UK Ocean Acidification Research Programme
Benthic Acidification

UKOA FINAL MEETING
St Andrews, 22-24th July 2013.

Scaling –up benthic community function, for inclusion in food web models

Silvana N.R. Birchenough, Ruth Parker, Julie Bremner, John Pinnegar and Finlay Scott.

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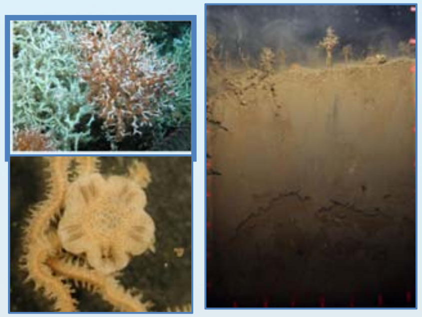
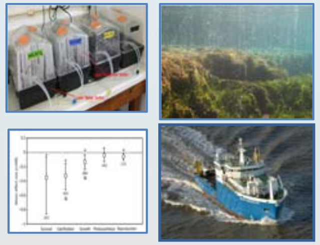
Ocean Acidification effects

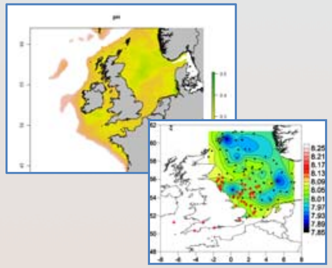
Experiments ⇄ Fauna | Habitats | Responses



Scaling- up ⇄ Meta-analysis | Experiments | Field work



Modelling ⇄ Parameters | Responses | Outcomes



OA effects ⇄ Evidence | Advice | End-users

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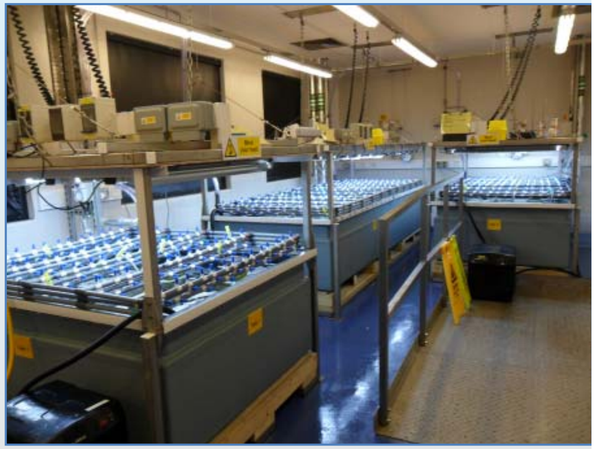
Experiments

Long-term effects of ocean acidification and climate change



•**Time:** 3,6,12,18 months

•**Parameters:**

i) growth,
ii) behaviour (bioturbation and bioirrigation)
iii) Nutrient generation
iv) metabolic depression

•**Species:** *Nereis virens*, *Amphiura filiformis* and *Ceratodesma edule.*

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Biological Traits Analysis

Species	Species traits	Assemblage traits
Species A	Deposit feeder No migration Burrower	Scavenger Deposit feeder No migration Horizontal migration Vertical migration Burrower Crawler
		
Species B	Scavenger Horizontal migration Vertical migration Burrower Crawler	
		

Bremner et al., 2003 MEPS; Bremner et al., 2006 JEMBE; Cooper et al. 2006 JEMBE; Birchenough et al. 2012

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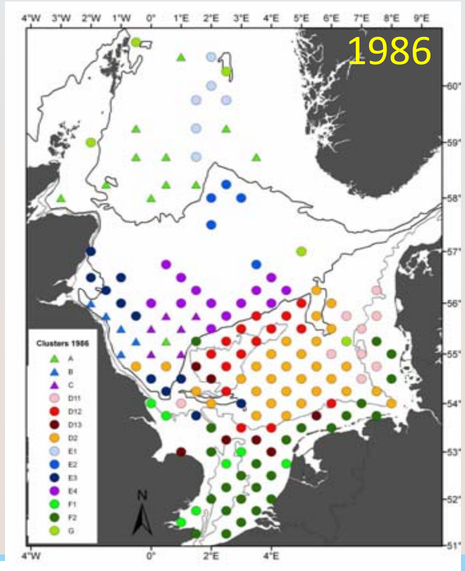
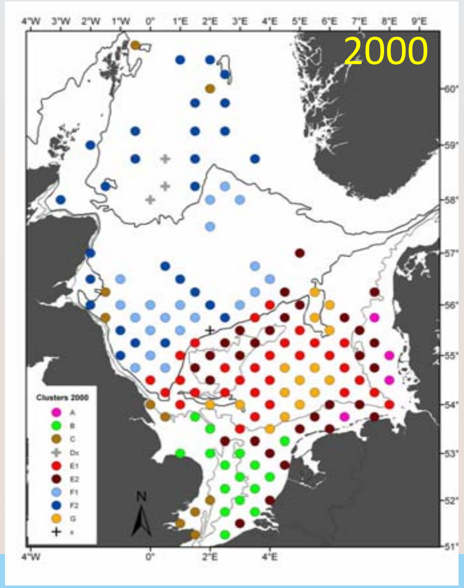
Scaling up observations

Traits	Attributes
Size (mm)	<20
	20-50
	50-100
	>100
Feeding	Carnivore (C)
	Scavenger (S)
	Selective deposit-feeder (sDF)
	Non-selective deposit-feeder (nsDF)
	Suspension-feeder (S)
Living habit	Tube
	Permanent burrow
	Free living
Bioturbation	Surface deposition (surf)
	Diffusive mixing (diff)
	Conveyor belt transport (convey)
	Reverse conveyorbelt (reverse)
	No bioturbation (No)
Reproduction type	Asexual (asex)
	Sexual-A
	Sexual-B

Trait	Function
Size	Carbon storage
Feeding	Energy transfer
Bioturbation	Nutrient cycling
Habit	Energy transfer
Reproduction	Connectivity Energy export
Larval life	connectivity

- •The ICES (NSBP, NSB)
- •Good spatial extent
- •Mapped benthic communities
- •Environmental conditions (sediment types, OM)





