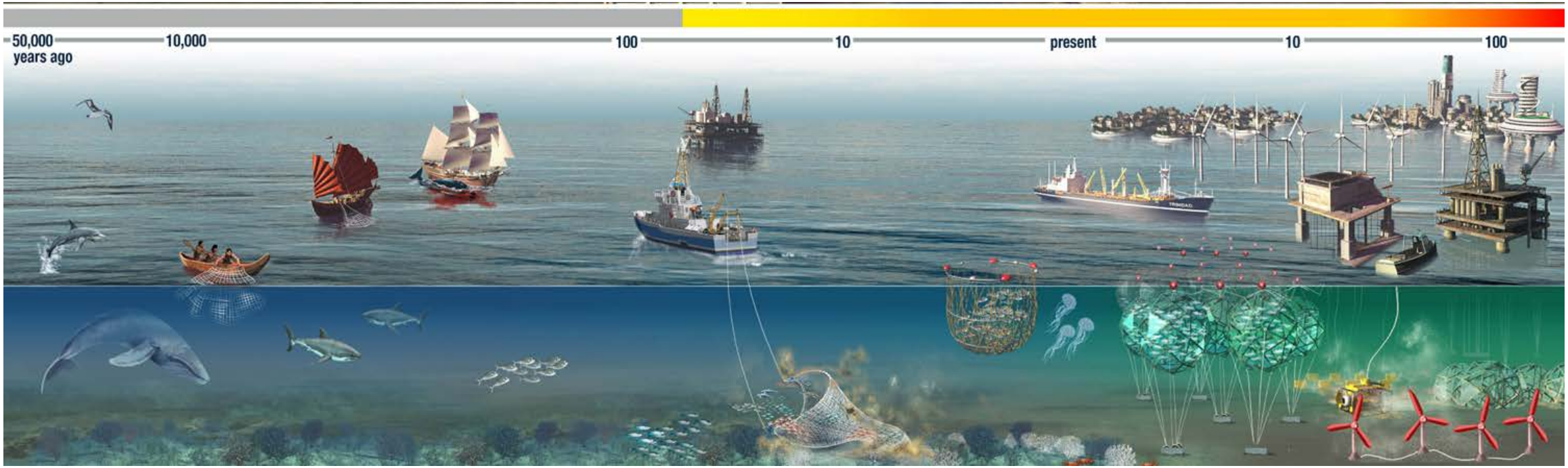
Ecologically sustainable futures for large scale renewables and how to get there…



McCauley et al. Science 16 Jan 2015

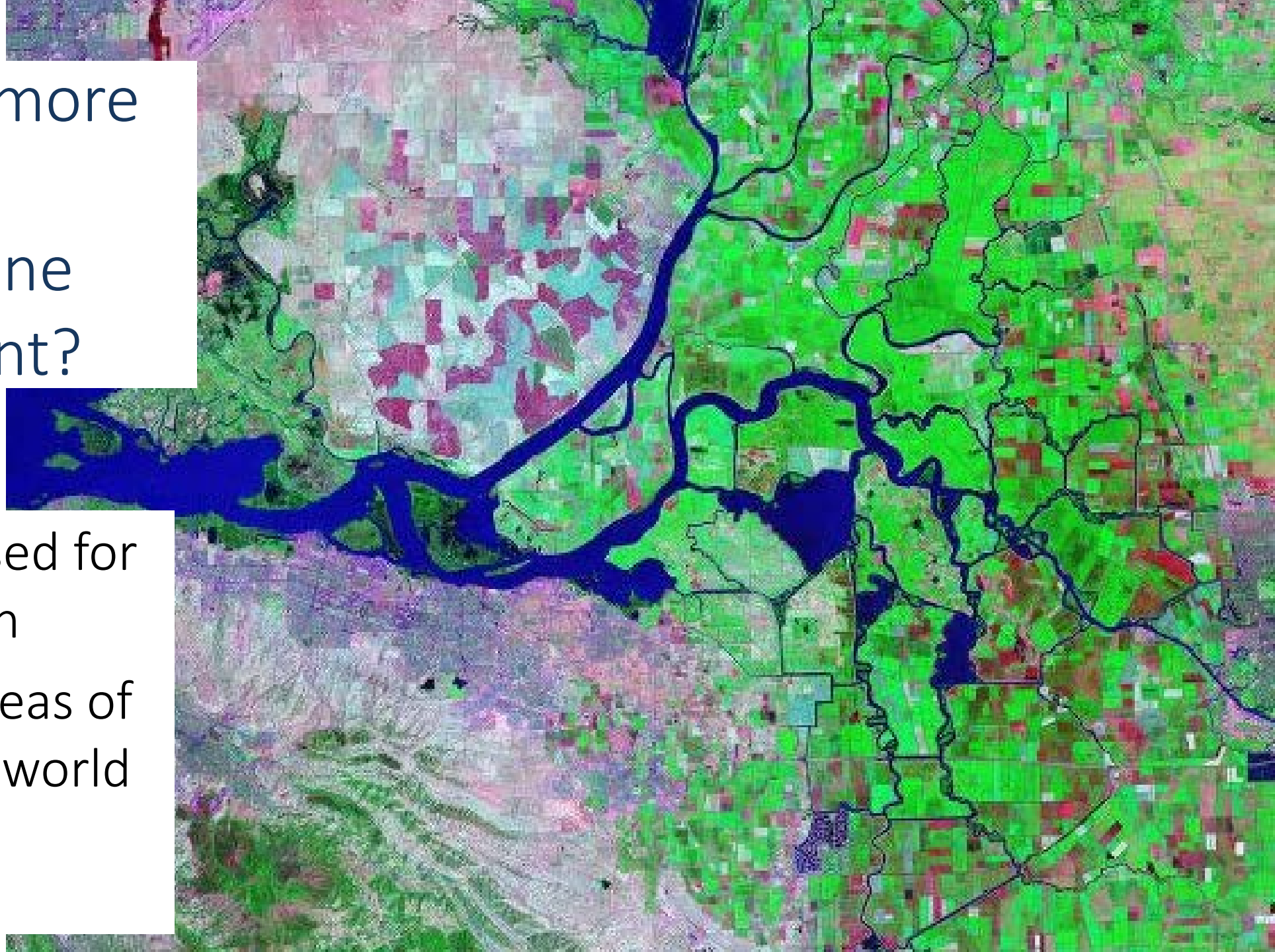
Prof. Beth Scott b.e.scott@abdn.ac.uk

Supergen Offshore Renewable Energy

EPSRC Engineering and Physical Sciences Research Council

UNIVERSITY OF ABERDEEN

Can we plan more sensibly in the marine environment?



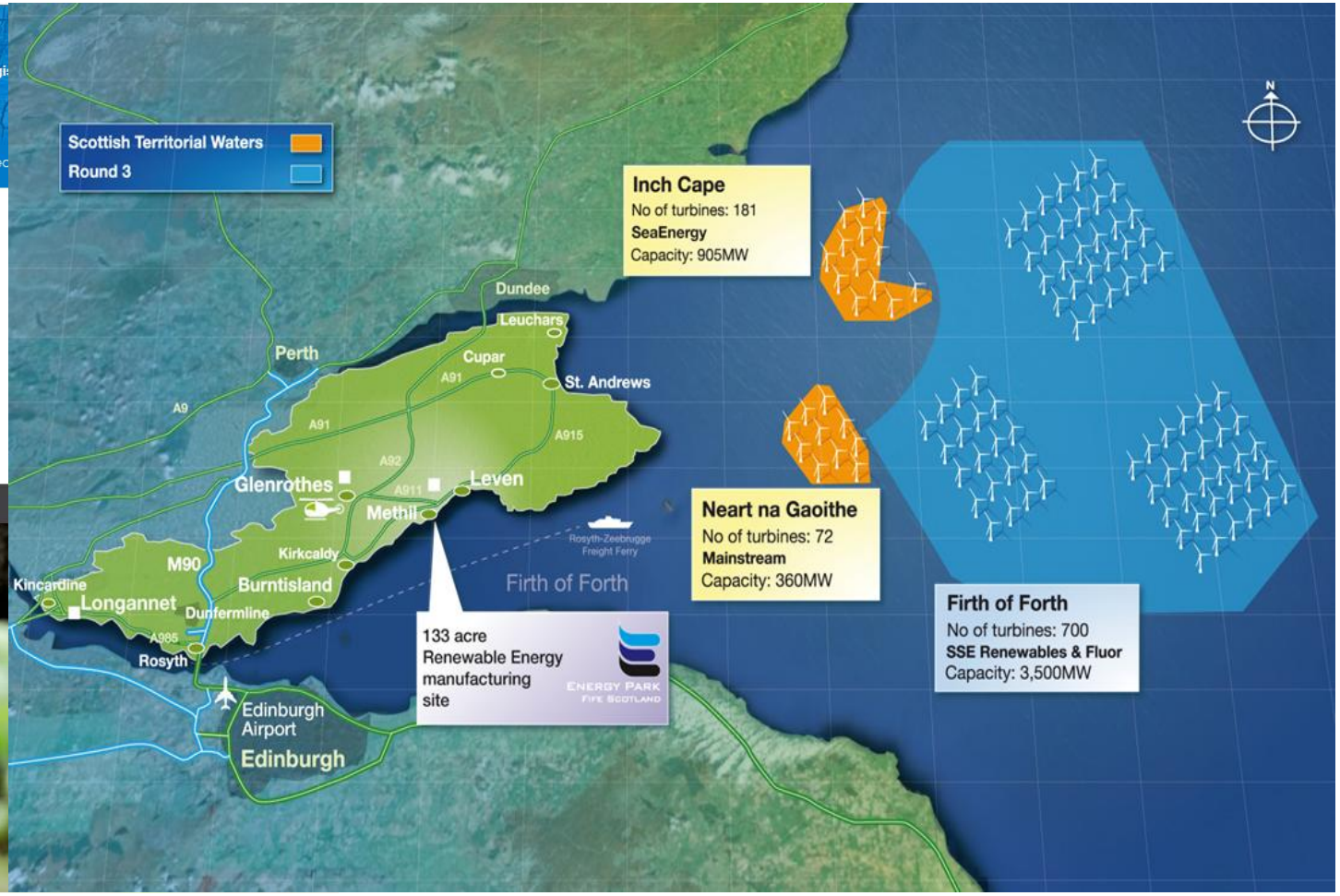
River Deltas used for habitation

Most fertile areas of the terrestrial world

SHOW STOPPERS: Laws and Process

RSPB Judicial Review in 2014 for Firth of Forth Wind farms -won/ Scot Gov appealed -won

