

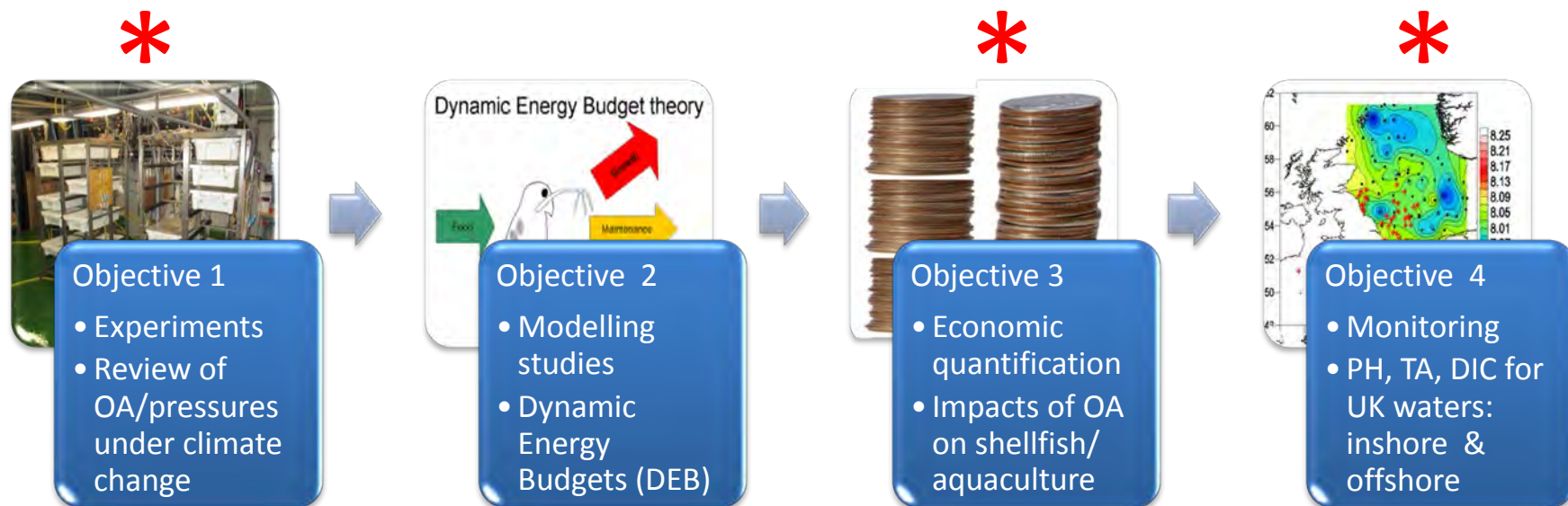


## Understanding Ocean Acidification: what will be the consequences for commercial species?

Silvana Birchenough, John Pinnegar, Matthew Sanders and Jeo Lee

20<sup>th</sup> March 2015

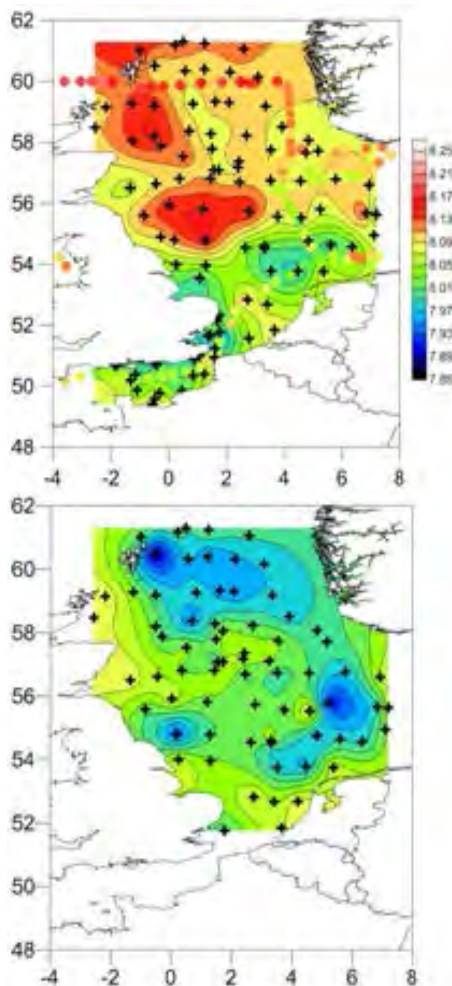
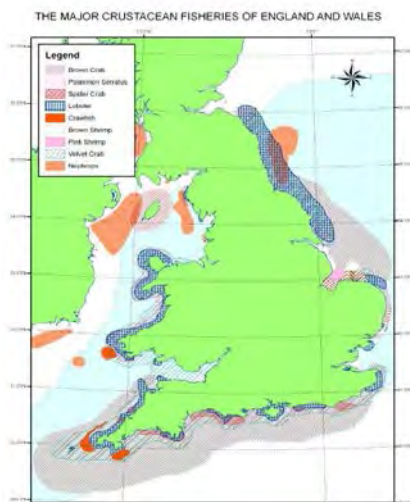
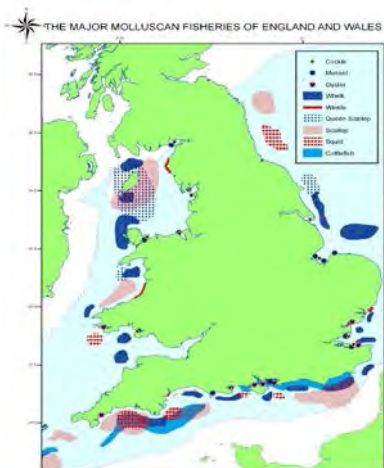
## Placing Ocean Acidification into a wider fisheries Context



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

# Distribution of commercial species

Greenwood et al.