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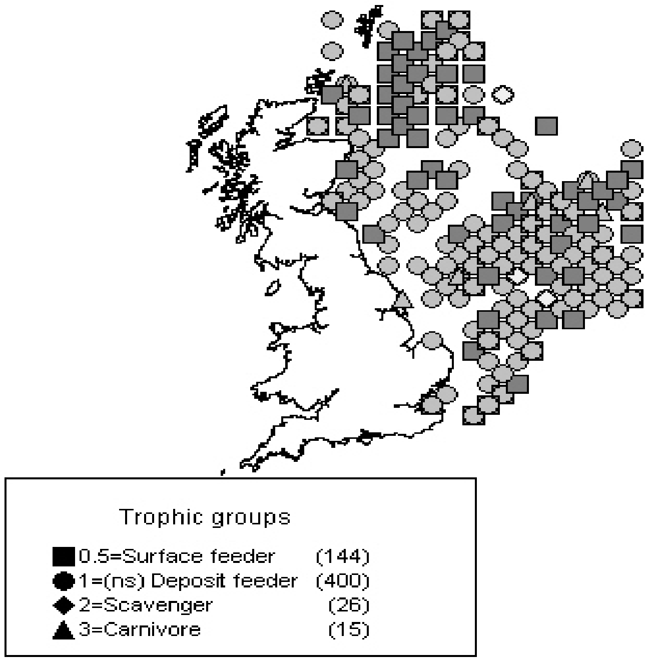
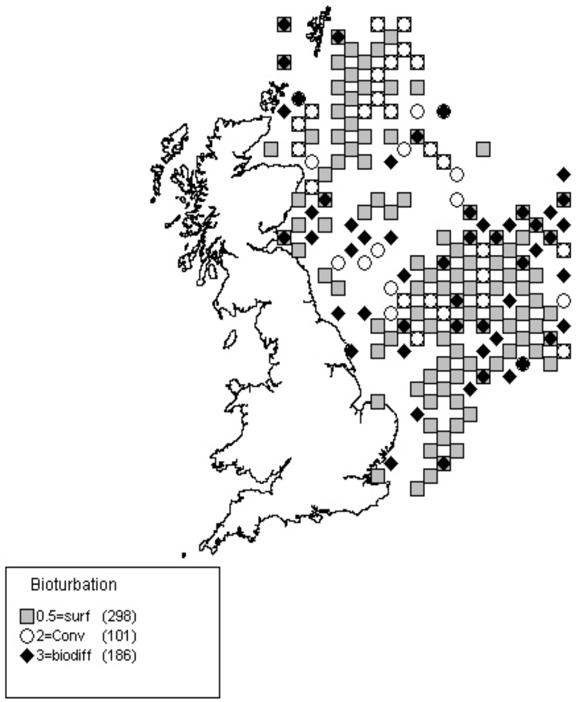
Mapping functions

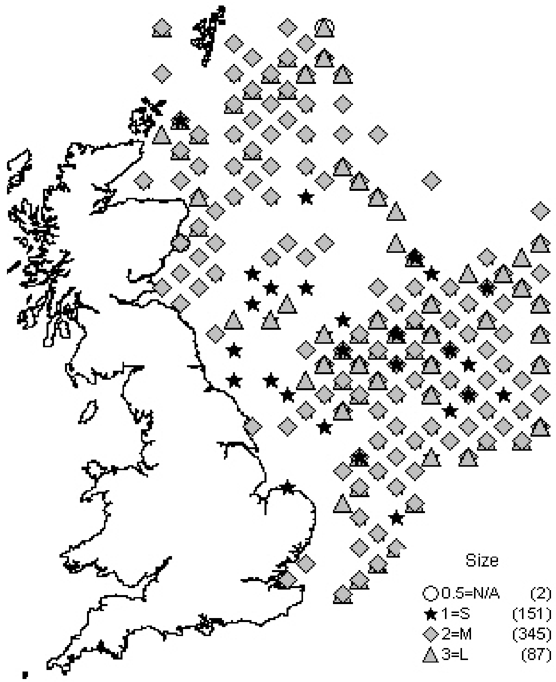
benthic traits for North Sea assemblages to map benthic function



Feeding
Carbon Storage



Bioturbation
Nutrient cycling



Size
Energy transfer

OA responses

Experimental evidence

•Implications (life-stages)
•Growth reduction (mass)
•Shell dissolution
•Behaviour

↓

Adaptation or Mortality

→

Responses

Traits

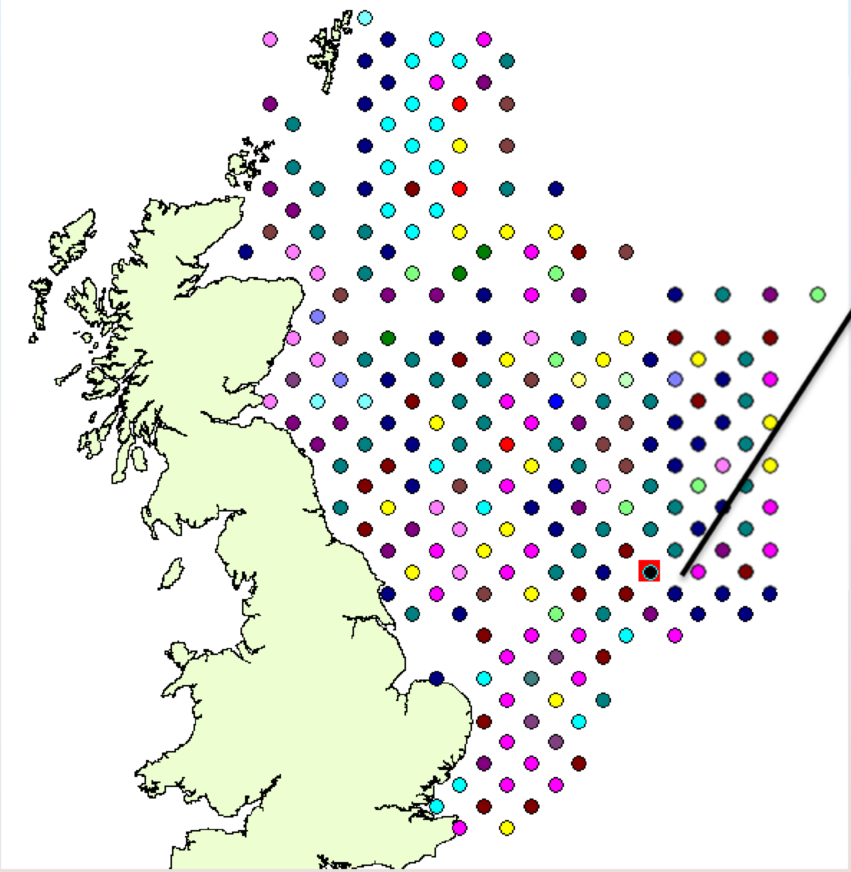
•Size
•Calcification (e.g. shells/skeleton)
•Feeding (energy)
•Physiological responses:

↓

Response to OA

•Sensitivity review : experiments, metadata, ecologists, physiologists….
•Expert judgement

OA traits



1. *Amphiura filliformis, lunatia catena, Liocarcinus holsatus , Upogebia deltaura, etc…*

Amphiura filiformis=> Echinoderm

Calcification:

- Presence of a skeleton or shell

Feeding:

- Suspension feeder

Physiological response:

- Low control of metabolic activity
- Low osmo-regulation
- *Base line homostasis*

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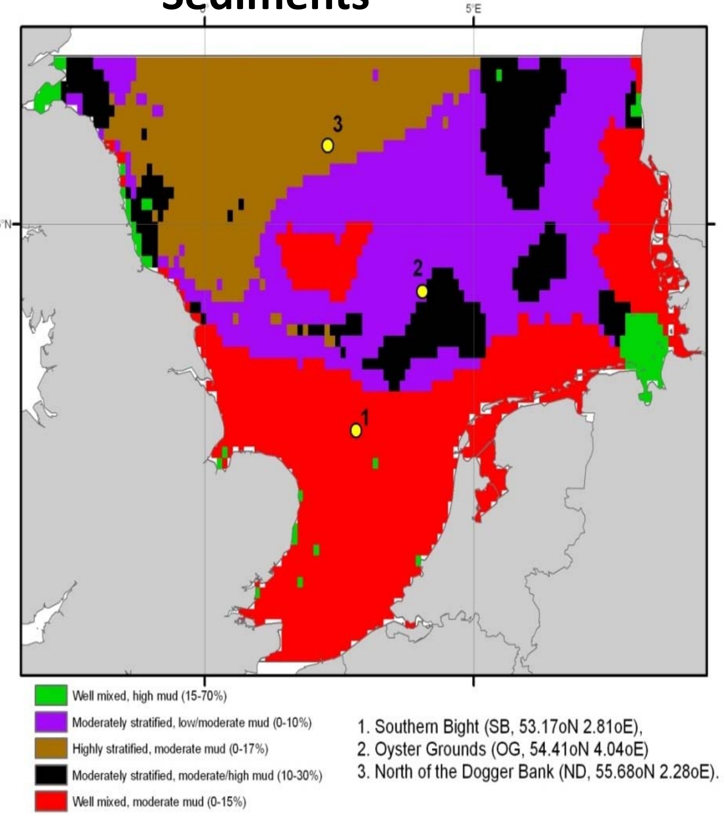
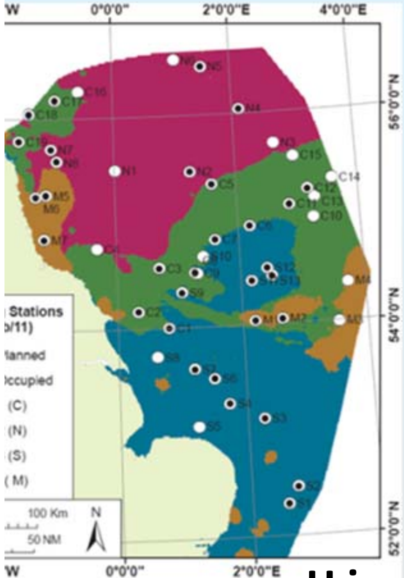
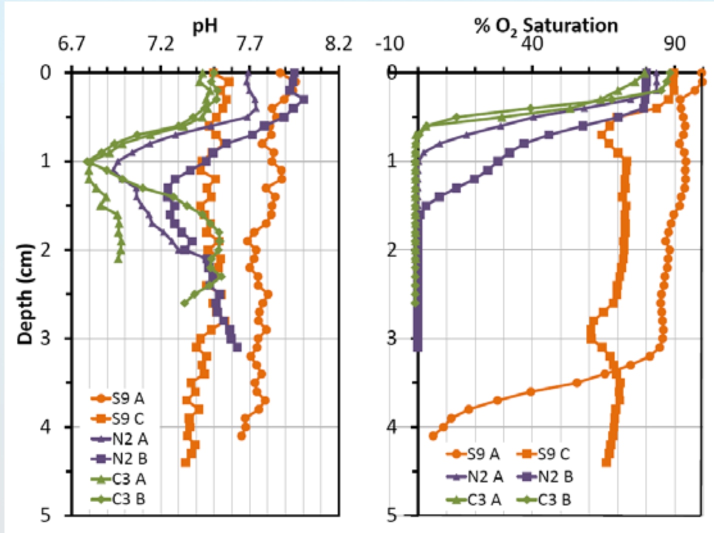
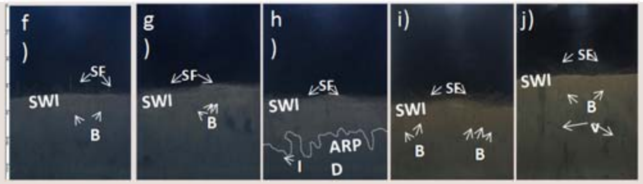
NS Environment

Sediments









pH in sediments

- Contrast muddy and sandy sediments (Perm and not)

- Decrease in pH in sediment porewater (ca. 0.5-1 pH unit within the top 1-2 cm of sediment) in the central and northern North Sea areas, correlated with the sharp decrease in oxygenation
- Southern North Sea the coarser and more deeply oxygenated sediments do not show the same trend.
- Significant spatial heterogeneity

key components of pH controls
(IC, OC, biotic/abiotic sediment matrix)

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MODELLING REGIONAL IMPACTS OF OA

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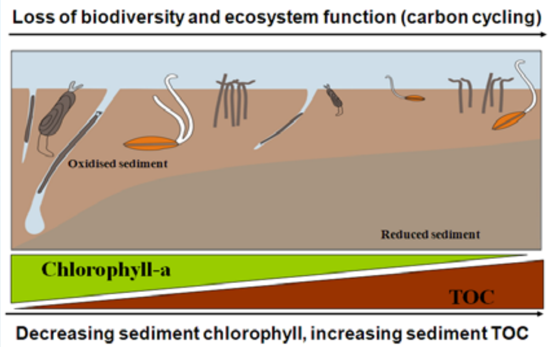
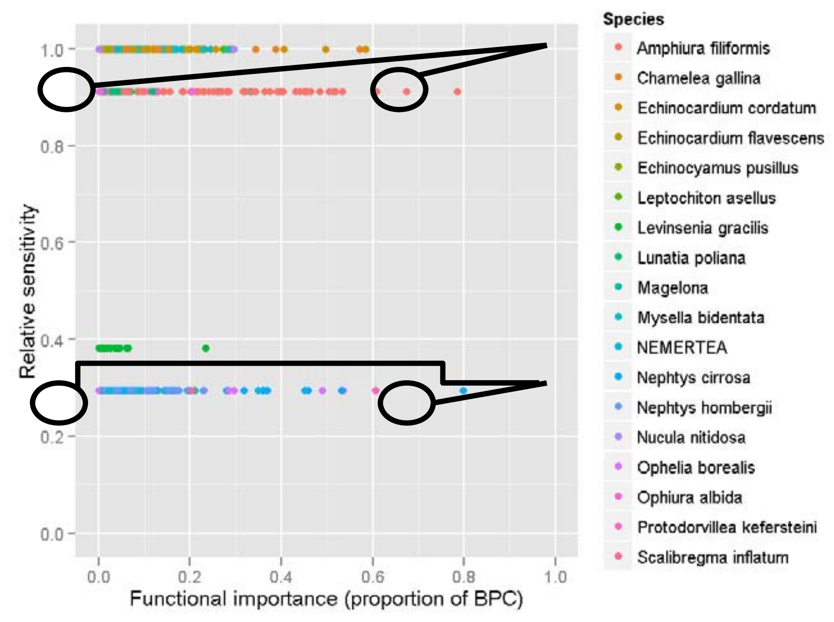
•Investigation of regional impact of ocean acidification on sediment function (BPc, organic C fractions) – North Sea.