3 Year Delay



Horrendrogram of laws that can effect offshore renewables

Marine Pollution Bulletin 86 (2014) 39–47

Contents lists available at ScienceDirect

Marine Pollution Bulletin

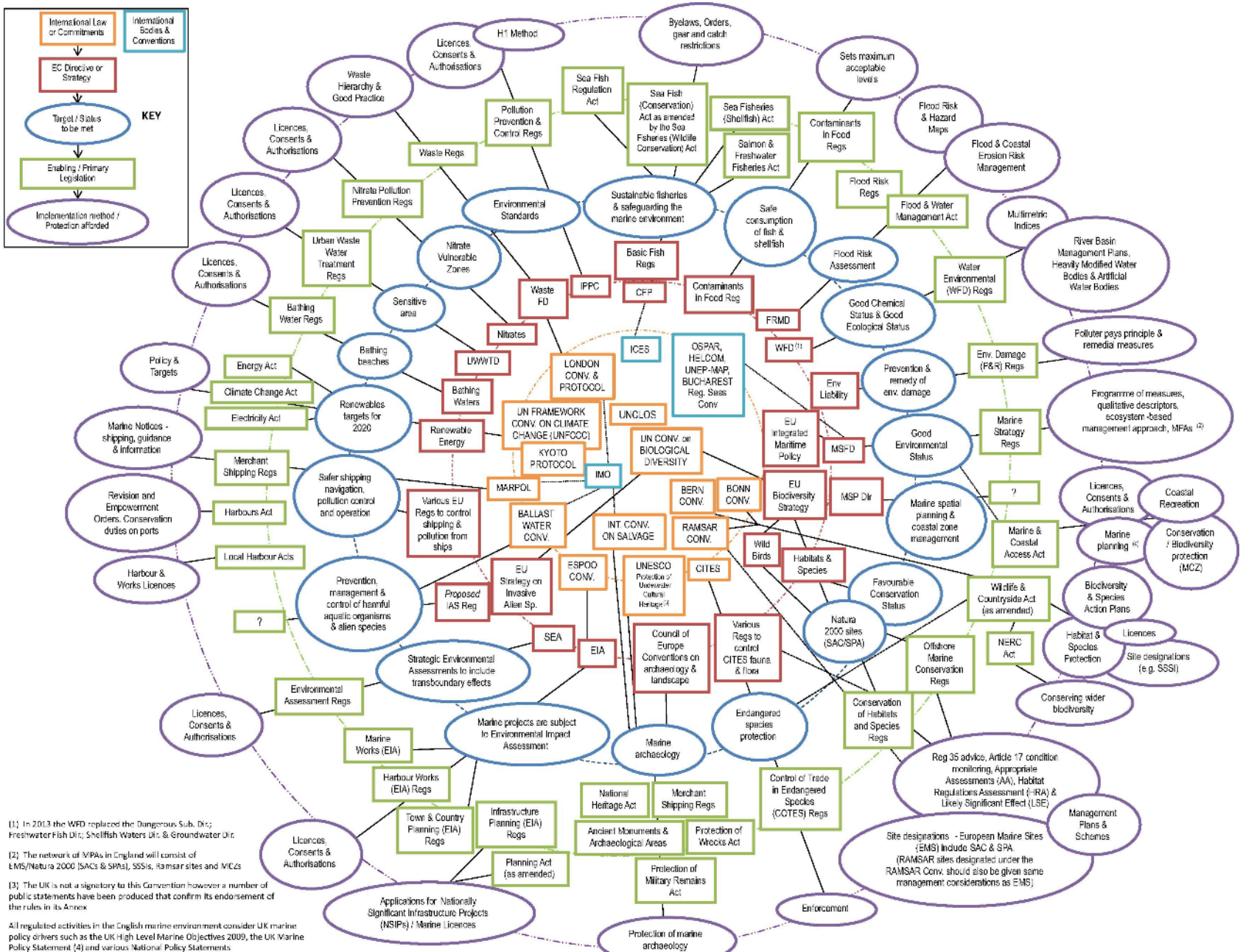
journal homepage: www.elsevier.com/locate/marpolbul

Viewpoint

Marine legislation – The ultimate 'horrendogram': International law, European directives & national implementation

Suzanne J. Boyes *, Michael Elliott

Institute of Estuarine and Coastal Studies (IECS), University of Hull, Hull HU6 7RX, UK



[1] In 2013 the WFD replaced the Dangerous Sub. Dir.; Freshwater Fish Dir; Shellfish Waters Dir. & Groundwater Dir.

[2] The network of MPAs in England will consist of EMS/Natura 2000 (SACs & SPAs), SSSIs, Ramsar sites and MCZs

[3] The UK is not a signatory to this Convention however a number of public statements have been produced that confirm its endorsement of the rules in its Annex

All regulated activities in the English marine environment consider UK marine policy drivers such as the UK High Level Marine Objectives 2009, the UK Marine Policy Statement (4) and various National Policy Statements

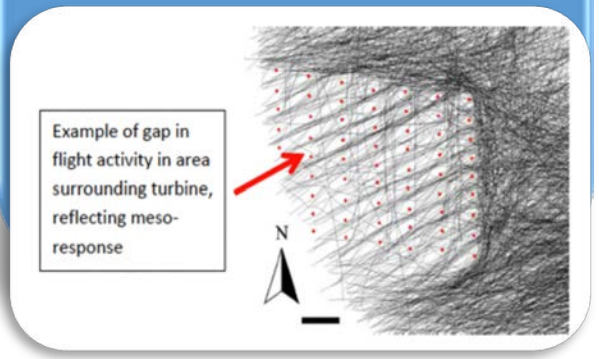
The 3 D's of Environmental Impacts

Disturbance

Reactions to boats, noise, etc. leads to more energy use and lack of ability of feed.

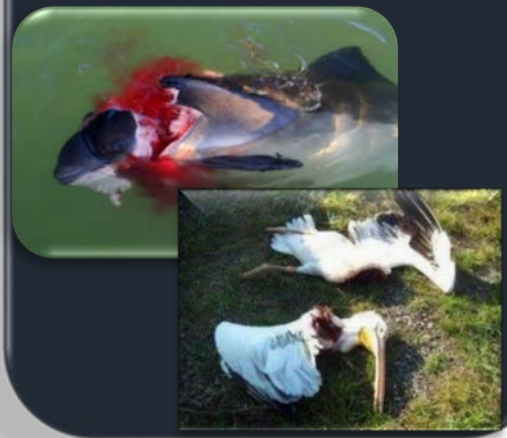
Displacement

Large scale (permanent) changes in movement/dispersal: daily foraging routes, annual migrations, ability of larvae to disperse



Death

Collision,
Entanglement,
Seabed habitat destroyed



Thou shalt not! Laws= Habitat & Bird Directives (Natura 2000) + MSFD

UNIVERSITY OF ABERDEEN

Outline:

Why is it important for engineers to consider ecological effects:

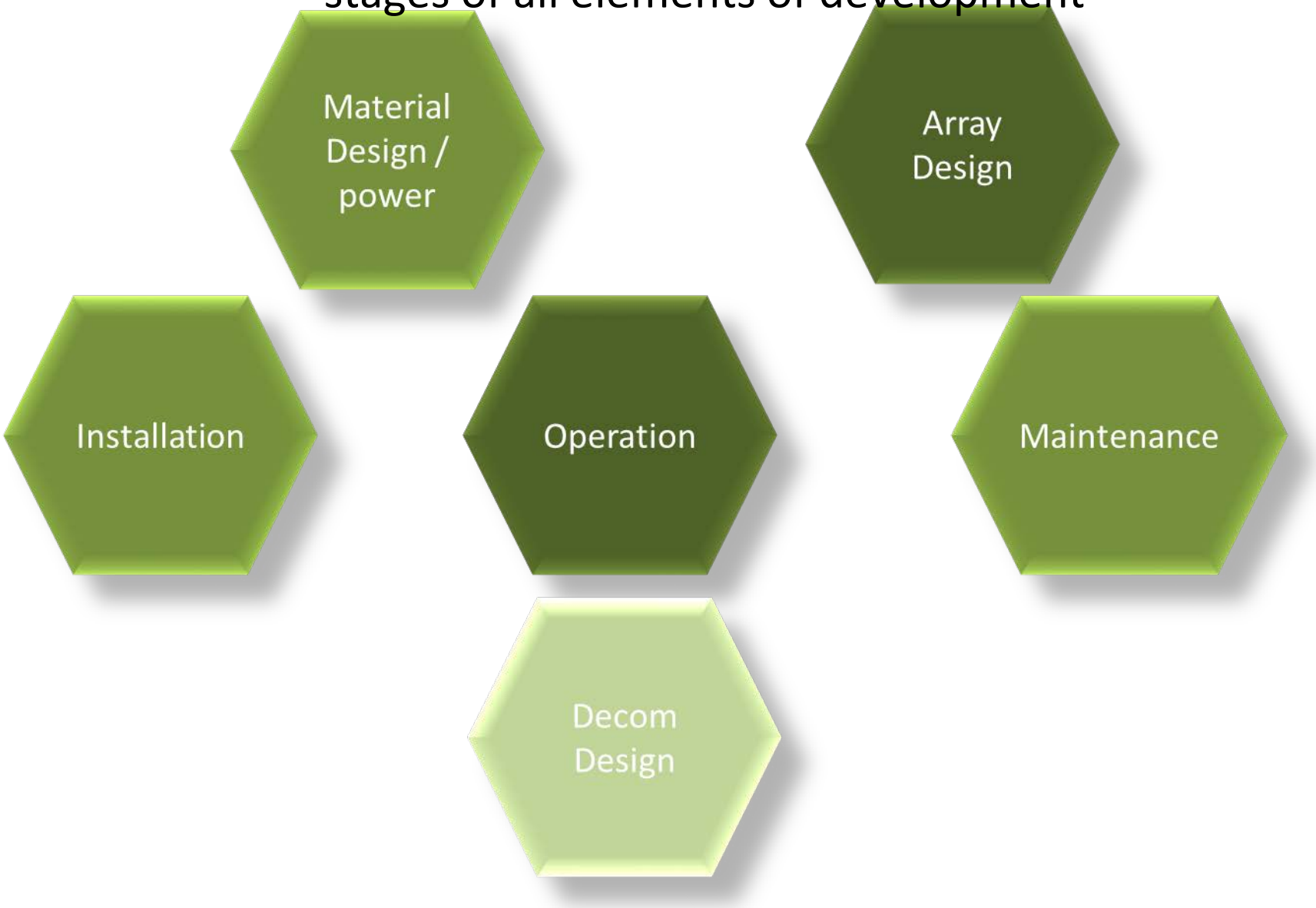
- Single turbine,
- Array design and location
- Cumulative effects of multiple arrays

- What about the FISH?
  - State of the art approaches predictably connecting animal behaviour to physics

- What about climate change?
- What about a new Framework for EIA / post consent process?

What can be done?

Ecologist working with Engineer in the designing stages of all elements of development



What can be done?

Noise
Blade/moving part design & hardness & speed
Shapes of components (attach-ability /growth)
Moorings: effects on benthos

Noise (effects on prey and predator)
Lines/ fences (barriers or cluster):

- Changes in prey availability
- Changes in flow – dispersal of larvae
- Changes in sedimentation

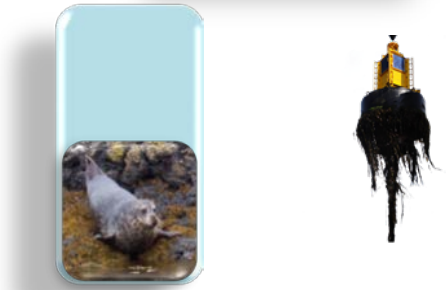
Noise: Hearing damage
Boats (dynamic positioning)
Disturbance for days, months

What can be done?

Operation

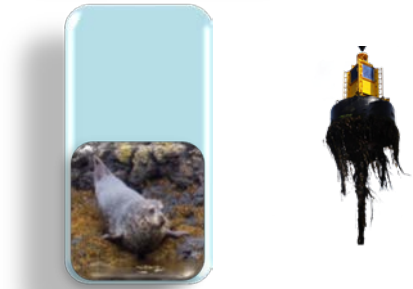
Noise
Collison risk
Permanent displacement
Change in flows (water & air)
leading to changes in ecosystem

Maintenance



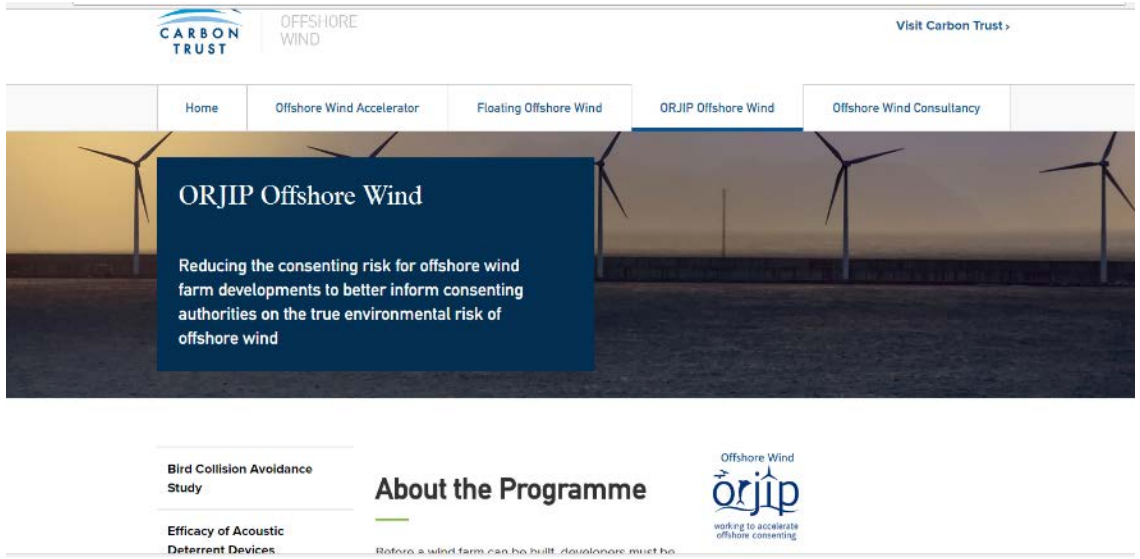
Noise / Disturbance

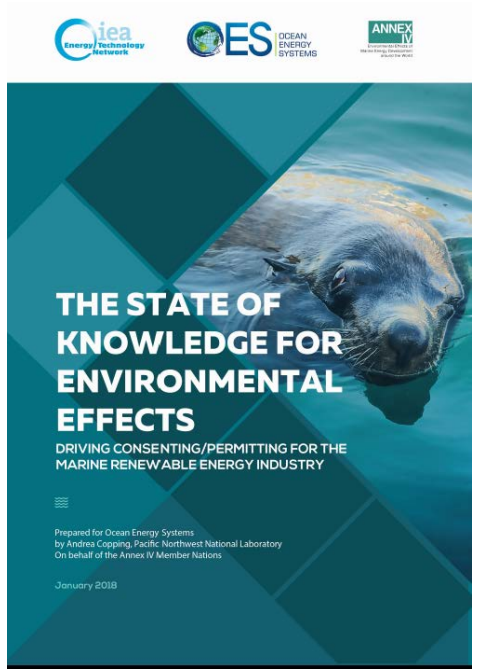
Decom
Design



Lots of unknowns?
Noise?
Changes in local habitat

Lots of prioritising lists of what needs doing – but only some research going – as very low levels of funding





marinescotland

Scottish Government
Riaghaltas na h-Alba
gov.scot

First Scottish Marine Energy Research (ScotMER) Programme Symposium:
Potential Interactions of Marine Renewables and Seabirds – Strategic Research for Scotland