England & Welsh Fisheries (MMO, 2012):

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



# Literature review: commercial species

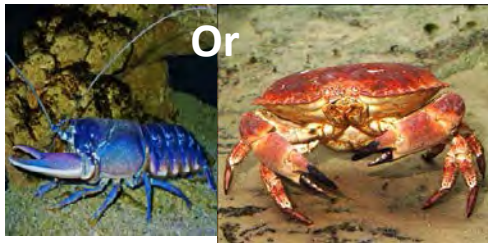
Species	Scientific name	pH tested/methods	Duration	Observations for pH decrease up to 0.4 units (effect size)	Other co-stressors	References
<b>Molluscs</b>						
Scallops (King)	<i>Pecten Maximus</i>	[8.18, 8.10, 7.81, 7.82] pH meter and tank	11 weeks ( 77 days)	*Clearance rates, respiration rates, condition index and cellular turn over (DNA:RNA) **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 mortality was observed in this treat	Temperature= 15oC	Sanders et al., (2013)
Mussels	<i>Mytilus edulis</i> <i>Mytilus edulis</i> <i>Perumytilus purpuratus</i>	[8.1, 7.6, 7.4, 7.1, 6.7]	44 days	**Signi		006) (2010) 2012
Oysters	<i>Crassostrea gigas</i> <i>Crassostrea gigas</i>	[8.07,7.55]	2hours	pH. **Shell		list (2010)
	<i>Crassostrea virginica</i>	[8.16,8.06,7.91, 7.76]	28 days	treatme thickness.		54-EPOCA ref. list
Clam	<i>Ruditapes decussatus</i>	[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. Effects observed in fertilization, embryogenesis and reduction of larval development		Range et al.(2011) van Colen et al. (2012)
Clam	<i>Macoma balthica (eggs, larvae and embryos)</i>	[8.1, 7.8, 8.5]		Direct effects: Reductions on shell length, shell weight and cockle flesh over high CO2 increased. Indirect effects: DEB but difficult to differentiate between assimilation, maintenance and growth		Klok et al (2014) Vargas et al., 2012
Cockles	<i>Ceratodesma edule</i>	[8.3, 6.7]	55 days	larvae-changes		
Abalone	<i>Concholepas concholepas</i>					
<b>Crustaceans</b>						
Nephrops	<i>Nephrops norvegicus (eggs)</i>	[control and -0.4 units]	4 months	Embryo rate and consum		)
Crabs	<i>Hyas araneus (larvae)</i> <i>Necora puber</i> <i>Cancer magister</i>	[8.01, 7.71] [8.05, 7.8, 7.6, 7.4, 7.2, 6.8 and 6.0]	30 days	Zoea I la affected		013) 0)
Shrimps	<i>Palaemon pacificus (egg, juvenile)</i>	[7.9, 7.6]	30, 15 wk	**Decreased survival, growth, egg production		Kurihara et al. (2008)
Prawns	<i>Palamon elegans</i> <i>Palamon serratus</i>		30 days 30 days			Kurihara (2008)
Lobster (European)	<i>Hommarus gammarus (larvae)</i> <i>Hommarus gammarus (juvenile)</i>	[8.10, 7.84] pH meter [7.95, 7.96] pH meter	5 months (140 days) 5 months (140 days)	**Growth was slow at 10oC and after 5 weeks none of the larvae molted into Stage 4. Deformities were observed in the larvae (curled carapace, damaged in the tail and bend rostrum) **Deformities were observed in juveniles ~40 in total (mainly claws, twisted legs and puffy carapace)	10- and 18oC 14oC	Agnalt et al. (2013) Agnalt et al. (2013)

**Molluscs:  
Changes in shape, shell morphology, growth**

**Crustaceans:  
Decrease in growth, reproduction some deformities**

# Our stars species!

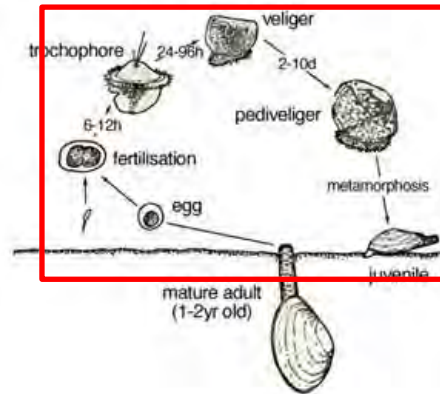
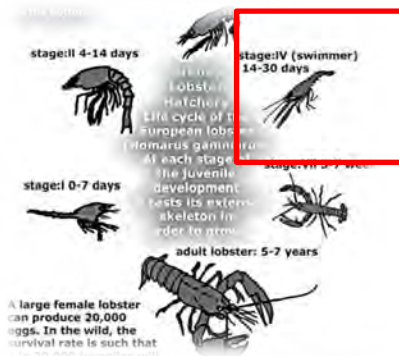
## Year 1: 2013-14



## 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*)**

Sanders, M.B.<sup>1</sup>, Bateman, K.S.<sup>1</sup>, Stenton, C., Kerr, R.C., Stentiford, G.D.

