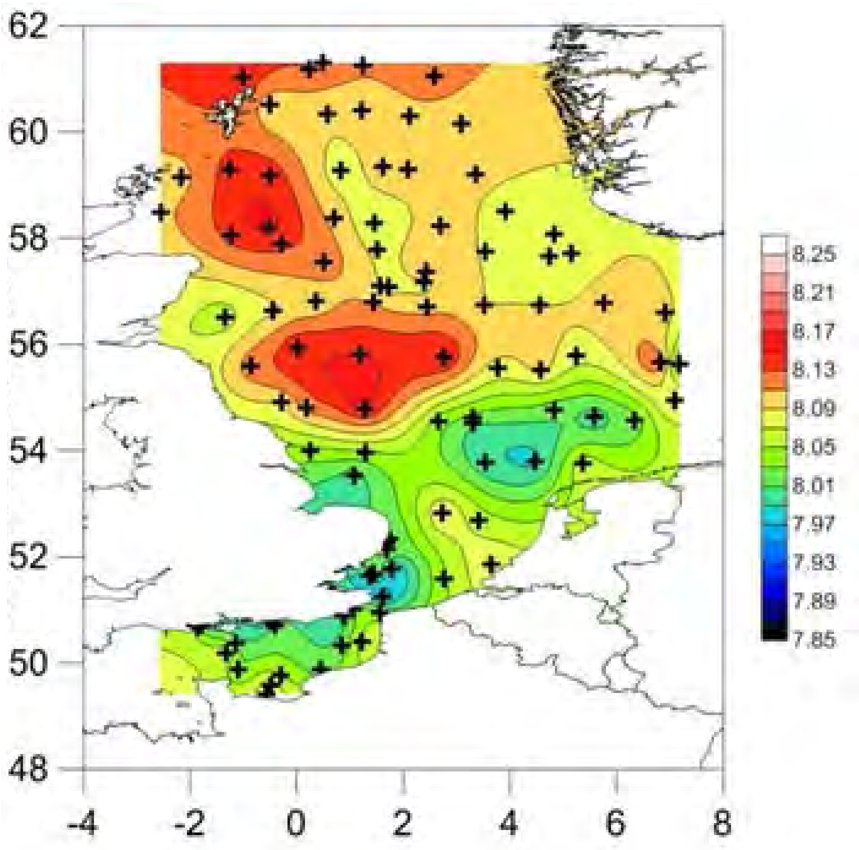
•Parameter measured: water samples every 10 days for DIC/TA and nutrients, pH using a probe measured also in vessels,
•Sub-samples of 25ml (~50 animals per treatment)

Cockles: *Cerastoderma edulis*

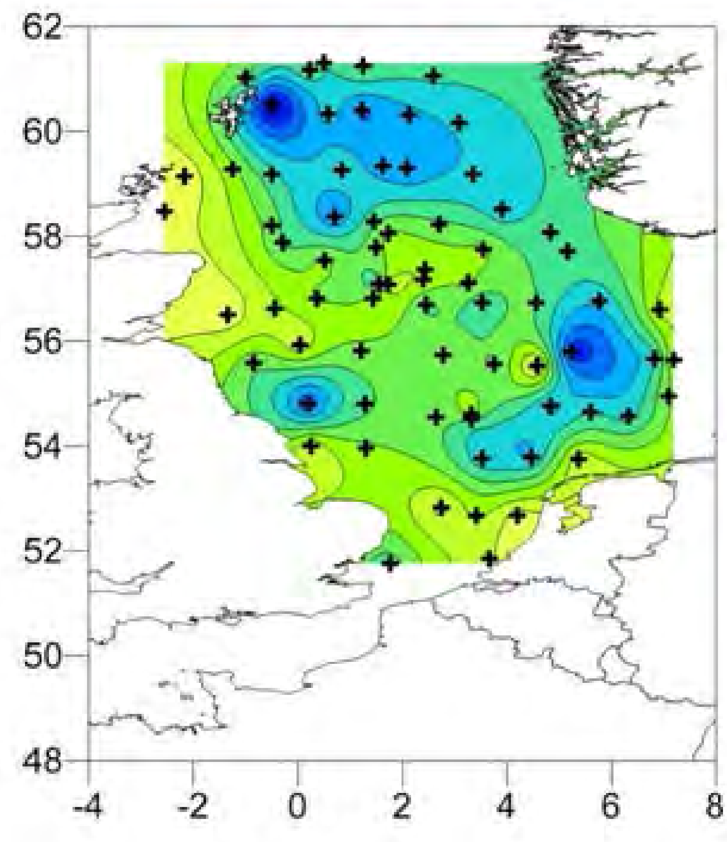


Spatial variability in pH (August)