•Combining regional BPc/organic C models, sensitivity of species to OA, their functional importance and regional assemblage differences
•=> Potential sensitivity and futures

•Sensitivity defined by BTA for each species
•Sensitivity and function:
Amphiura is very important at some sites, not at others, high sensitivity
Nephtys cirrosa – important at some sites, but less sensitive
Combination gives potential site response





Scott, F ., Parker , R.E., and Birchenough, SNR. (*in prep*.) Predicting the regional impacts of ocean acidification: integrating sediment assemblage characteristics and ecosystem function. *Biogeosciences*

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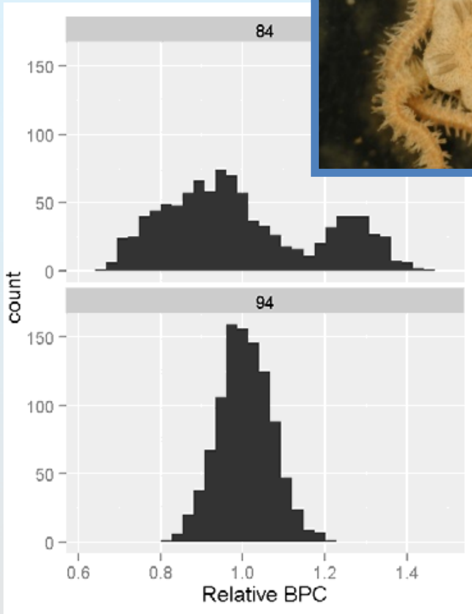
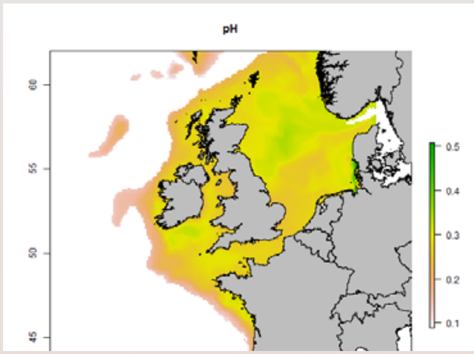
MODELLING REGIONAL IMPACTS OF OA

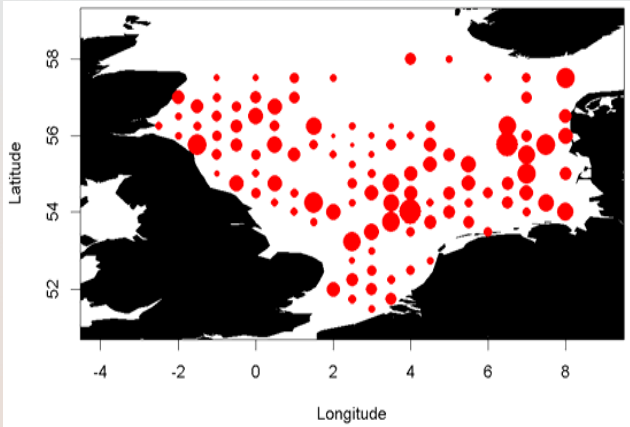
•Stochastic simulations were performed separately at each station.

•Illustrates the potential for species and areas to be affected by OA using probabilities of OA pressure rather than a direct scenario per se.

•Spread of BPc relative to baseline BPc for two stations
•Range of values ~ magnitude of impact of an OA stressor
•Wider range = bigger potential impact







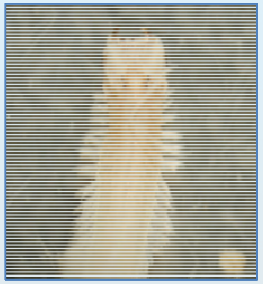
Overall….

•Understanding the effects of ocean acidification on benthic organisms is rapidly advancing, but still most of the experiments are targeted to single species, very few have concentrated on assemblages;

•Experiments, meta-analysis and expert judgment can be combined into a BTA framework to scale up OA responses for benthic systems and to map benthic function.

•The BTA analysis is useful as it can combine a suite of information: ecology, physiology, morphology to provide an overall assessment of community responses,

•Experimental evidence is rapidly advancing and this type of approaches can be augmented as more data is available and traits categories and analysis can help to parameterise ecosystem models and responses.



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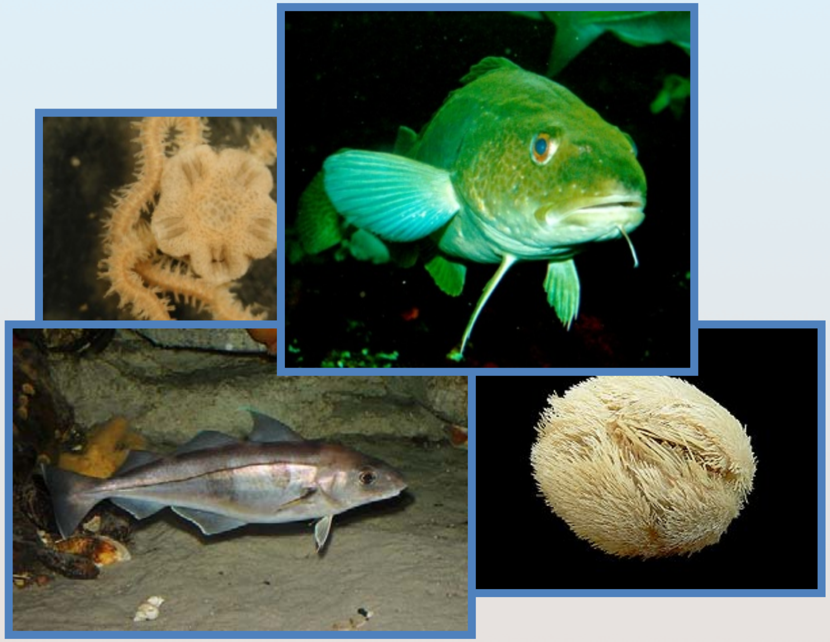
How might ocean acidification affect fisheries and food-webs?