Presented on behalf of the authors by Siavana Bhattacharya (Sibhana.Bhattacharya@cefas.co.uk) E-mail: Matthew.Sanders@cefas.co.uk

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**Introduction**

- Predicted increases in atmospheric CO<sub>2</sub> levels from the current 390ppm to >1200ppm could cause a reduction in seawater pH of 0.3 - 0.8 pH units by 2100<sup>1</sup>
- White Spot Disease (WSD) caused by White Spot Syndrome Virus (WSSV) is a commercially important crustacean disease. Approximately \$1.5bn (15%) of potential tropical shrimp production is lost to viral pathogens each year, of which 10% is due to WSSV<sup>2</sup>.
- Previous studies have shown that *Homarus gammarus* is susceptible to WSSV<sup>3</sup>.
- This study aimed to identify whether changes in pH and temperature would increase the susceptibility and pathogenicity of WSSV to a commercially important European species.

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**Experimental Design**

As WSSV is not endemic to UK waters strict biosecurity was enforced. For example the pH was recorded in all tanks by probes twice weekly but TA/DIC analysis was only conducted in control (non-diseased) tanks and parity with treated tanks was assumed.

- 24 tanks with 20 juvenile lobsters per tank
- Duplicate tanks per treatment
- 30 d acclimation + 30 d disease challenge

$$\left(\frac{390}{800}\right) \times \left(\frac{12^\circ\text{C}}{20^\circ\text{C}}\right) \times \left(\frac{\text{WSSV treated}}{\text{Untreated (SPF)}}\right)$$

[pCO<sub>2</sub>] × [T°C] × [disease]

<sup>1</sup>SPF = 'Specific Pathogen Free' animals

**Observations & measurements**

- Histopathology (EM)
- Survival
- Growth / moulting
- Viral titres (qPCR)
- TA / DIC and pH (potent)

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**Results**

**Figure 1.** Viral replication was clearly evident in gill tissues; arrows indicate infected nuclei. TEM image of WSSV inset.

Treatment (Temperature, pCO <sub>2</sub> (µatm))	WSSV copy number (per mg tissue)
12°C 390	558236
12°C 800	10
12°C 1300	28
20°C 390	2
20°C 800	2899064
20°C 1300	6297397

**Figure 2.** Viral loading increased with increasing temperature and pCO<sub>2</sub>.

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**Figure 3.** Survival<sup>4</sup> following exposure to WSSV and various pCO<sub>2</sub> treatments; survival was lower at 20°C, 800 µatm.

**Figure 4.** Temperature increased growth (x ± std) with no significant inhibitory effect from elevated pCO<sub>2</sub> or WSSV.

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**Conclusions**

- Elevated pCO<sub>2</sub> influenced WSSV viral loading without a concomitant significant increase in mortality.
- Temperature remained the greatest driver influencing lobster growth & survival.
- At 20°C the elevated 1300 µatm pCO<sub>2</sub> treatment resulted in a small non-significant decrease in mass.

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**References**

<sup>1</sup>IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, 958 pp.