Surface

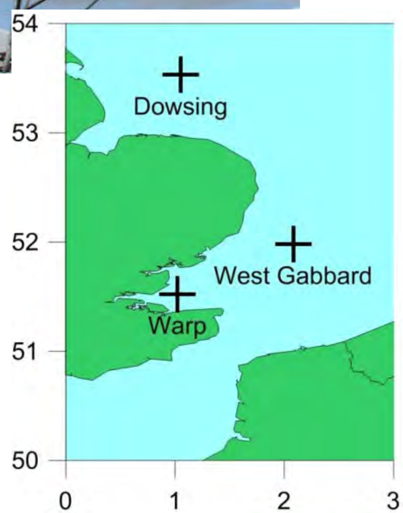


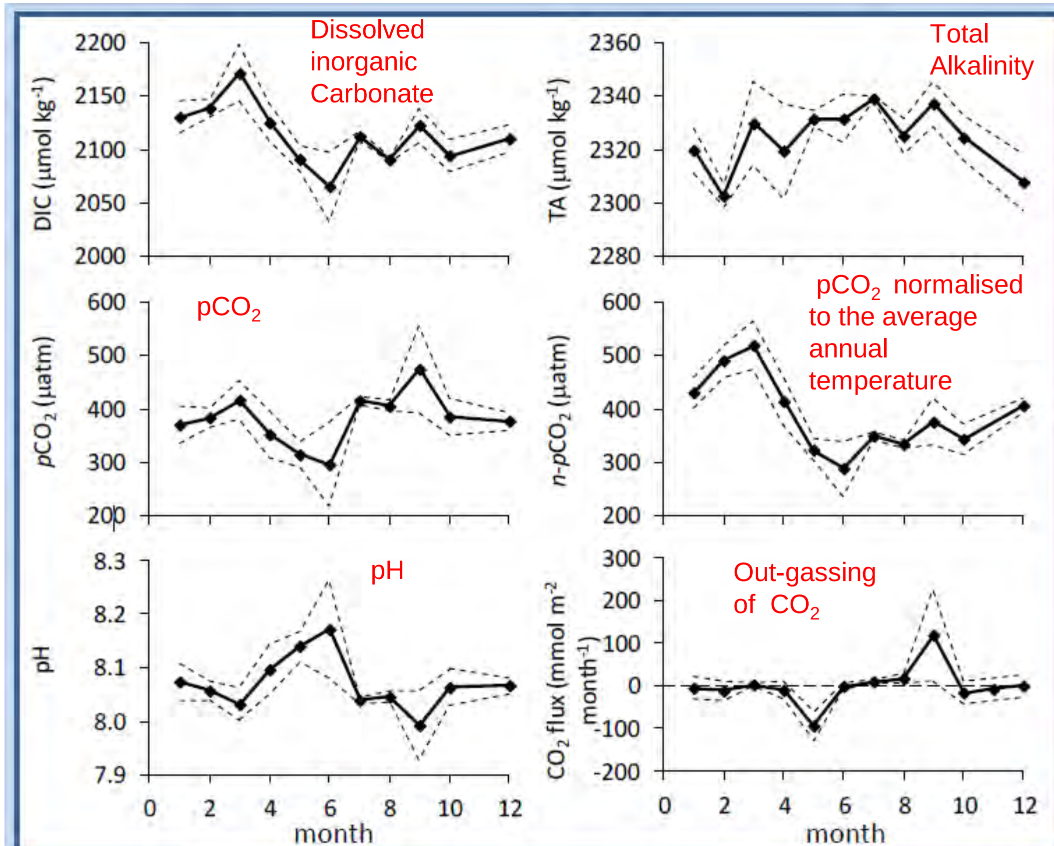
Bottom



Monitoring

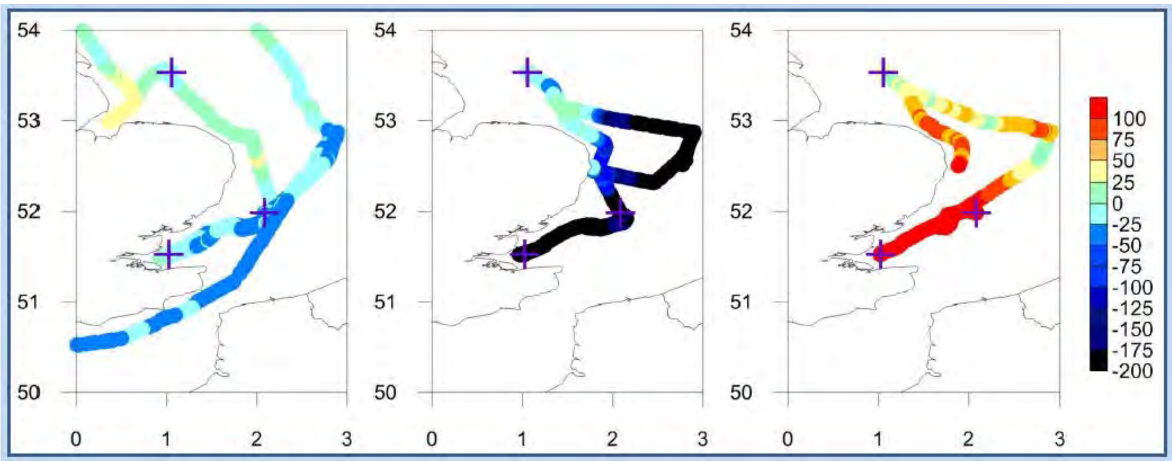
Monthly mean (± standard deviation) values for carbonate parameters at West Gabbard





Spatial variability in the carbonate system

February 2013 June 2013 October 2013

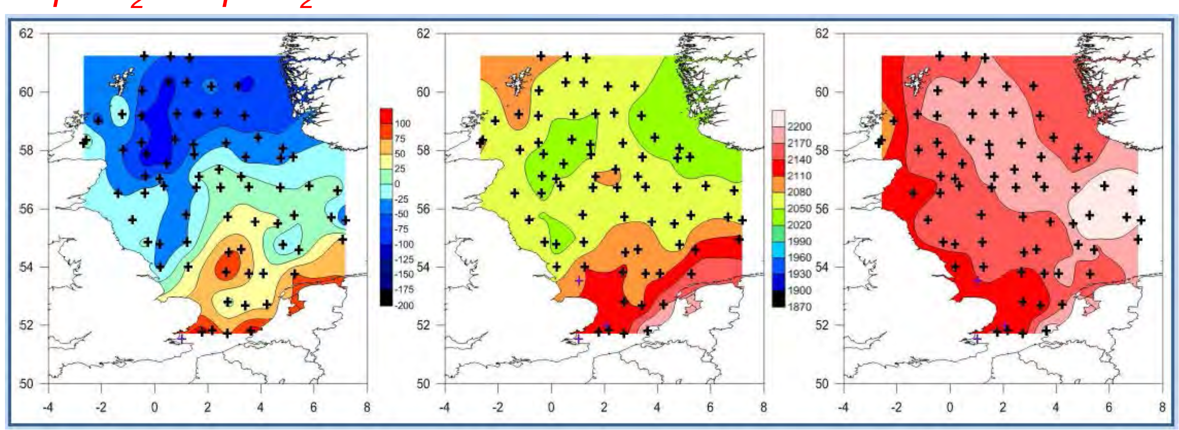


(pCO_2sw - pCO_2air)

Strong draw down of CO_2 in June due to a large *Phaeocystis* bloom

The CO_2 flux to the atmosphere in October due to remineralisation of organic matter

pCO_2sw - pCO_2air *Surface DIC* *Bottom DIC*



August 2013

The out-gassing of CO_2 to the atmosphere observed in the southern North Sea during the late summer is in contrast to that found in the northern North Sea

ECONOMICS

•**PLACID will investigate the utility of various econometric techniques** (NPV, PEA and RAEV) with a view to assessing the economic consequences resulting from OA on fisheries and aquaculture in the UK, and globally.