John K. Pinnegar, Silvana Birchenough
Bryony Townhill and
William J.F. Le Quesne

Manuscript submitted to ICES Journal of Marine Science (May 2013)

VECTORS

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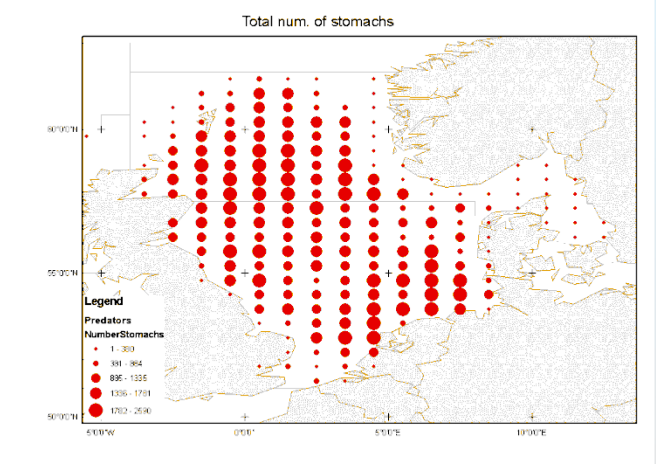
fizzyfish

Two complimentary databases….

We examined fish stomach content data from two sources.

The ICES 'Year of the Stomach' (YOS) database comprises North Sea fish records collected in 1981 and in 1991. This dataset has excellent spatial coverage in the North Sea however, it only contains information on eight key predator species

The Cefas DAPSTOM database contains information on the feeding preferences of 149 fish species, but is not as spatially-resolved as the YOS dataset.



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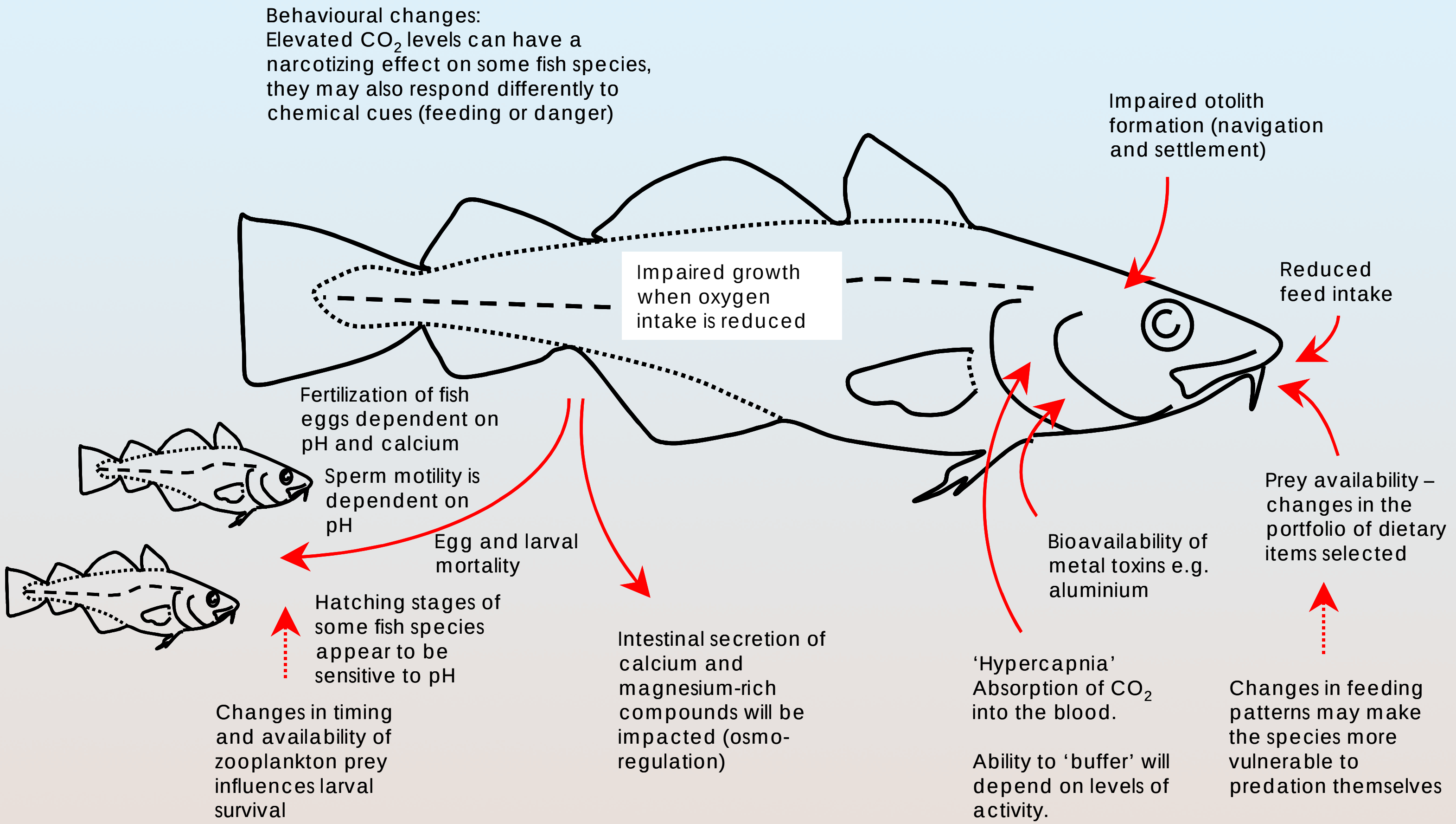
How might fish be affected???



We suspect that indirect (food-web) effects may be more important for fish, than direct physiological impacts.

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Who eats them?

Ophiuroids (including *Amphiura*) are an important prey item for dragonet, dab and haddock but are occasionally consumed by a further 13 species

Predator Name	***Amphiura* consumed**	**Total ophiuroids consumed**	**Number of stomachs examined**	**Number of empty stomachs**	***Amphiura* per stomach**	**Ophiuroids per stomach**
Catfish	-	3	15	1	-	**0.214**
Dragonet	-	24	42	26	-	**1.500**
Cod	9	153	12321	811	0.001	0.013
Dab	395	659	2115	288	**0.216**	**0.361**
Grey gurnard	-	1	5242	1919	-	0.000
Haddock	941	2483	8966	1666	**0.129**	**0.340**
LR Dab	6	16	222	73	0.040	**0.107**
Plaice	107	464	7919	817	0.015	0.065
Sole	3	12	518	167	0.009	0.034
Herring	-	1	11510	8637	-	0.000
Lemon sole	-	4	656	146	-	0.008
Megrim	-	1	65	31	-	0.029
Whiting	9	42	18374	9570	0.001	0.005
Sandeel	-	1	161	33	-	0.008
Tub gurnard	-	1	139	19	-	0.008
Witch	-	1	90	29	-	0.016