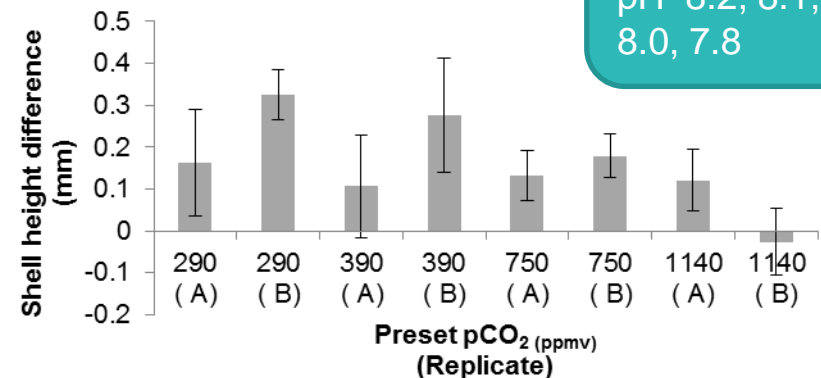
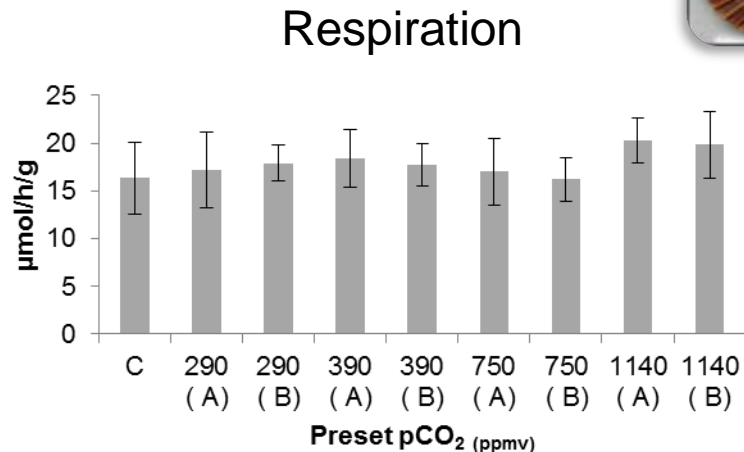
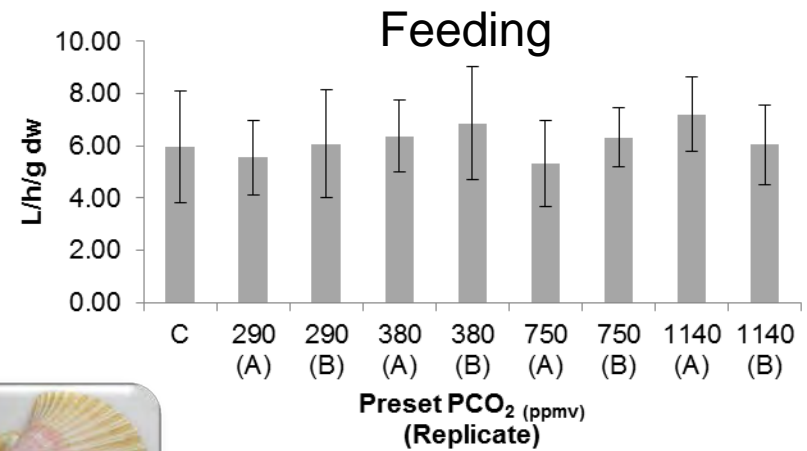
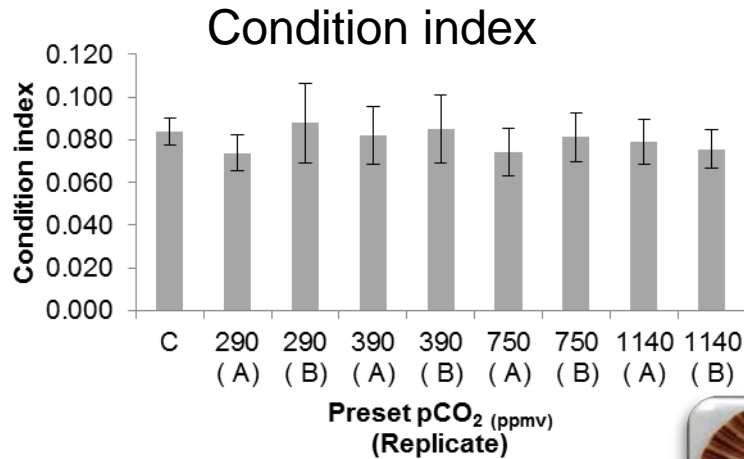
<sup>2</sup>Sharma, S.K., 2012. Shrimp and Crustacean Viral Diseases. In: Shrimp and Crustacean Diseases. Springer, Dordrecht, 101-111.

<sup>3</sup>See also: Journal of Aquatic Animal Health, 2006, 18(4), 144-148.

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

- Elevated pCO<sub>2</sub> influenced WSSV viral loading without a concomitant significant increase in mortality;
- Temperature remained the greatest driver influencing lobster growth & survival;
- At 20°C the elevated 1300 µatm pCO<sub>2</sub> treatment resulted in a small non-significant decrease in mass.

# Scallop: *Pecten Maximum*



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



## Cockles Background

Journal of the Marine Biological Association of the United Kingdom, 2013, 93(7), 1563–1577. © Crown Copyright. Published by Cambridge University Press, 2013.  
doi:10.1017/S0025315413000935

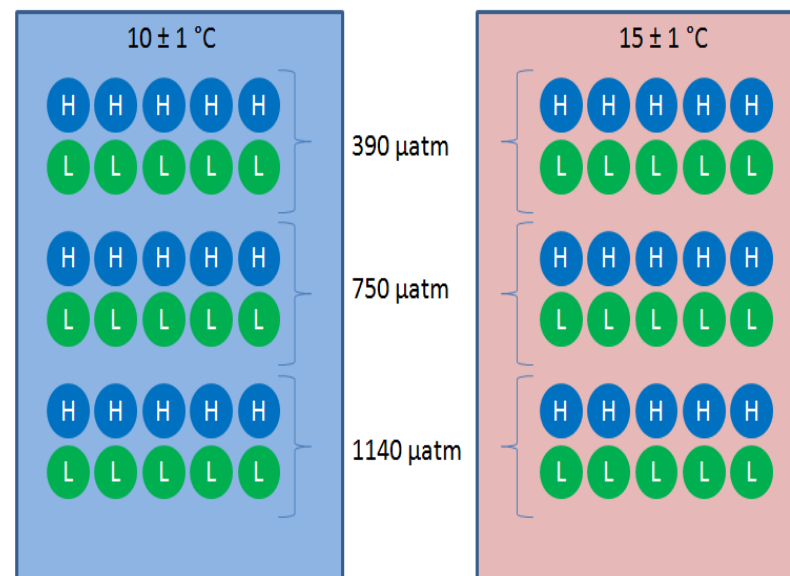
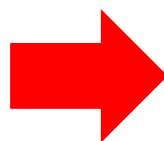
### A review of the biology of European cockles (*Cerastoderma* spp.)