•**Marine molluscs** (oysters, scallops, mussels, whelks and cockles) have a **significant commercial value worldwide**, some of the existing OA physiological and ecological evidence has already been used in economic assessments.

•Pinnegar et al. (**CCRA, 2012**) estimated the cost at **£55-379 million** of losses to shellfish fisheries depending on emissions scenario, and **£59.8-124.6 million** of losses to aquaculture by 2100.

•**PLACID will build on this work and also employ a novel ‘risk adjusting economic valuation’ (RAEV) approach** to assess impacts on the wider UK economy.

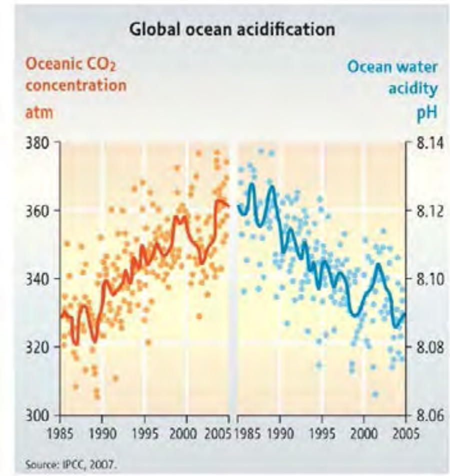
Take home messages

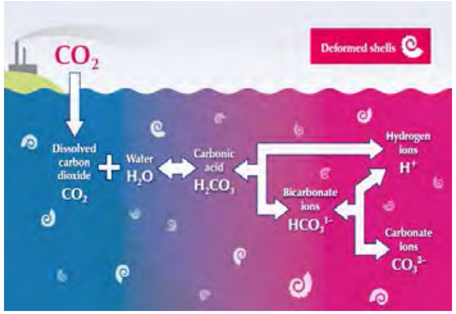
•**Understanding the natural variability** of which organisms are living/coping is key to understand any single or multiple stressors effects;

•**Experiments, acclimation** (feeding regimes, plasticity and tolerance) period is important, rather than immediately placing organisms into treatments. Consider also end-points that will be measured.

•**Differing stages**, It is clear that different larval stages when compared to adult stages will exhibit different responses to pH changes

•**Marine species** have a **significant commercial value worldwide**, it is important to understand the effects of OA, disease and other stressors have over physiological and ecological responses to warrant food security.





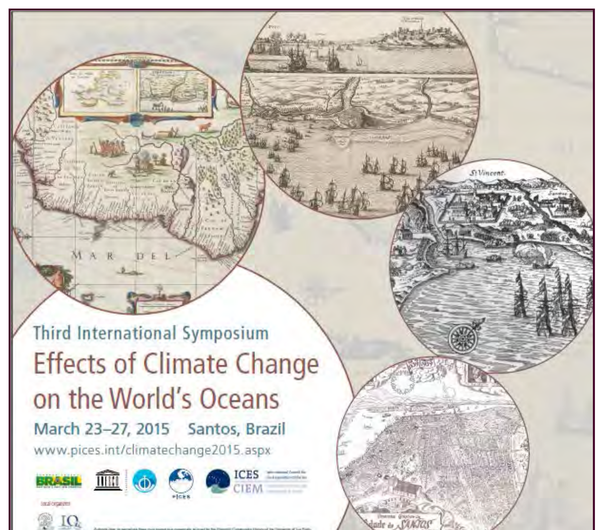
International Conferences

ICES/PICES

Ocean Acidification (OA): Understanding chemical, biological and biochemical responses in marine ecosystems.

Abstract : open until 30th April 2015

Conveners: Drs. Silvana Birchenough (UK), Pamela Walsham (UK), Klaas Kaag (the Netherlands), Tsuneo Ono (PICES)



Ocean Acidification session (S2):Wednesday and Thursday

PLACID

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- Naomi Greenwood
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- Phil Williamson (UKOA/NERC)
- Steve Newstead (Bangor)
- Matthew Sanders
- Craig Stenton

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