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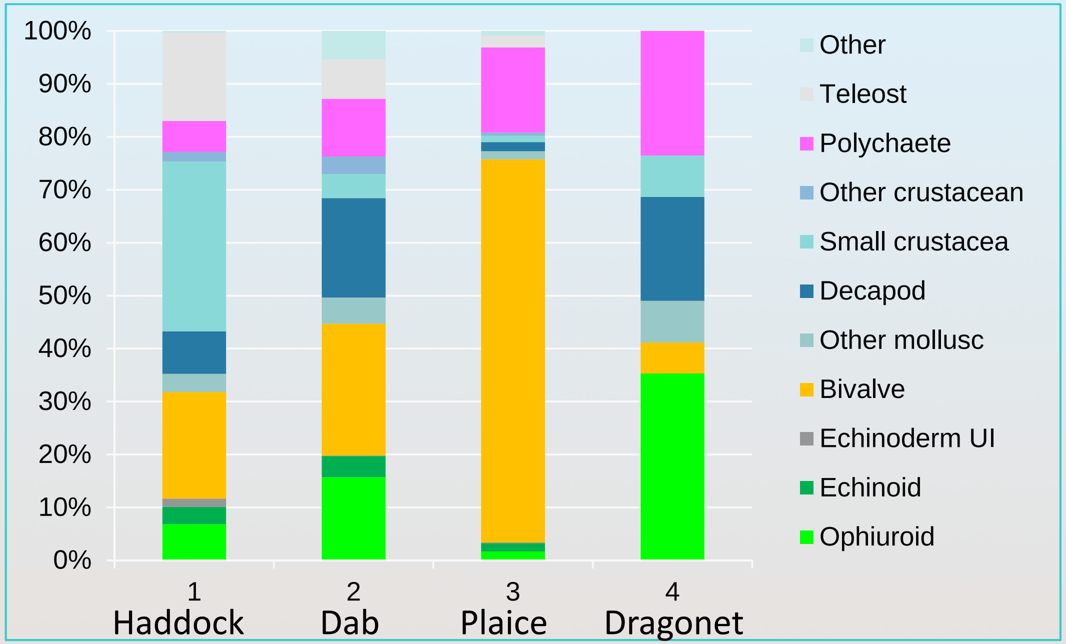
How important are they as a prey item?

Percentage of prey items



Diet % ophiuroid	6.8	15.7	1.7	35.3
Diet % echinoderm	11.7	19.8	3.4	35.3
Ophiuroids per fish	0.34	0.36	0.07	1.50
North Fish Sea Biomass (tonnes)	59300	2600000	400700	17700
QB Ratio	2.4	4.0	3.4	6.9
Mass of food consumed (tonnes)	139355	10400000	1370394	122130
Mass of ophiuroids consumed (tonnes)	**9493**	**1634498**	**23065**	**43105**
Approx number consumed	**47464289781**	**8.172E+12**	**1.15E+11**	**2.16E+11**

Duineveld & Van Noort (1986) suggested that annual consumption of *Amphiura* arms by Dab was of the order of 0.84 g wet weight m^2 or 6% of the population per year.

ophiuroids in the North Sea

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What would happen if they were gone?

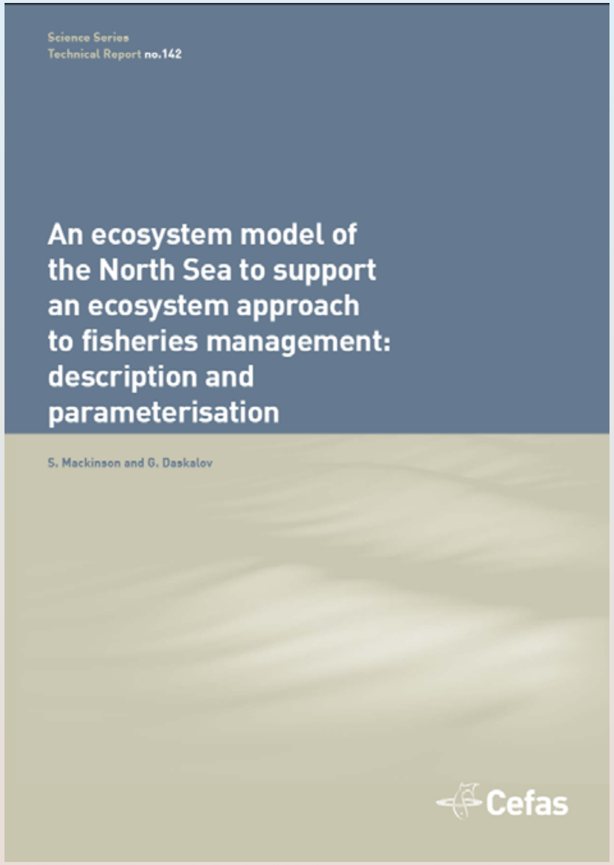
Mackinson & Daskalov constructed a complex ecosystem model for the North Sea, which incorporates 68 functional groups and 12 fleet categories defined by the EU Data Collection Regulations.

Parameterisation for each functional group was reviewed by external experts

This model was used to investigate the impact of declining echinoderms on fishes, fishing fleets and profits etc.

Echinoderms are included in the model as:

1. 'Epifaunal macrobenthos'
2. 'Infaunal macrobenthos'