SHELAGH K. MALHAM<sup>1</sup>, THOMAS H. HUTCHINSON<sup>2</sup> AND MATT LONGSHAW<sup>2</sup>

<sup>1</sup>Bangor University, School of Ocean Sciences, Centre for Applied Marine Sciences, Menai Bridge, Anglesey, LL59 5AB,  
<sup>2</sup>Cefas Weymouth Laboratory, Barrack Road, The Nothe, Weymouth, Dorset, DT4 8UB

*This review examines the biology of the two main cockle species Cerastoderma edule and C. galucum 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: Chaetoceros:  
High dose: 100 cells µl<sup>-1</sup> (60:20:20)  
In 4L; 240 x 10<sup>6</sup> cells Isochrysis, 80x 10<sup>6</sup> Pav and 80 x 10<sup>6</sup> Chaetoceros

Low: 60 cells µl<sup>-1</sup> (30:10:10)  
In 4L; 120 x 10<sup>6</sup> cells Isochrysis, 40 x 10<sup>6</sup> Pav and 40 x 10<sup>6</sup> Chaetoceros

Sample dates: 3, 7, 10, 14, 17.  
Measurements: 1) surface area, 2) CE 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 & 15°C, pH: 380, 750, 1140 ppm-----14days

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

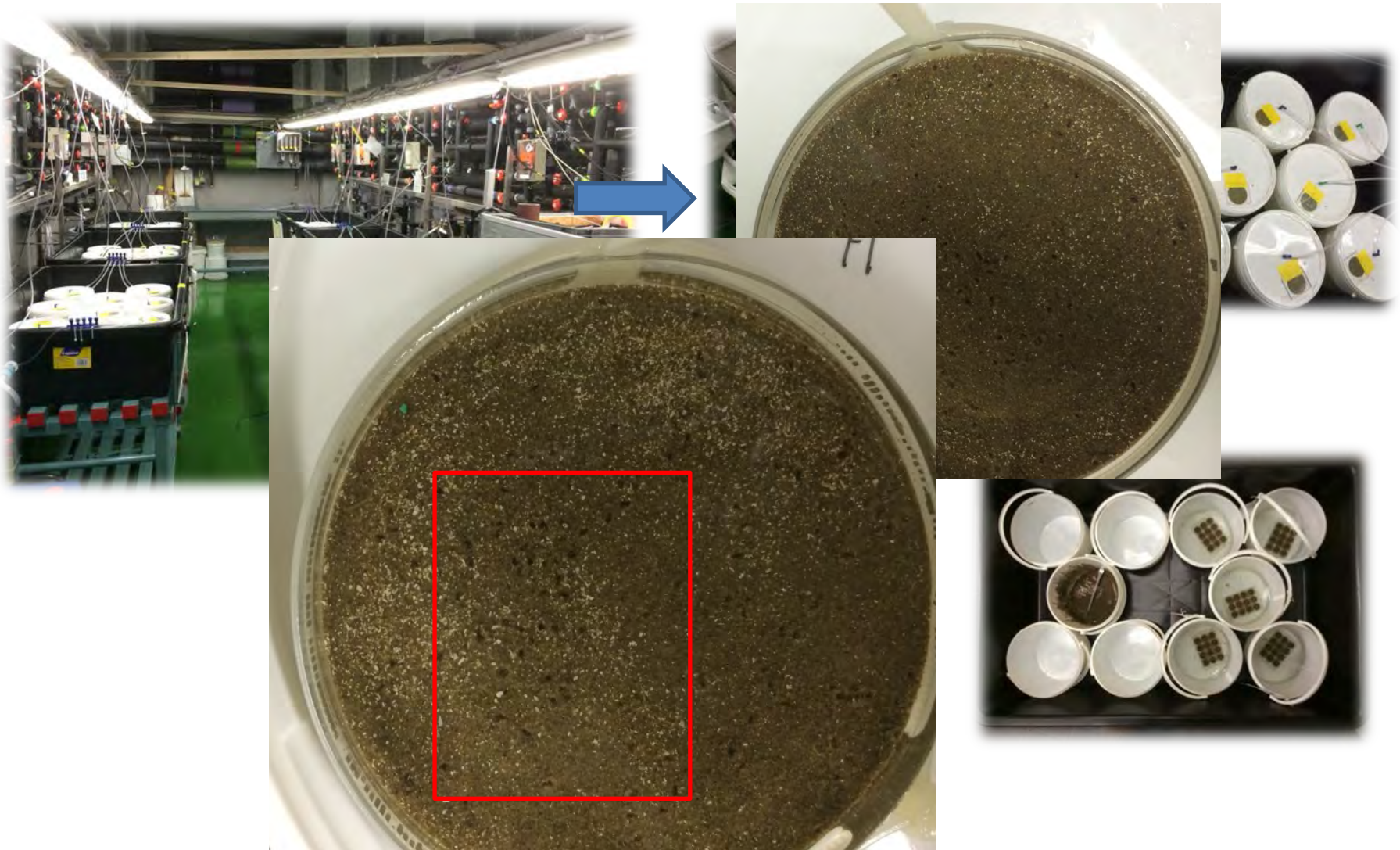
15°C, pH: 380, 750, 1140ppm-----55days

## Sample, image and data analysis

January /February 2015

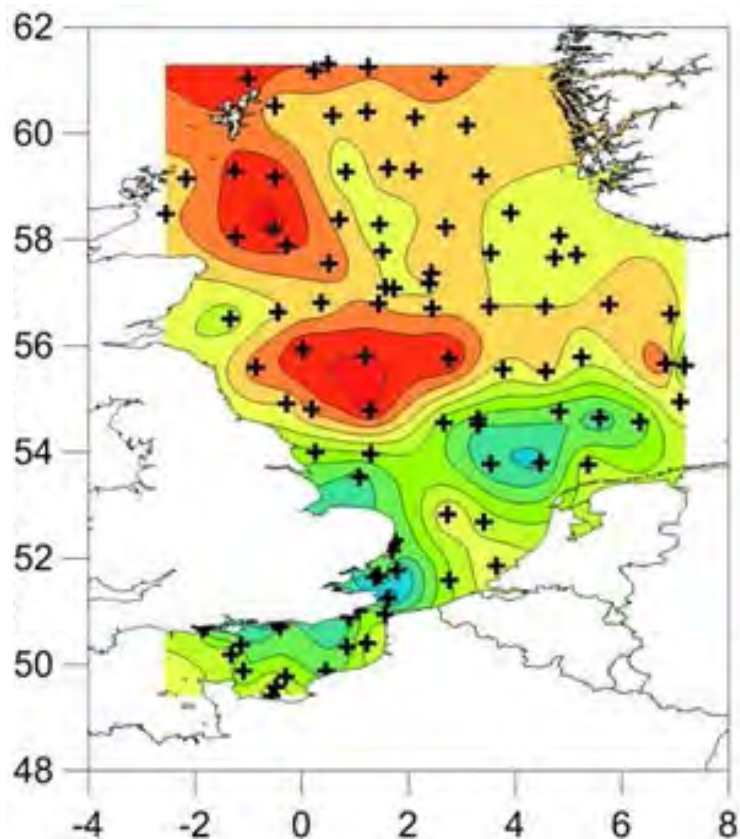
- Parameter measured: water samples every 10 days for DIC/TA and nutrients, pH using a probe measured also in vessels,
- Sub-samples of 25ml (~50 animals per treatment)