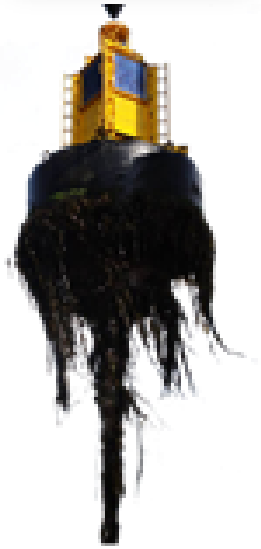
09:00 – 16:00 Tuesday 2nd October 2018

Scottish Government, Victoria Quay, Commercial Street, Edinburgh, EH6 6QQ

https://www2.gov.scot/Topics/marine/marineenergy/mre/research/maps

Biofouling: Subsea's dirty little secret

Material
Design
/power



The need to deal with biofouling head on:
know your enemy……
GROW your enemy?

Photos from Adrian Macleod, SAMS

International Journal of Marine Energy 19 (2017) 292–303

Contents lists available at ScienceDirect

International Journal of Marine Energy

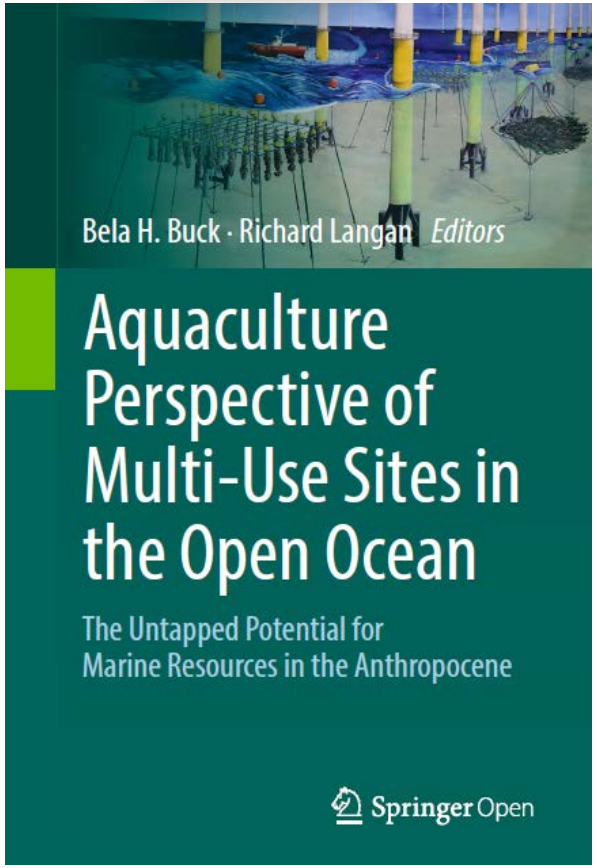
journal homepage: www.elsevier.com/locate/ijome

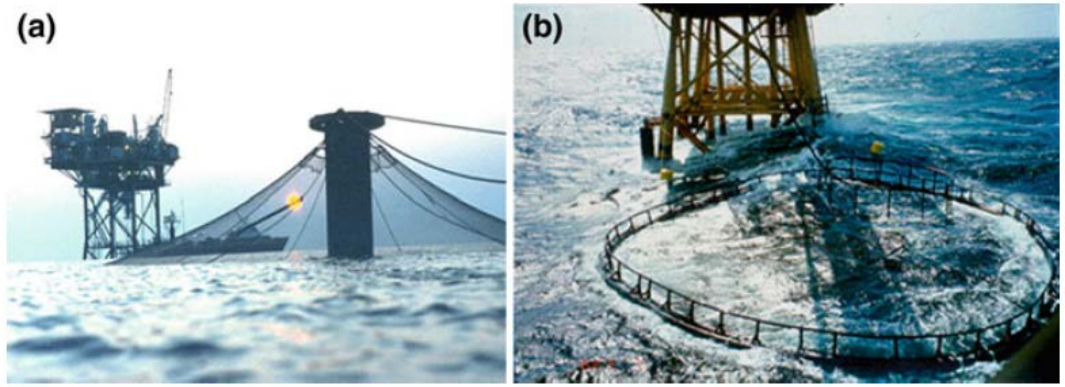
Setting an agenda for biofouling research for the marine renewable energy industry

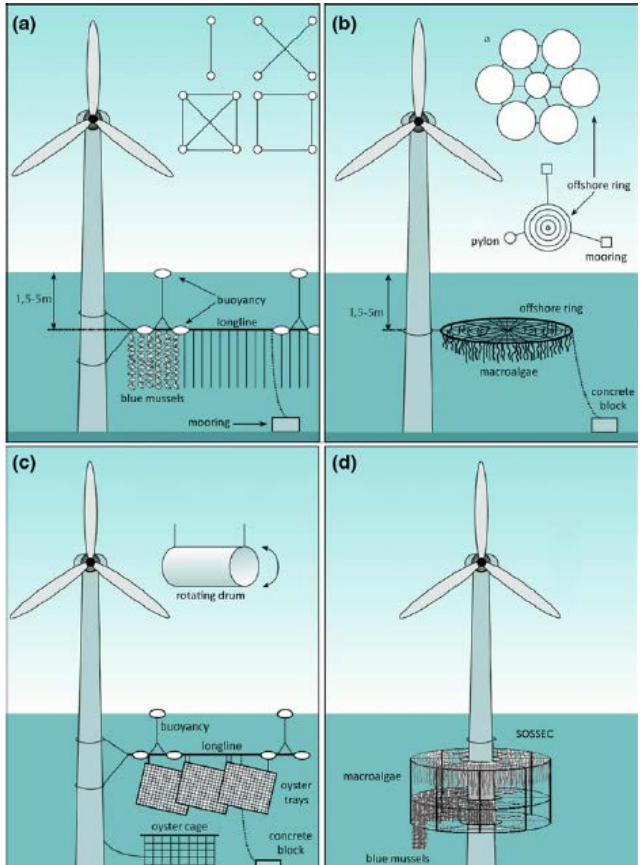
J. Loxton [a,*], A.K. Macleod [b], C.R. Nall [a], T. McCollin [c], I. Machado [d], T. Simas [d], T. Vance [e], C. Kenny [f], A. Want [g], R.G. Miller [b]

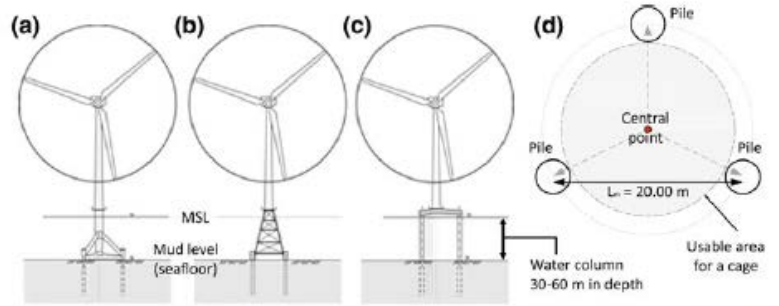
Multi –use of site: Aquaculture

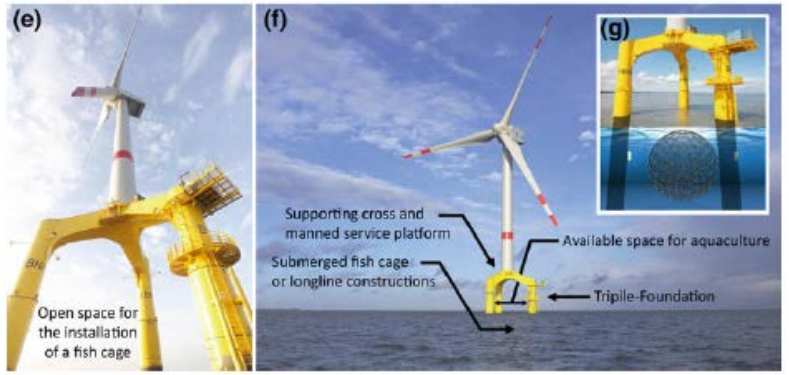
Material
Design
/power





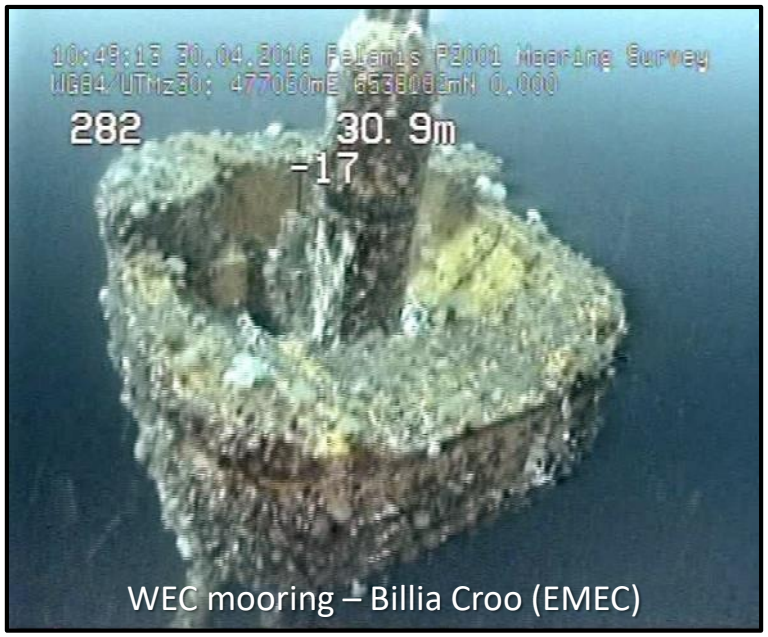




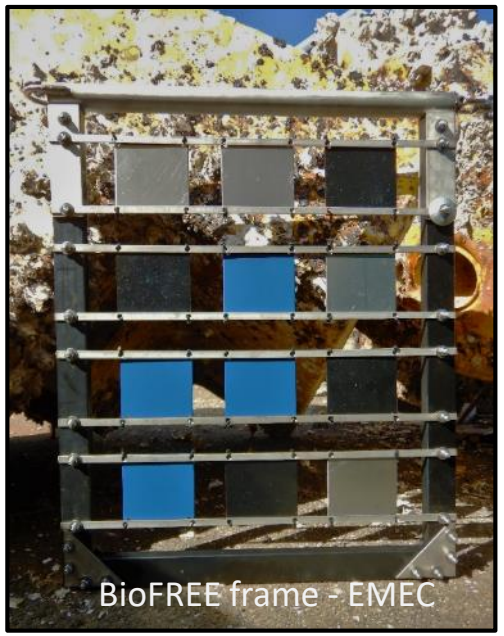


- Dr Andrew Want
  (SuperGen III PhD)
- Dr Joanne Porter


WRB – Biilia Croo



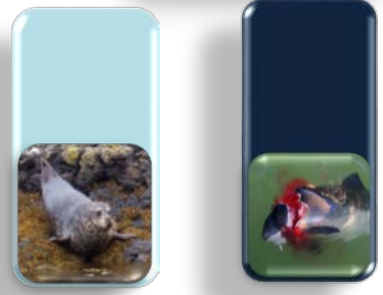
WEC mooring – Billia Croo (EMEC)