Cefas Technical Report, Number 142

Two scenarios

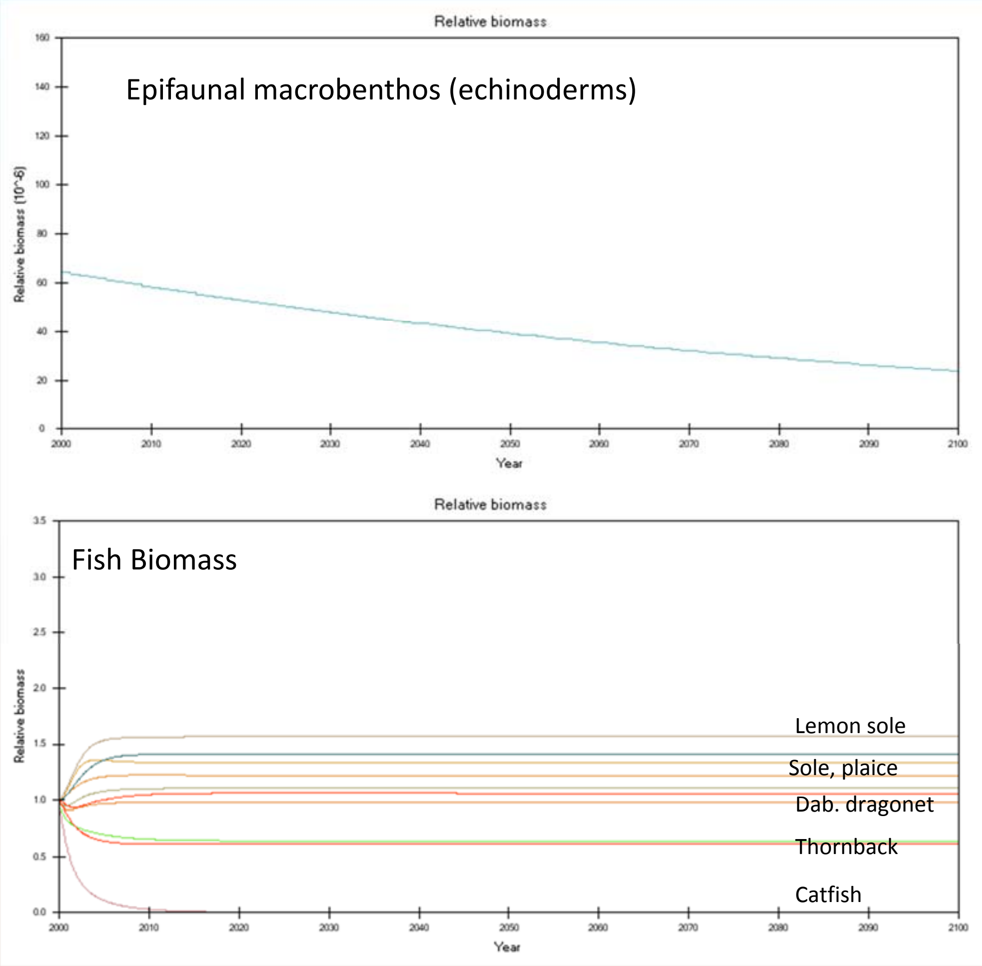
Echinoderms are included in the model as:

1. 'Epifaunal macrobenthos'
2. 'Infaunal macrobenthos'

•1% decline (year on year) in 'Epifaunal macrobenthos' or 'Infaunal macrobenthos' biomass would equate to an effect size of 0.63 over the 100 year duration

•A 0.5% year on year decline would equate to an effect size of 0.39,

•These are broadly comparable in magnitude to those from laboratory studies (Dupont et al. 2010)

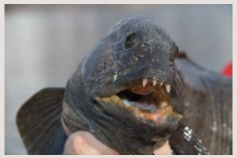


Winners & losers…..

Winners…….




Losers…….




	OA impact on epifaunal macrobenthos	OA impact on infaunal macrobenthos	OA impact on both groups
	V=2	V=2	V=2
Epifaunal macrobenthos	**0.61**	**1.33**	**0.61**
Infaunal macrobenthos	1.13	**0.61**	**0.61**
Small sharks	**0.73**	1.06	**0.59**
Thornback/spotted ray	**0.64**	1.17	**0.74**
Cod (adult)	1.01	1.13	**1.23**
Whiting (adult)	1.08	1.07	**1.25**
Haddock (0-20cm)	1.13	**1.32**	**1.65**
Haddock (adult)	1.15	1.18	**1.52**
Norway pout	1.16	0.88	0.88
Saithe (adult)	1.10	0.92	0.91
Mackerel	1.16	**1.49**	**2.09**
Sandeel	1.09	**1.25**	**1.62**
Plaice	**1.41**	**2.11**	**3.70**
Dab	1.01	**1.58**	**1.90**
Long-rough dab	**1.21**	**1.33**	**1.95**
Dragonets	**1.33**	**1.99**	**3.15**
Sole	**1.23**	**1.59**	**2.72**
Lemon sole	**1.55**	**2.34**	**4.32**
Catfish	**0.00**	**1.17**	**0.00**
Nephrops	**1.52**	**1.31**	**2.23**
Large crabs	1.01	0.84	**0.49**
Small mobile epifauna	0.99	1.19	**1.24**
Infauna (polychaetes)	1.11	**1.34**	**1.69**

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Fisheries winners & losers??

	OA impact on epifaunal macrobenthos	OA impact on infaunal macrobenthos	OA impact on both groups
	V=2	V=2	V=2
Demersal trawl (catch)	1.08	**1.23**	**1.50**
Demersal trawl (value)	1.13	**1.32**	**1.79**
Beam trawl (catch)	**1.27**	**1.83**	**3.01**
Beam trawl (value)	**1.26**	**1.71**	**2.88**
Nephrops trawl (catch)	1.18	**1.33**	**1.91**
Nephrops trawl (value)	**1.34**	**1.47**	**2.37**
Drift and fixed nets (catch)	1.15	**1.50**	**2.19**
Drift and fixed nets (value)	1.16	**1.48**	**2.23**
Gears using hooks (catch)	1.11	**1.29**	**1.68**
Gears using hooks (value)	1.11	**1.27**	**1.64**
Total fishery catch	1.10	**1.27**	**1.62**
Total fishery value	1.10	**1.38**	**1.85**

Catastrophic predictions regarding the economic consequences of ocean acidification may be over-stated!!!!!

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Some conclusions……

1. Large quantities of echinoderms are eaten by commercial and non-commercial fish, but they are rarely a major part of the diet

2. Some echinoderms may be negatively impacted by ocean acidification but this is context specific

3. We have a suite of tools available to examine the indirect consequences of ocean acidification on the rest of the foodweb, if we can agree which organisms will be impacted…

4. It does not necessarily follow that a loss of echinoderms (or bivalve molluscs) will result in negative consequences for fin-fish fisheries

Overall….