## Cockles: *Cerastoderma edulis*

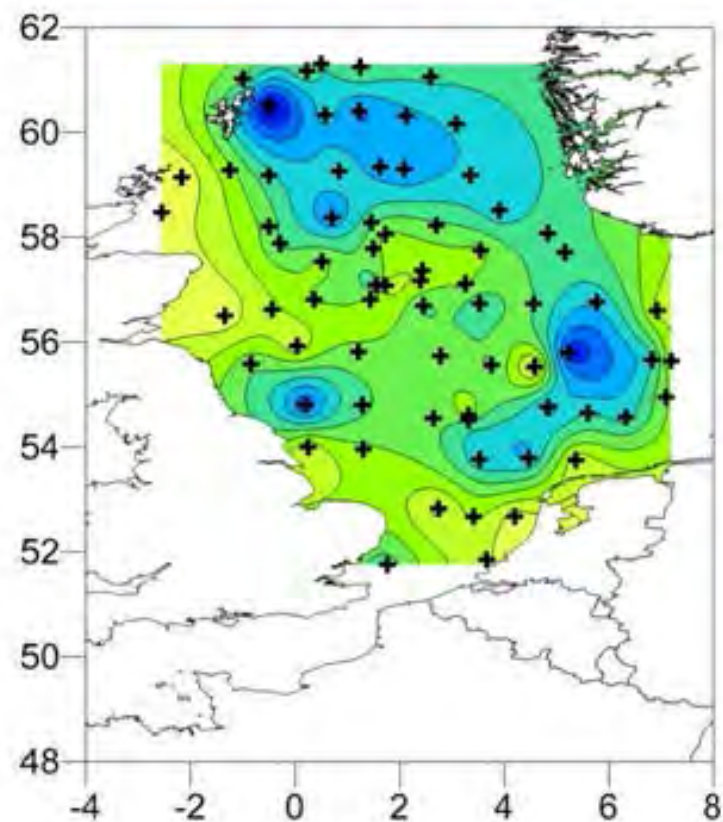


## Spatial variability in pH (August)

### Surface

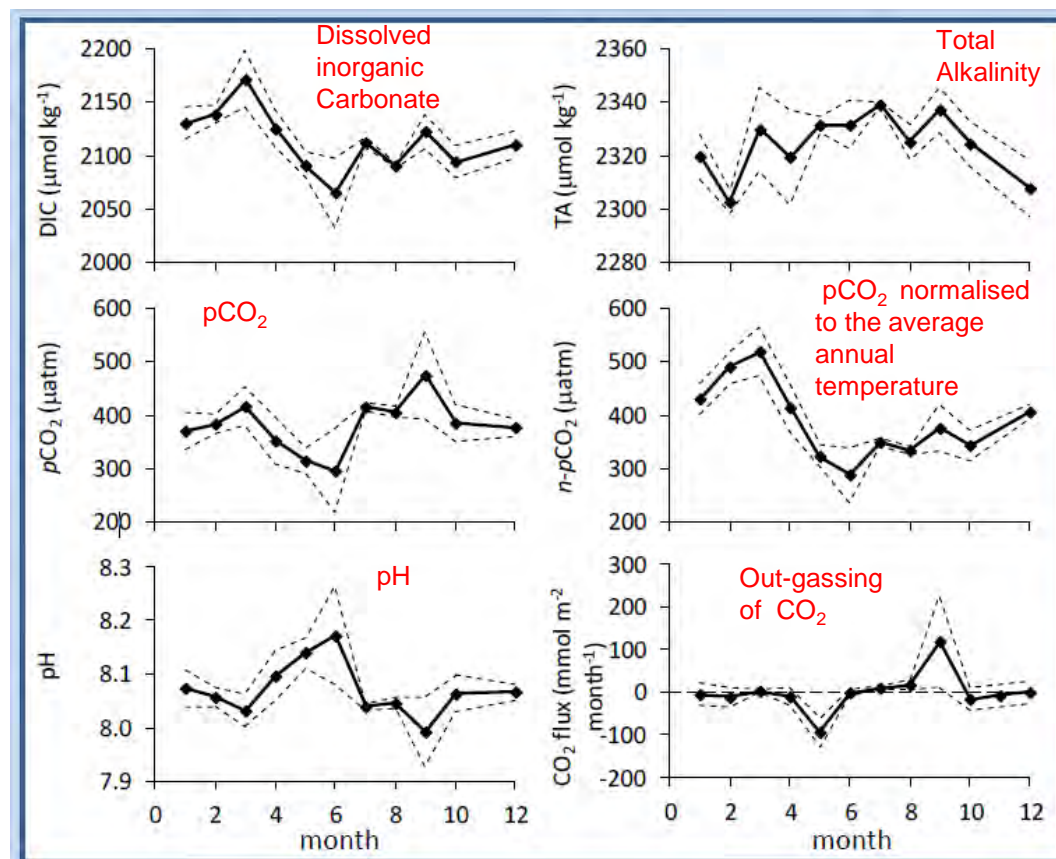
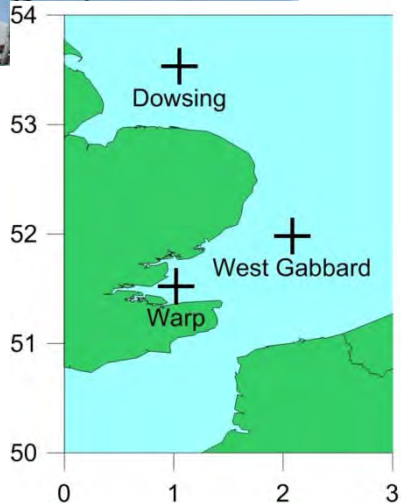


### Bottom



## Monitoring

Monthly mean ( $\pm$  standard deviation) values for carbonate parameters at West Gabbard