BioFREE frame - EMEC

- Working with technology developers and test centre engineers towards best practice and standardised operating procedures for monitoring and sensor systems used to detect fouling organisms at different depths and energy levels
- Integrated system development to allow testing of different materials with anti-fouling and corrosion coatings
- Providing guidance to the offshore renewable energy sector to lower electricity generating costs through anti-fouling/corrosion mitigation strategies

Installation – most animals return, so impacts but are they ‘effects’

Installation



Journal of Applied Ecology

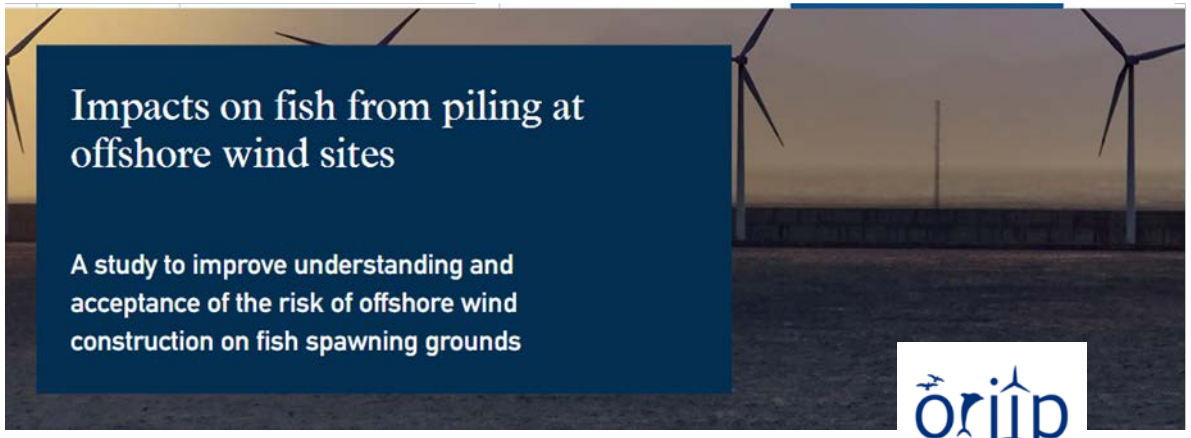
Journal of Applied Ecology 2006 doi: 10.1111/1365-2664.12678

Avoidance of wind farms by harbour seals is limited to pile driving activities

Debbie J.F. Russell[1,2*], Gordon D. Hastie[1], David Thompson[1], Vincent M. Janik[1], Philip S. Hammond[1], Lindesay A.S. Scott-Hayward[2], Jason Matthiopoulos[3], Esther L. Jones[1,2] and Bernie J. McConnell[1]

Pile-Driving Noise Impairs Antipredator Behavior of the European Sea Bass *Dicentrarchus labrax*

Kirsty A. Everley, Andrew N. Radford, and Stephen D. Simpson

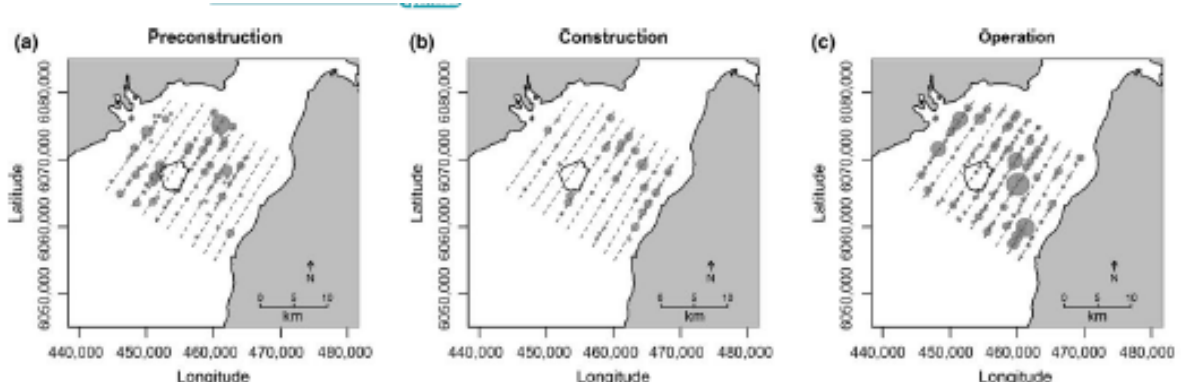


ORIGINAL RESEARCH

WILEY Ecology and Evolution

Responses of two marine top predators to an offshore wind farm

Gillian C. Vallejo[1] | Kate Grellier[1] | Emily J. Nelson[1] | Ross M. McGregor[1] | Sarah J. Canning[2] | Fiona M. Caryl[1] | Nancy McLean[1]



orjip
working to accelerate offshore consenting

Marine Mammals: change foraging patterns

Russell et al 2014 Current Biology 24: R638–R639

Correspondences

Marine mammals trace anthropogenic structures at sea

Deborah J.F. Russell[1,2,*], Sophie M.J.M. Brasseur[3], Dave Thompson[1], Gordon D. Hastie[1], Vincent M. Janik[1], Geert Aarts[3,4], Brett T. McClintock[5], Jason Matthiopoulos[6], Simon E.W. Moss[1], and Bernie McConnell[1]

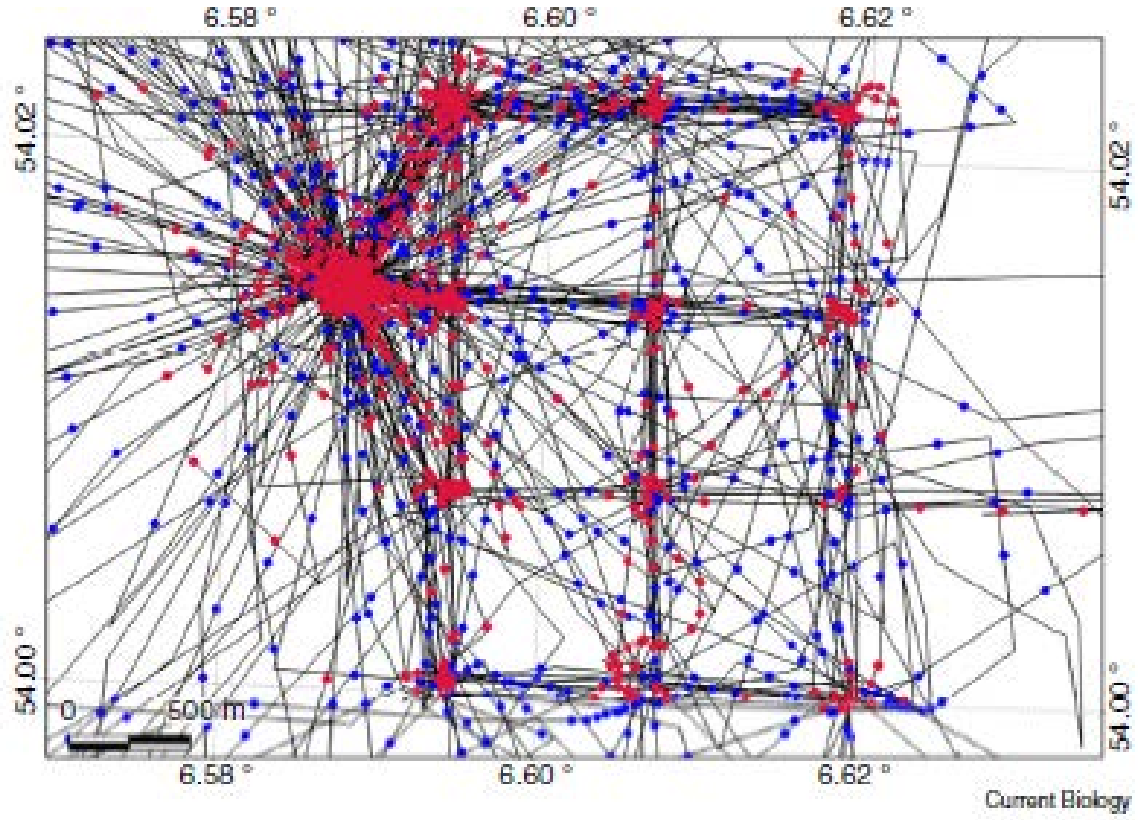


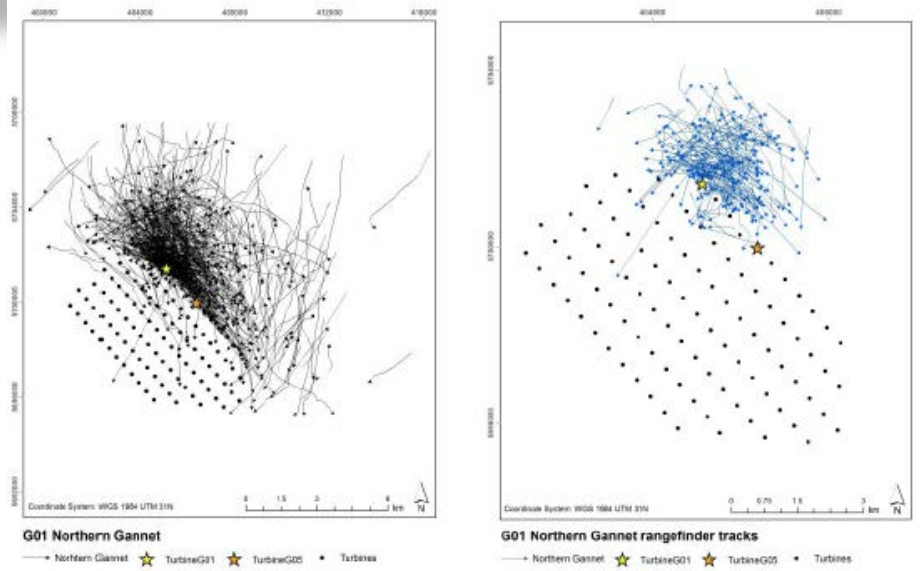
Figure 1. The tracks of a harbour seal around Alpha Ventus windfarm.

Seabirds: Empirical Avoidance Rate (EAR) high

Array Design

ORJIP

Figure 4.1. Examples of radar (left) and rangefinder (right) tracks collected from turbine G01 identified as Northern Gannets.



NIRAS DHI CARBON TRUST

Bird Collision Avoidance Study

Pioneering study finds seabirds avoid offshore wind turbines much more than previously predicted

Table 5.11. Estimated overall EAR and standard deviations (SD), which reflect the propagated variability estimated based on the bootstrap samples.