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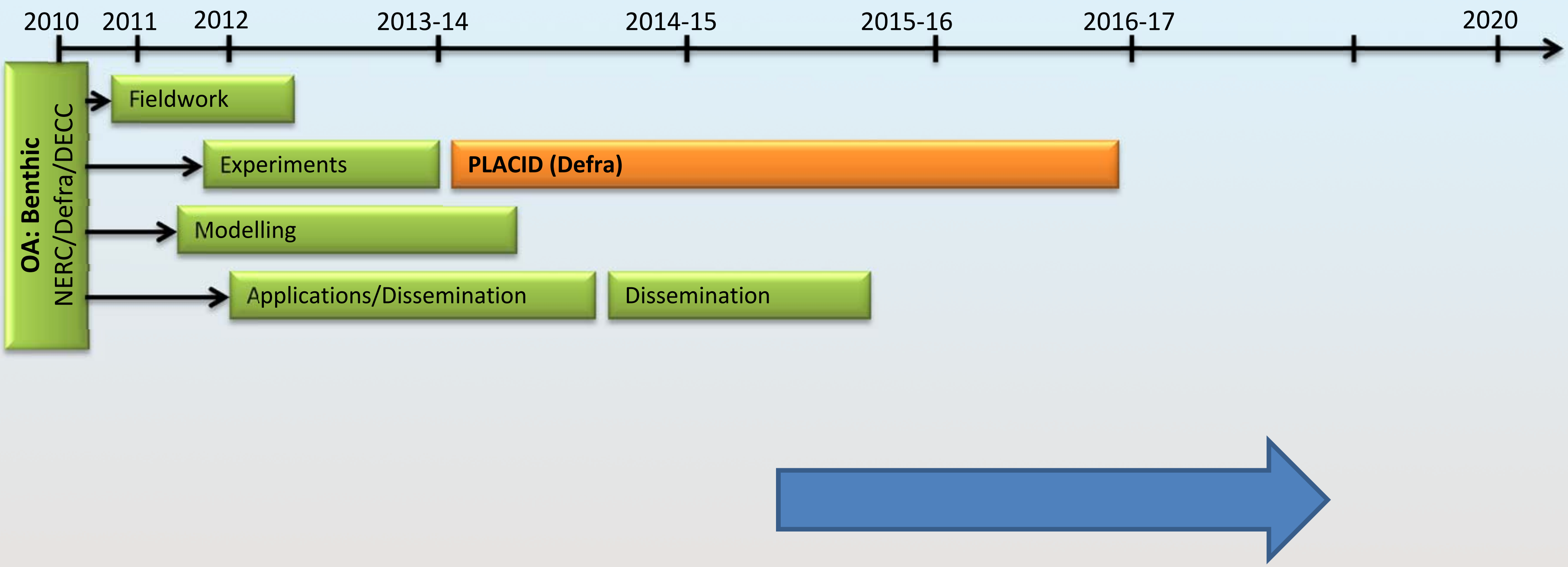
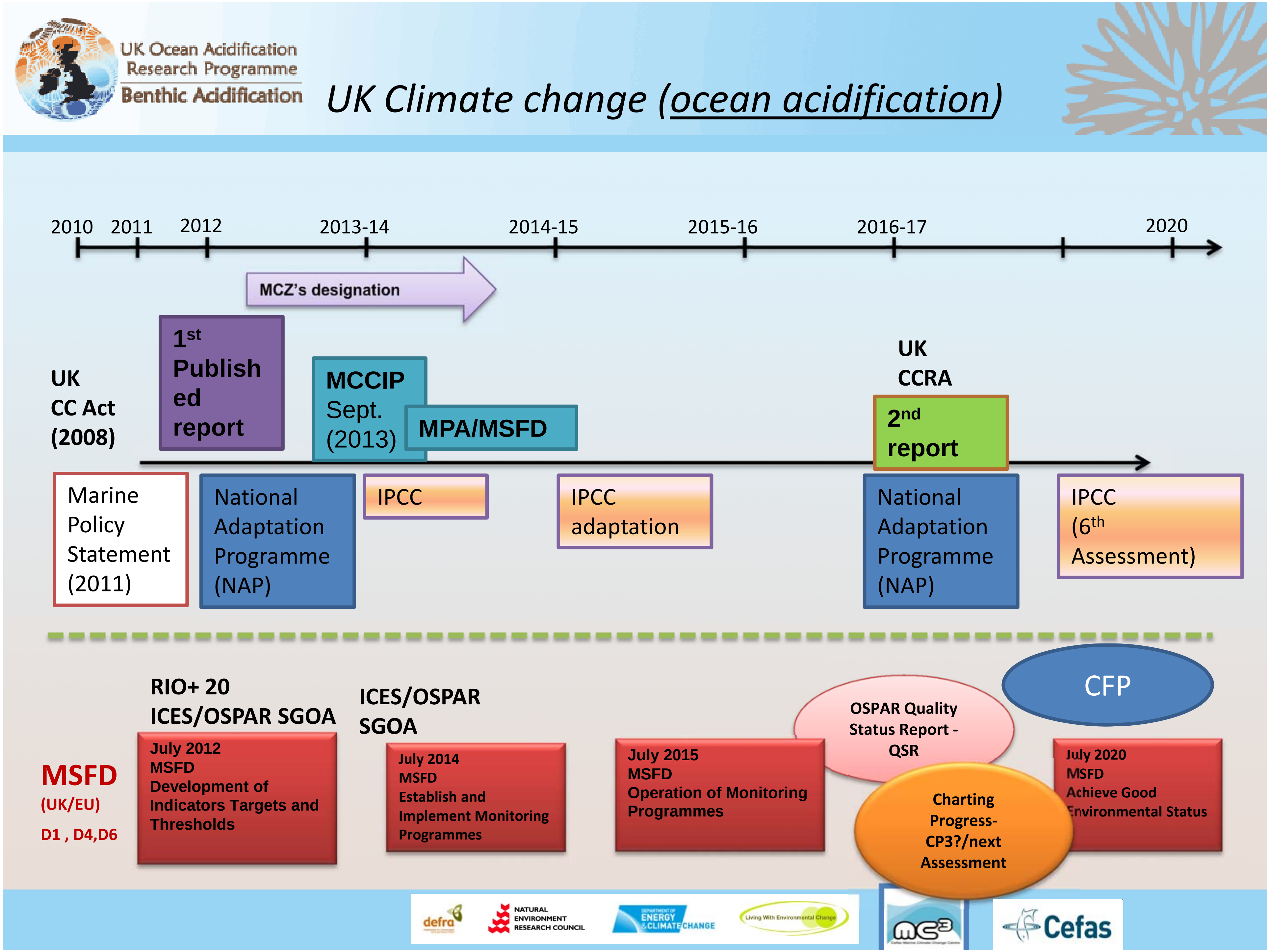
UK Climate change (<u>ocean acidification</u>)

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Benthic Acidification
UK Climate change (ocean acidification)
2010
2011
2012
2013-14
2014-15
2015-16
2016-17
2020
MCZ's designation
1st Publish ed report
UK CC Act (2008)
MCCIP Sept. (2013)
MPA/MSFD
UK CCRA
2nd report
Marine Policy Statement (2011)
National Adaptation Programme (NAP)
IPCC
IPCC adaptation
National Adaptation Programme (NAP)
IPCC (6th Assessment)
RIO+ 20
ICES/OSPAR SGOA
ICES/OSPAR SGOA
OSPAR Quality Status Report - QSR
CFP
MSFD
(UK/EU)
D1 , D4,D6
July 2012 MSFD Development of Indicators Targets and Thresholds
July 2014 MSFD Establish and Implement Monitoring Programmes
July 2015 MSFD Operation of Monitoring Programmes
Charting Progress- CP3?/next Assessment
July 2020 MSFD Achieve Good Environmental Status
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Acknowledgements……

- NERC/Defra/DECC
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