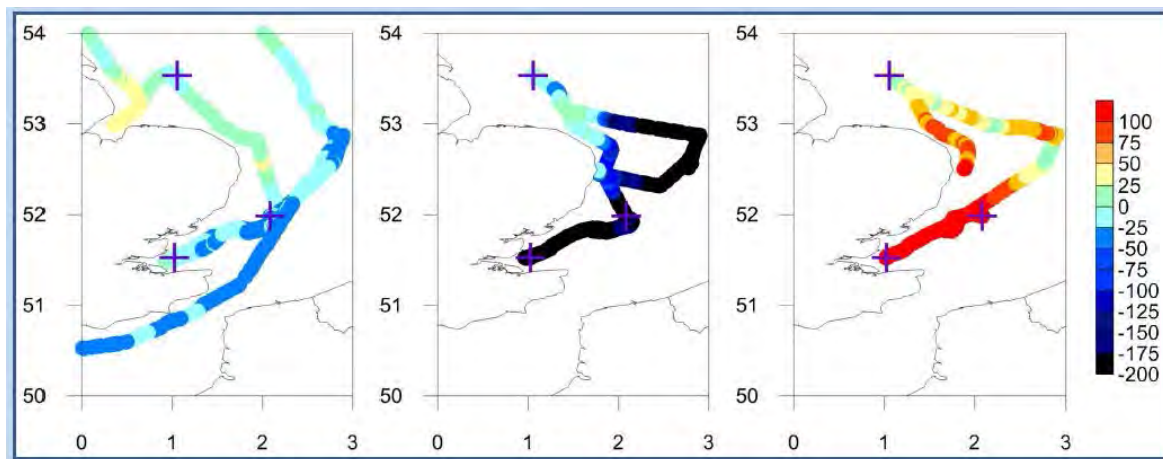


## Spatial variability in the carbonate system

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

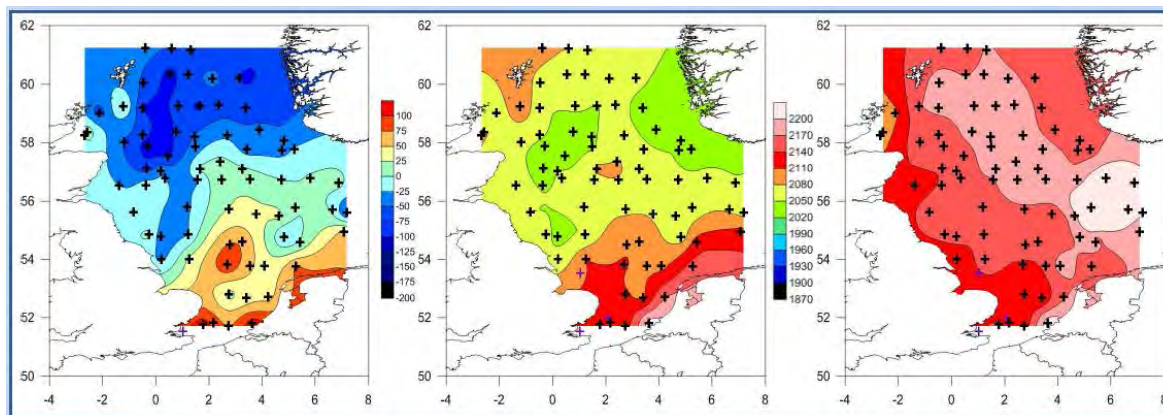
August 2013

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

$pCO_{2sw} - pCO_{2air}$

Surface DIC

Bottom DIC



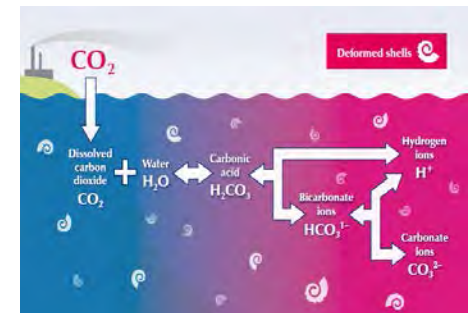
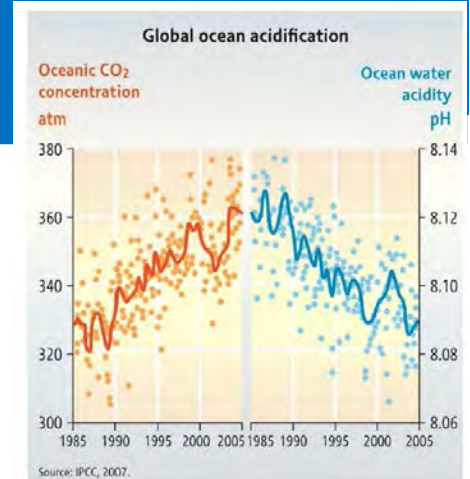
## ECONOMICS

- **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 Annual Science Conference 2015

21-25 September 2015  
DGI Byen, Copenhagen, Denmark  
[www.ices.dk/asc2015](http://www.ices.dk/asc2015)  
#ICES\_ASC

Invited speakers

Understanding patterns in marine species richness  
Prof. Elinor Östlund, National Institute of Aquatic Resources  
Danish Institute for Ecological Research, Copenhagen, DTU, Lyngby, Denmark

Too important to fail:  
Creating opportunities in small-scale fisheries  
Dr. Kallan Choudhury, Canada Research Chair in Natural Resources  
Ecosystems and Community Development, Ottawa

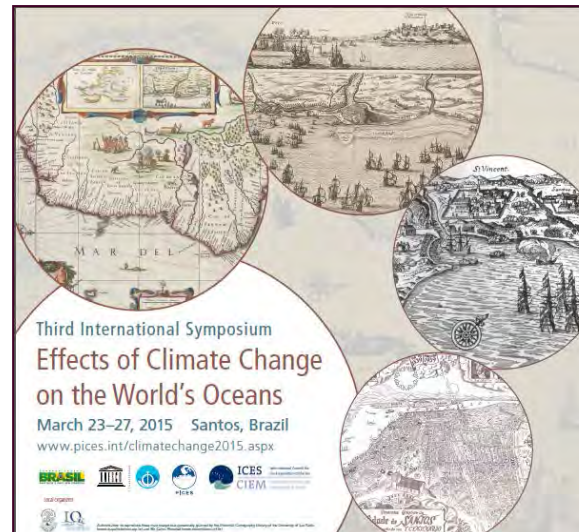
Mapping migrations onto dynamic seascapes:  
"The most essential things are invisible to the eye"  
Dr. David Garza, Chesapeake Biological Laboratory, USA

## ICES/PICES

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

**Abstract : open until 30<sup>th</sup> April 2015**

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



Third International Symposium  
Effects of Climate Change  
on the World's Oceans  
March 23-27, 2015 Santos, Brazil  
[www.pices.int/climatechange2015.aspx](http://www.pices.int/climatechange2015.aspx)

BRASIL ITCM ICES CIEM

**Ocean  
Acidification  
session  
(S2): Wednesday  
and Thursday**



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- Naomi Greenwood
- Ana Leocadio (Defra)
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- Steve Newstead (Bangor)
- Matthew Sanders
- Craig Stenton

From more information please,  
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