	Northern Gannet	Black-legged Kittiwake	Herring Gull	Great Black-backed Gull	Lesser Black-backed Gull	All large gulls
Overall Macro EAR	0.999	0.998	0.998	0.998	0.999	0.996
SD	0.0003	0.001	0.0009	0.0009	0.0007	0.0019

Multi arrays and cumulative effects

Journal of Environmental Management 231 (2019) 429–438

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

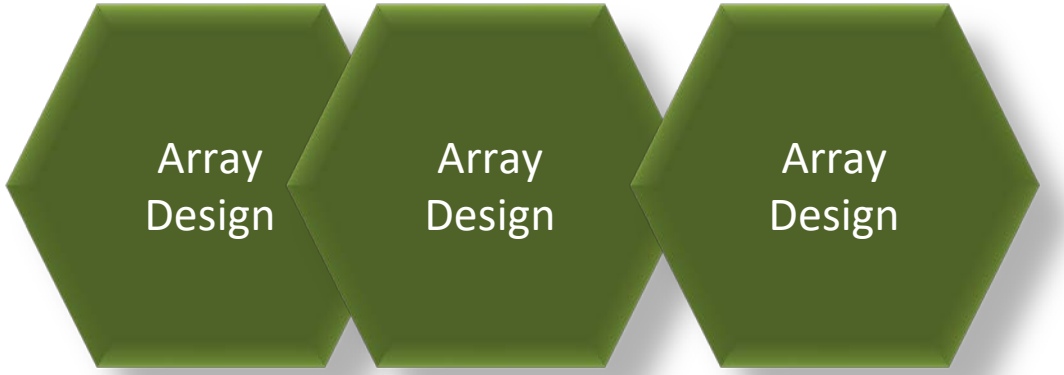
Research article

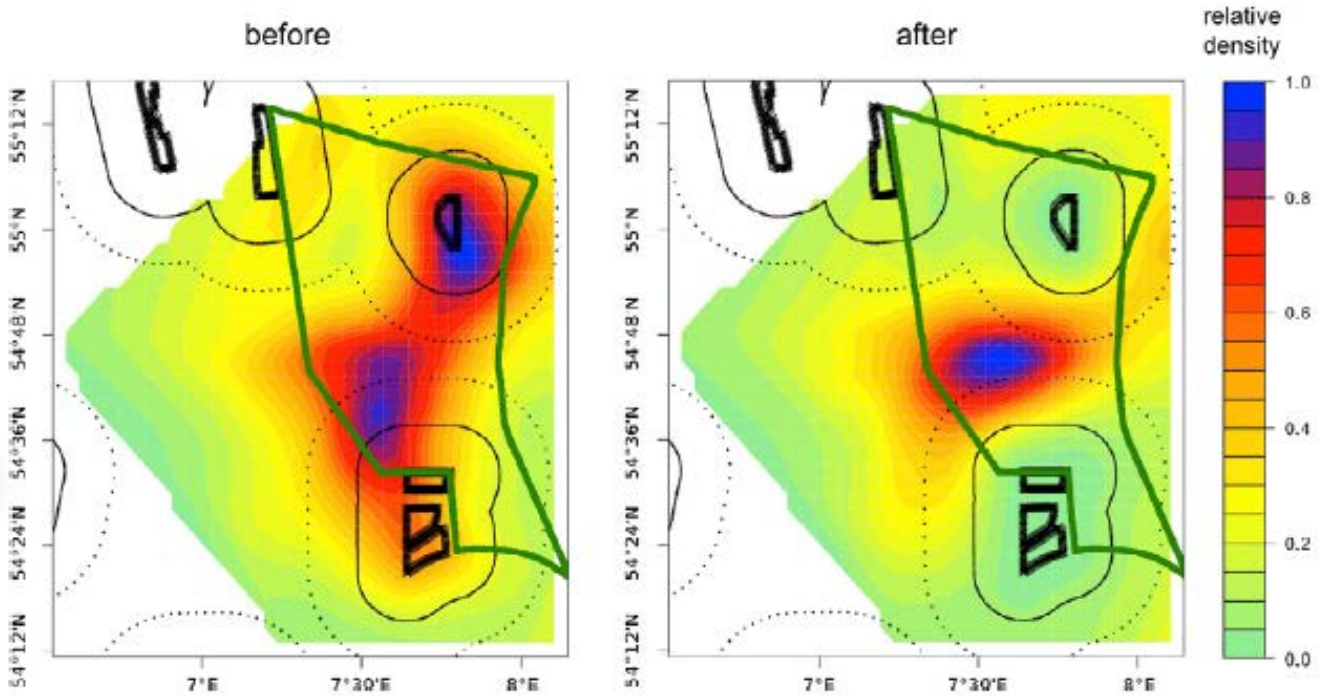
Operational offshore wind farms and associated ship traffic cause profound changes in distribution patterns of Loons (*Gavia* spp.)

Bettina Mendel[a], Philipp Schwemmer[a,*], Verena Peschko[a], Sabine Müller[a], Henriette Schwemmer[a], Moritz Mercker[b], Stefan Garthe[a]

[a] Research and Technology Centre (FTZ), University of Kiel, Hafentörn 1, 25761 Büsum, Germany
[b] BIONUM - Büro für Biostatistik, Finkenwerder Norderdeich 15 A, 21129 Hamburg, Germany

The most sensitive seabirds (loons/divers) are showing some drastic changes in foraging distributions





UNIVERSITY OF ABERDEEN

Physical changes from large scale wind farms

Progress in Oceanography 145 (2016) 25–41

Contents lists available at ScienceDirect

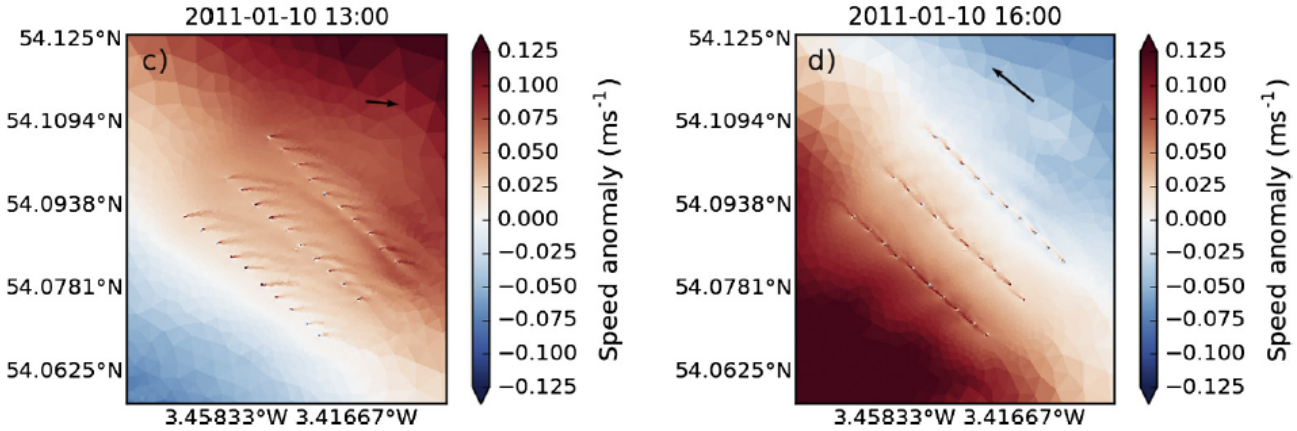
Progress in Oceanography

journal homepage: www.elsevier.com/locate/pocean

Unstructured grid modelling of offshore wind farm impacts on seasonally stratified shelf seas

Pierre William Cazenave *, Ricardo Torres, J. Icarus Allen

Plymouth Marine Laboratory, Prospect Place, The Hoe, Plymouth PL1 3DH, United Kingdom

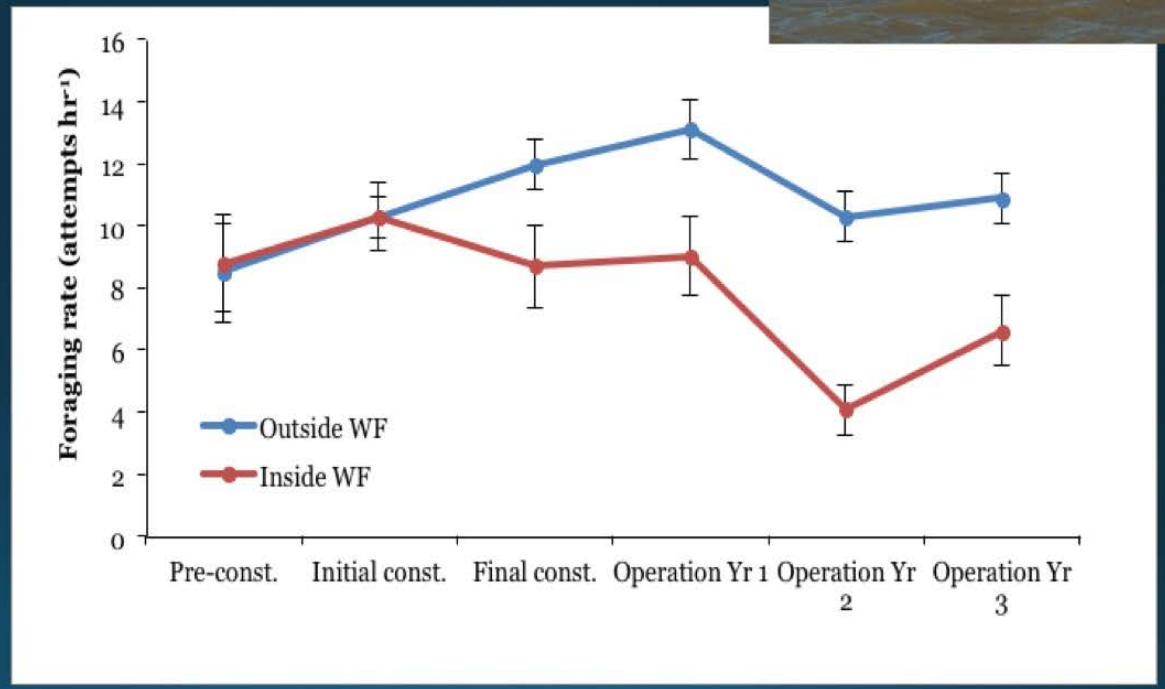


Some species of forage fish may not return?

We need to understand the effects on fish – they drive the system

Sandwich tern foraging

- Significant reduction in foraging attempts within the wind farm as construction advanced persisting into operation
- As birds concentrating on crossing the site?
- Or are fewer preferred prey now present?



From M. Perrow, ECON Ecological Consultancy Ltd

What about the fish?

In models they are the most sensitive parameter

RESEARCH ARTICLE

Journal of Applied Ecology

Predicting the impacts of wind farms on seabirds: An individual-based model

Victoria Warwick-Evans[1] | Phil W. Atkinson[2] | Ian Walkington[3] | Jonathan A. Green[1]

Ecological Modelling 273 (2014) 31–43

Contents lists available at ScienceDirect

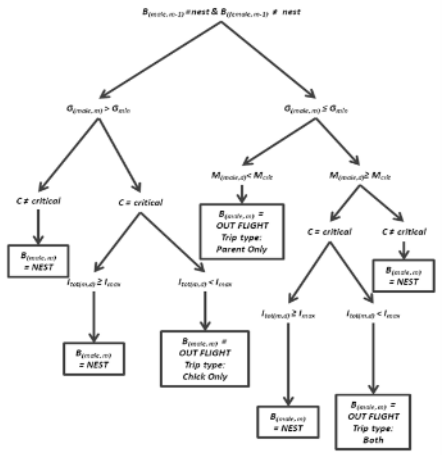
Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel

A simulation model coupling the behaviour and energetics of a breeding central place forager to assess the impact of environmental changes

R. Langton[a,*], I.M. Davies[b], B.E. Scott[a,*]

[a] Institute of Biological and Environmental Sciences, Zoology Building, University of Aberdeen, Tillydrone Ave, Aberdeen AB24 2TZ, UK
[b] Marine Scotland-Science, Marine Laboratory, 375 Victoria Road, Aberdeen AB11 9DB, UK



FISH EFFECTS

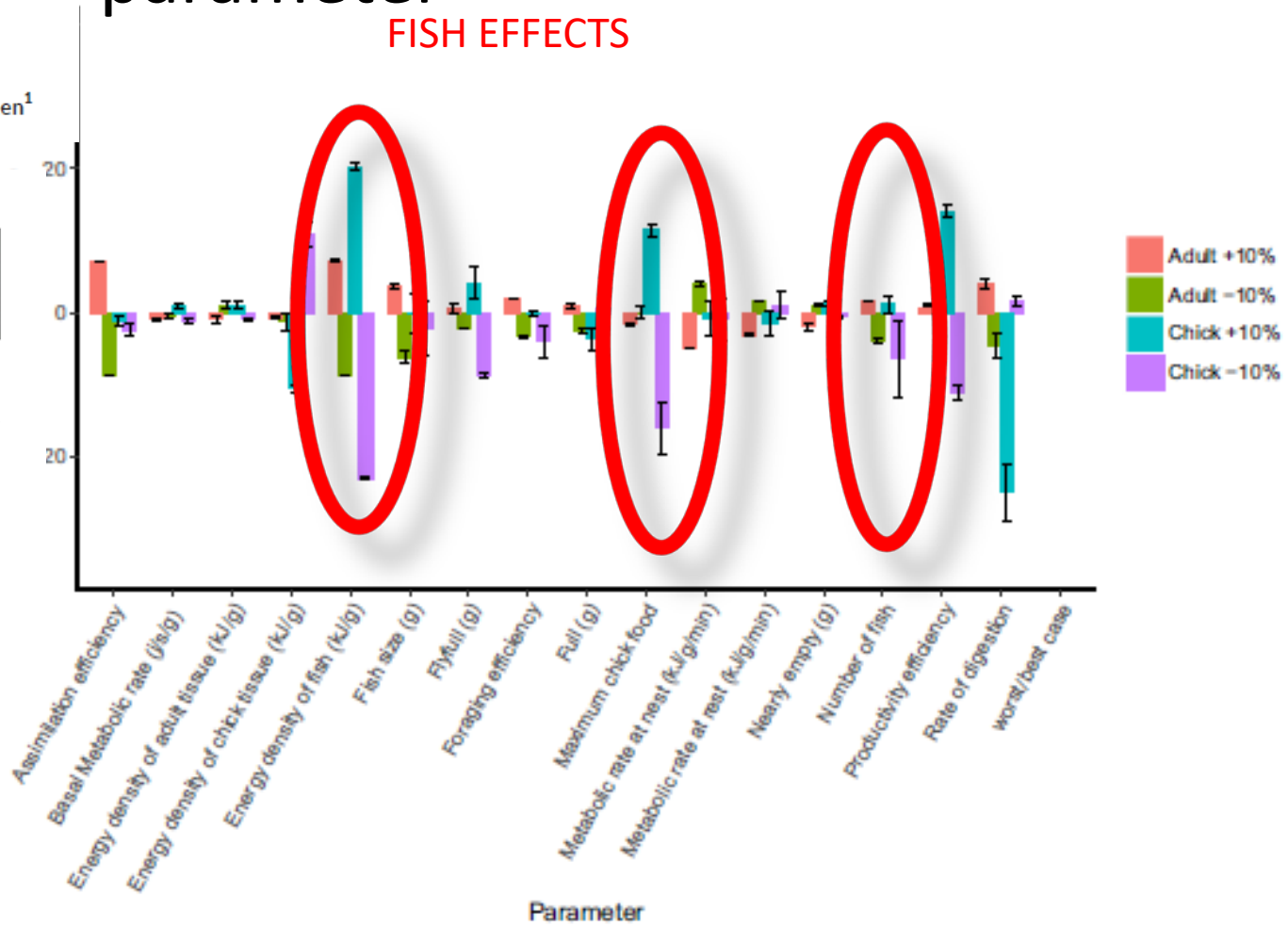
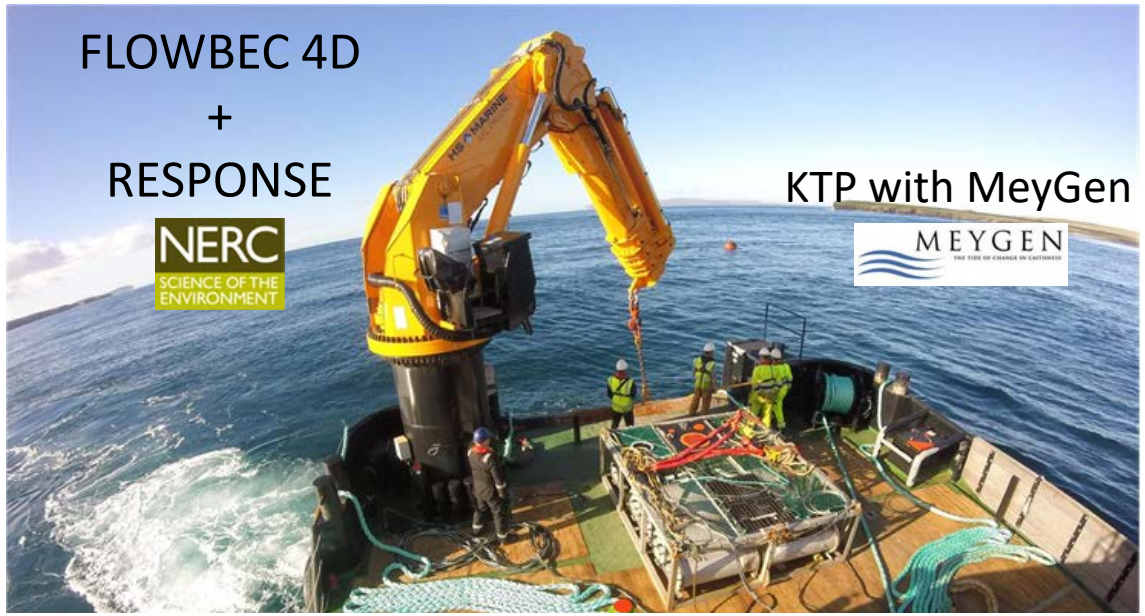
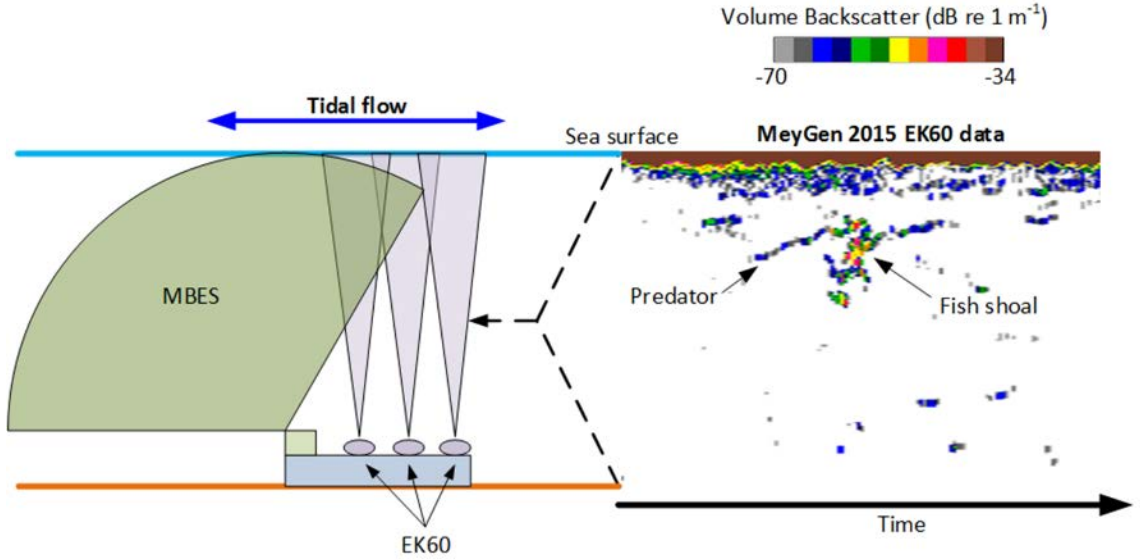


FIGURE 7 Sensitivity analysis of adult and chick body mass. Each of the model parameters were varied singly and sequentially by a standard variability of ± 10% and their effect on adult and chick body mass calculated as a percentage of the baseline model [Colour figure can be viewed at wileyonlinelibrary.com]

Fine Scale issues: are animals using physical aspects of high energy sites to forage?





Linking predictable physical attributes of water column directly to behaviour of both predator and prey

- Use of multiple acoustic instruments
- Working towards the use of physical trigger for mitigation measures (i.e. signs of herring migration –occur for few weeks – to slow turbines so low collision risk to seals)

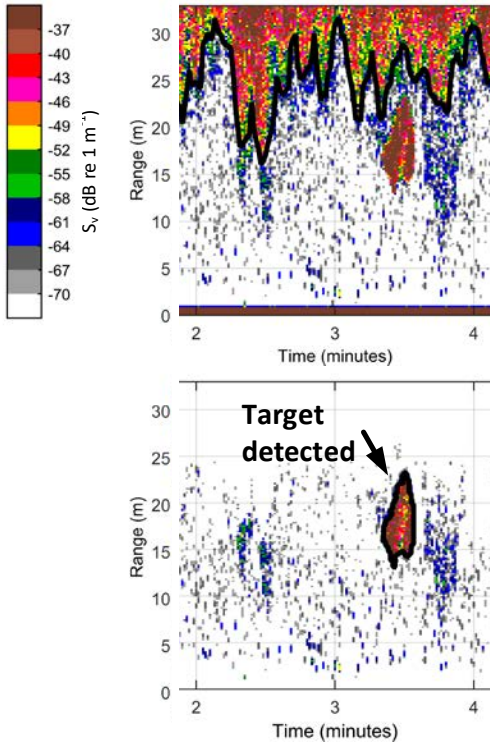
Williamson et al 2017 IEEE JOE 42: 948-965
Williamson et al 2016 IEEE JOE 41: 67-81.

There are changes in behaviour: But not quite as expected….

LIMNOLOGY and OCEANOGRAPHY: METHODS — ASLO

Automatic active acoustic target detection in turbulent aquatic environments

Shaun Fraser,[1]* Vladimir Nikora,[1] Benjamin J. Williamson,[2] Beth E. Scott[2]



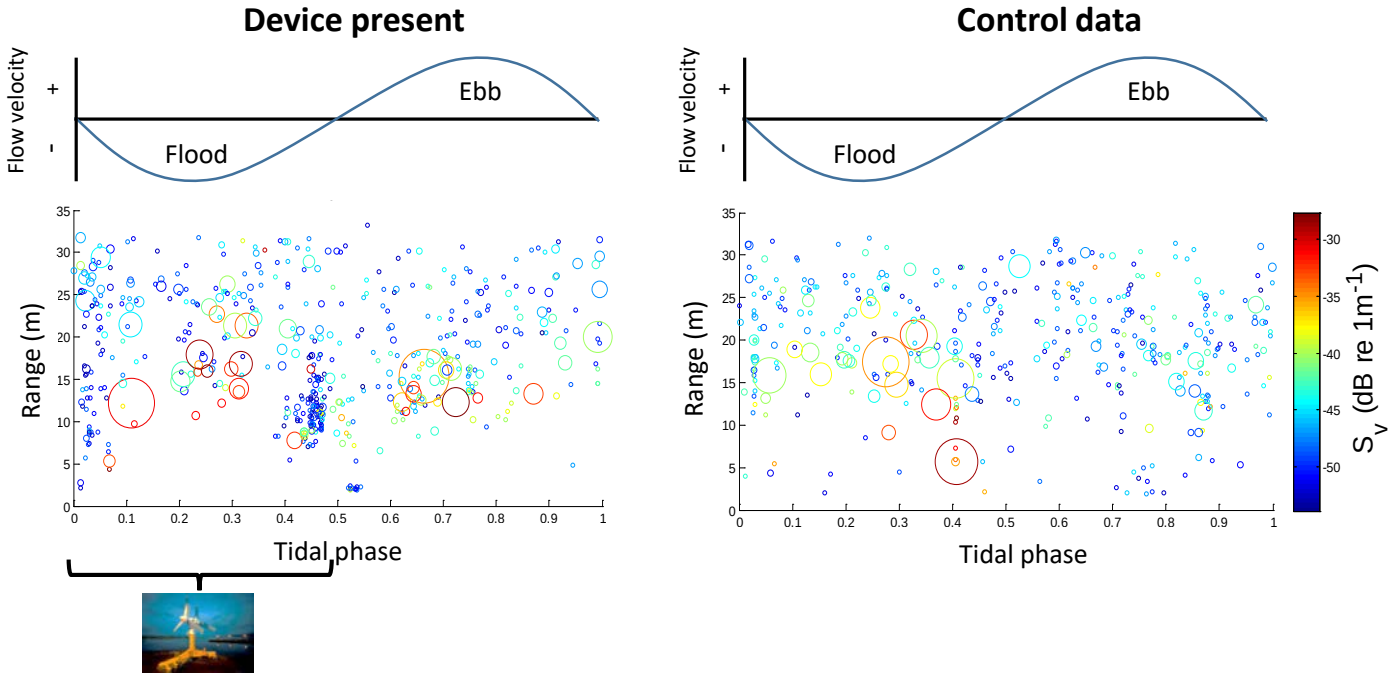
Adaptive processing approach:
Turbulence delineation
Additional scale-dependent filtering
Target morphology requirements
Multi-frequency validation

UNIVERSITY OF ABERDEEN

Active acoustic monitoring in extreme turbulence around marine renewable energy devices

Shaun Fraser
s.fraser@abdn.ac.uk

Target distribution results: Fish Change Behaviour at Turbines



- Aggregation and school density clearly also related to **tidal phase**
- Change in **behaviour in wake of structure**, particularly during slowing flow

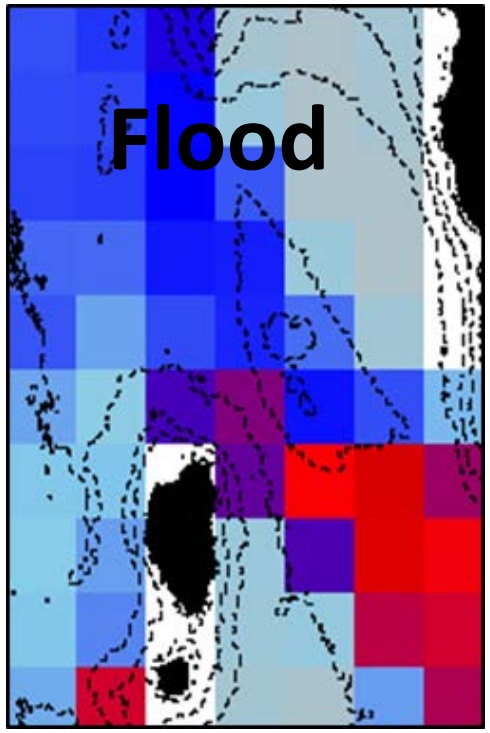
Fraser et al 2018 Energy Reports, Fraser et al 2017 Energy Procedia,
Fraser et al 2017 Limnology and Oceanography

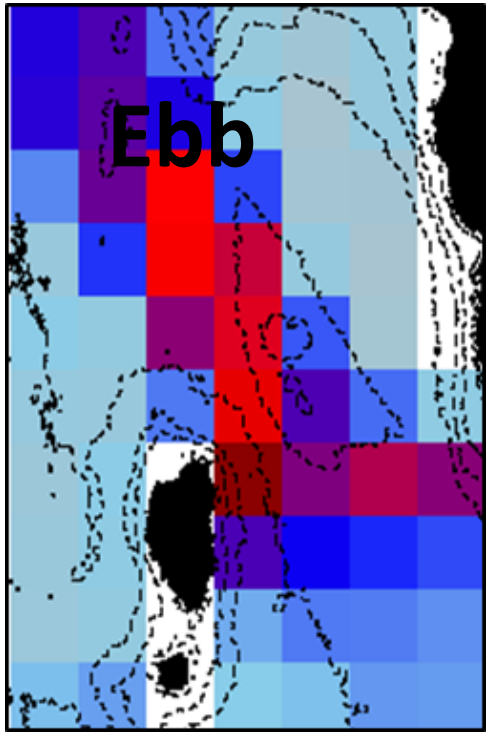
Shaun Fraser

The Norman Heaps Prize: For the best presentation by an early-career researcher at The Challenger Society for Marine Science September 2016

Statistical Model (GLMM) Predictions of increased **Atlantic puffin foraging in areas with fast upwelled water**)

Max speed and turbulence (particular turbulent water with upward motion)



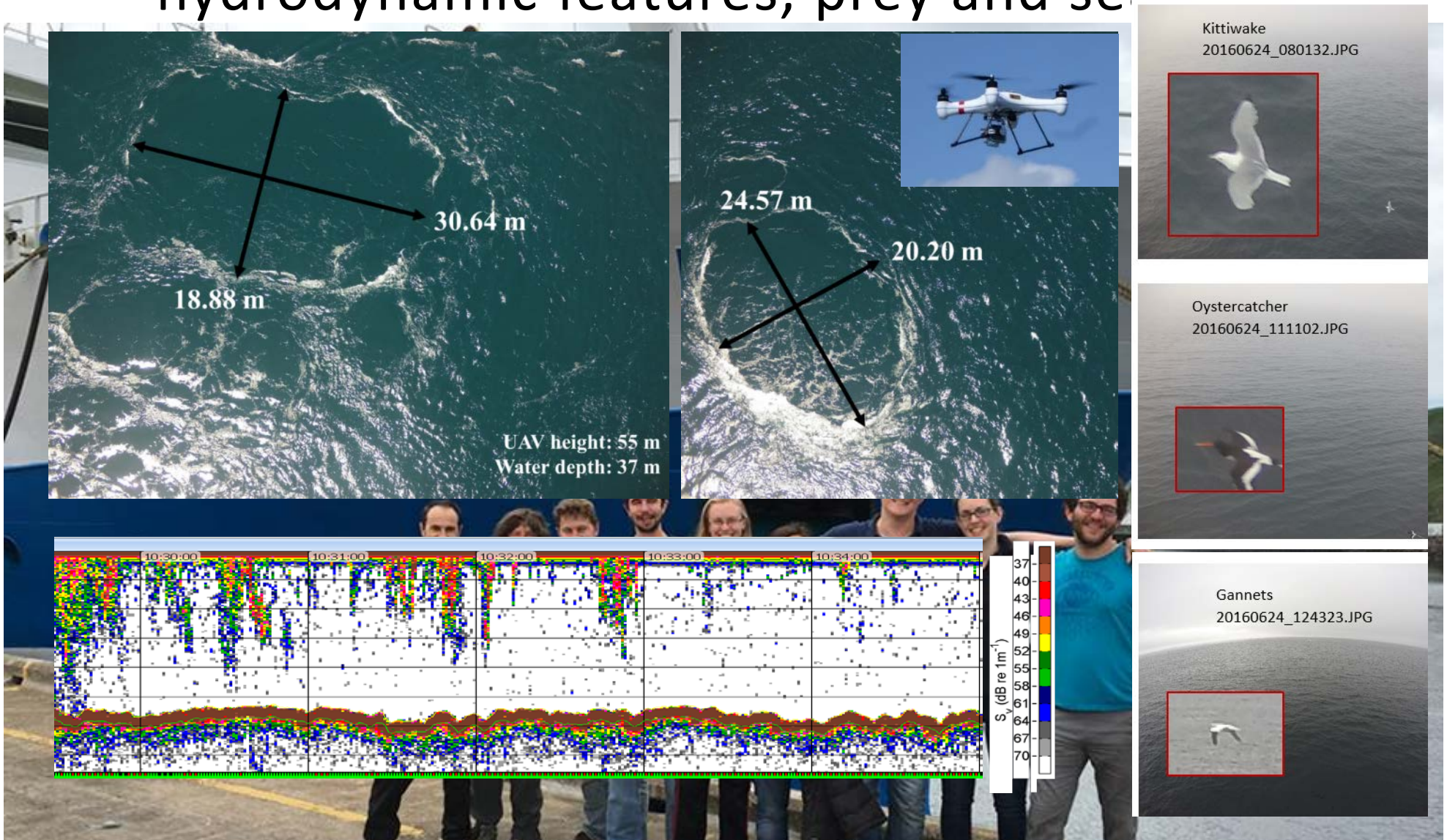


James Waggitt
NERC CASE

Yes – there are differences between how species use the physical aspects of the water column: Evidence of fine scale niche separation

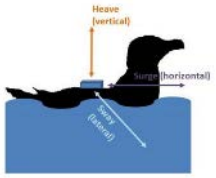
Drones to replace surveys

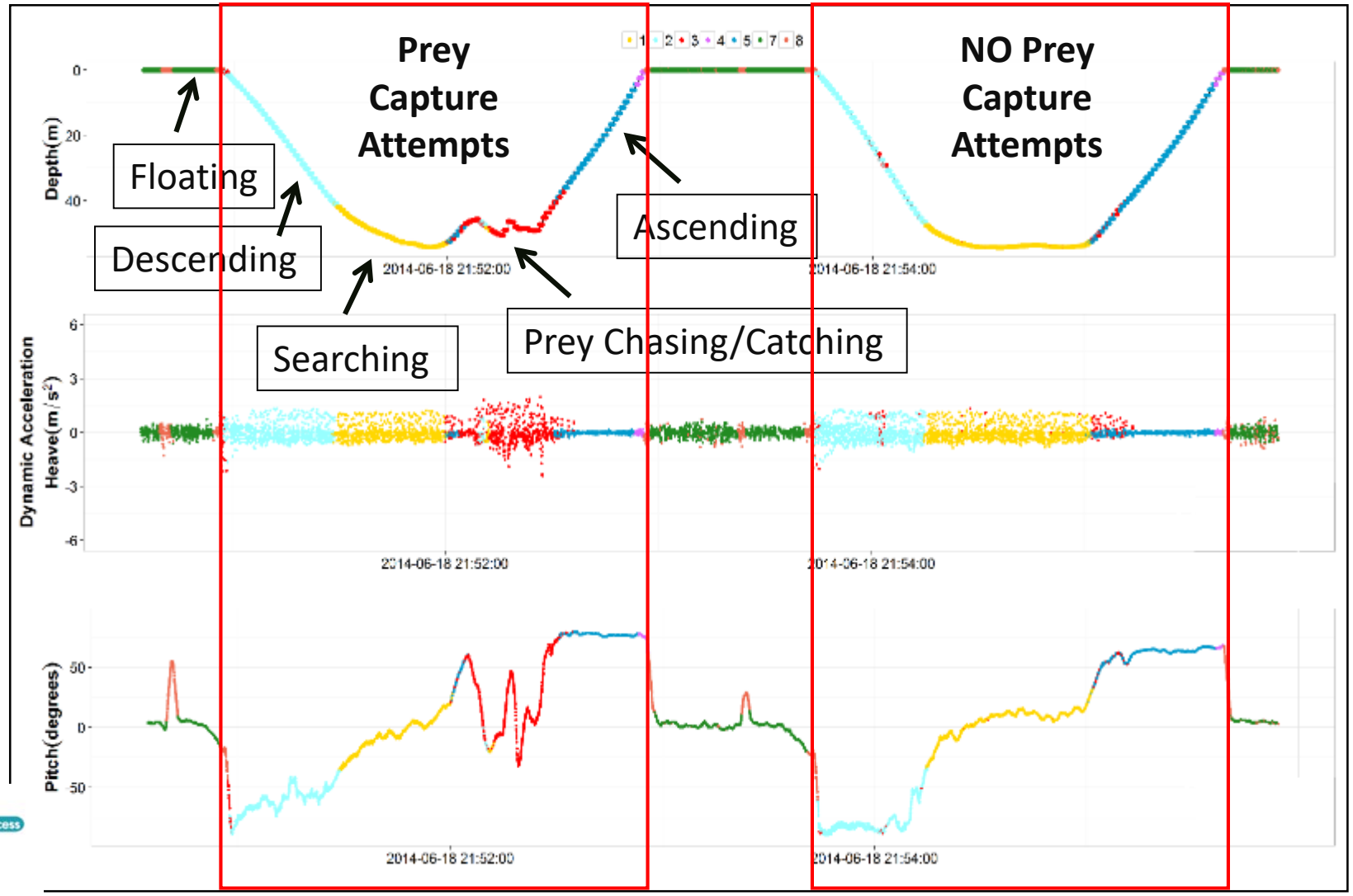
Co-registered EK60, visual analysis of hydrodynamic features, prey and seabirds



Behavioural classification – from Accelerometer Data with ‘unsupervised’ machine learning

Marianna Chimienti
NERC CASE 2013-17
With RSPB



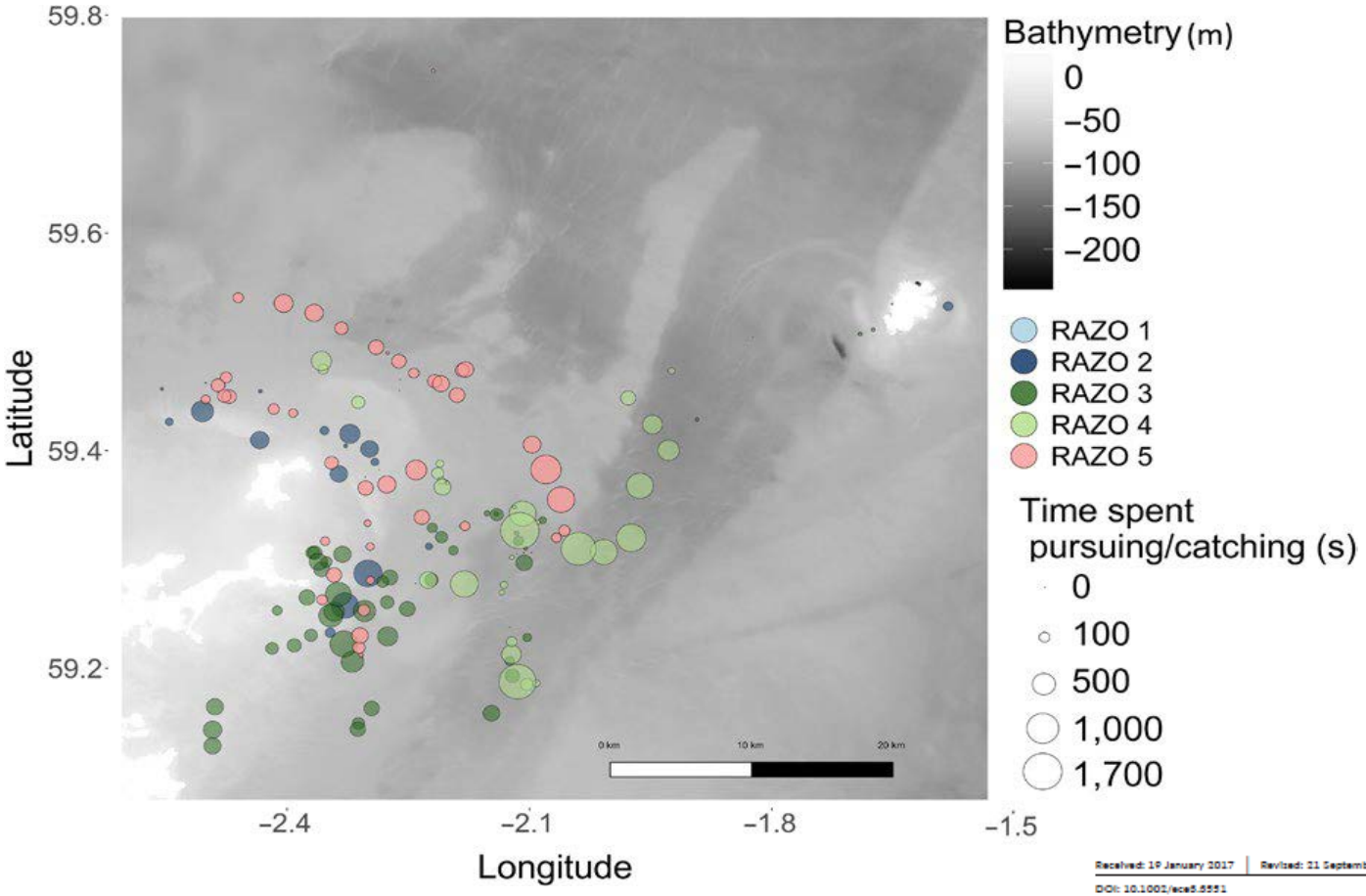


Ecology and Evolution
Open Access
The use of an unsupervised learning approach for characterizing latent behaviors in accelerometer data
Marianna Chimienti[1,2], Thomas Cornulier[3], Ellie Owen[3], Mark Bolton[4], Ian M. Davies[2], Justin M.J. Travis[3] & Beth E. Scott[1]

Chimienti et al. (2016) Ecology and Evolution

Can find the very important areas for successful feeding

Marianna Chimienti



Using Prey capture attempts - can find the areas with most available prey

Received: 19 January 2017 | Revised: 21 September 2017 | Accepted: 22 September 2017
DOI: 10.1002/ece3.3551

ORIGINAL RESEARCH

WILEY Ecology and Evolution

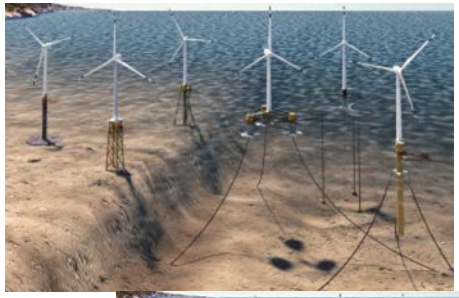
Taking movement data to new depths: Inferring prey availability and patch profitability from seabird foraging behavior

Marianna Chimienti[1,2] | Thomas Cornulier[1] | Ellie Owen[3] | Mark Bolton[4] | Ian M. Davies[2] | Justin M. J. Travis[1] | Beth E. Scott[1]

There is a lot going on out there

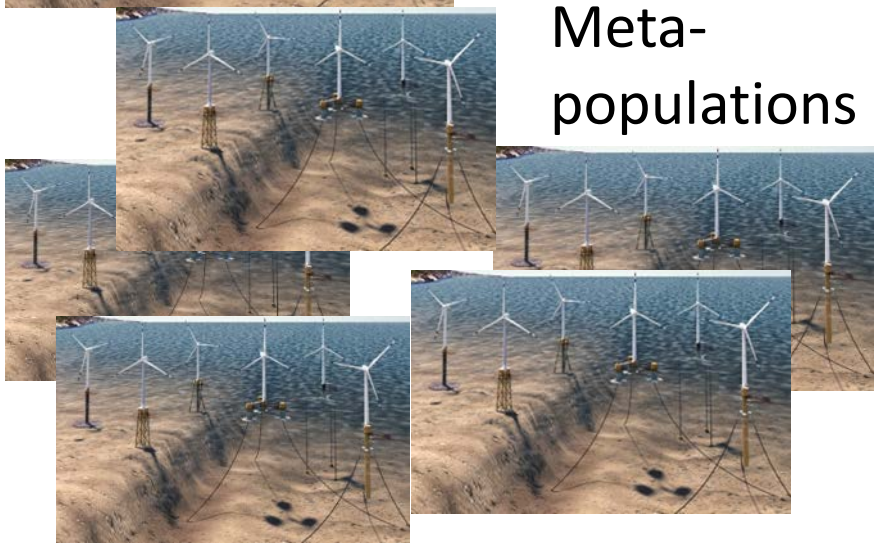
Individuals



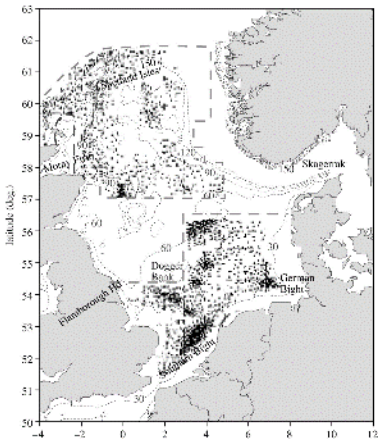



Populations

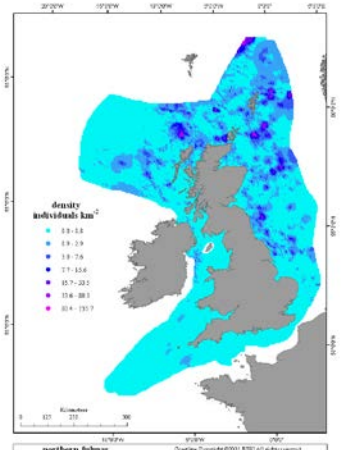


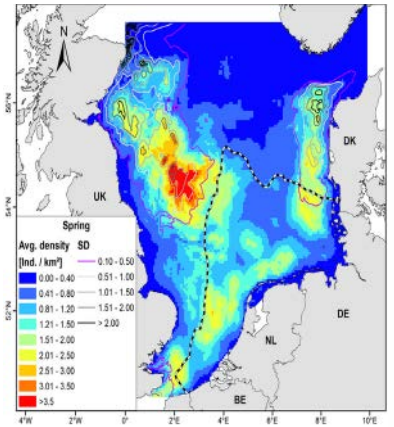
Meta-populations



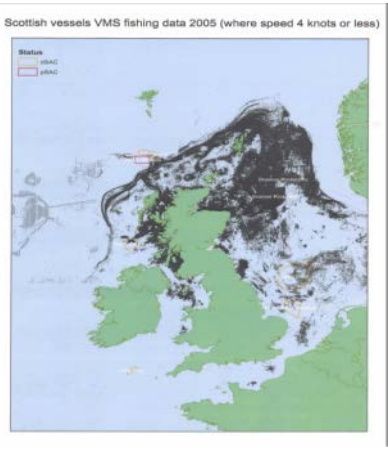
Fox et al 2008



JNCC Report 431



Gilles et al. 2016

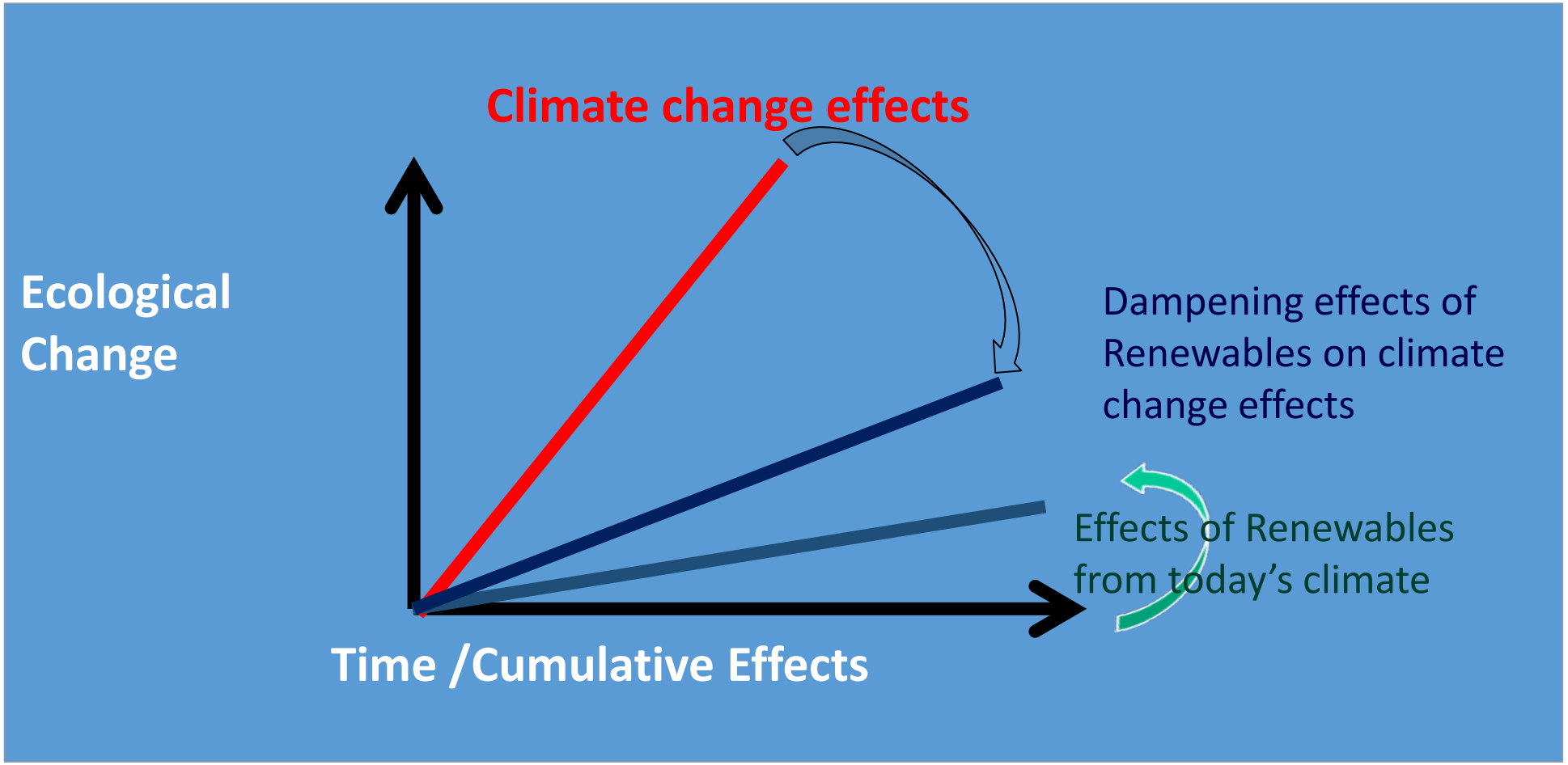


Scottish fishing

https://www.energy.gov/eere/office-energy-efficiency-renewable-energy

Climate change will have major effects on populations

Should our laws/policies include effects of climate?
Should we change approach to EIAs ?



Large Scale issues: EcoWatt2050

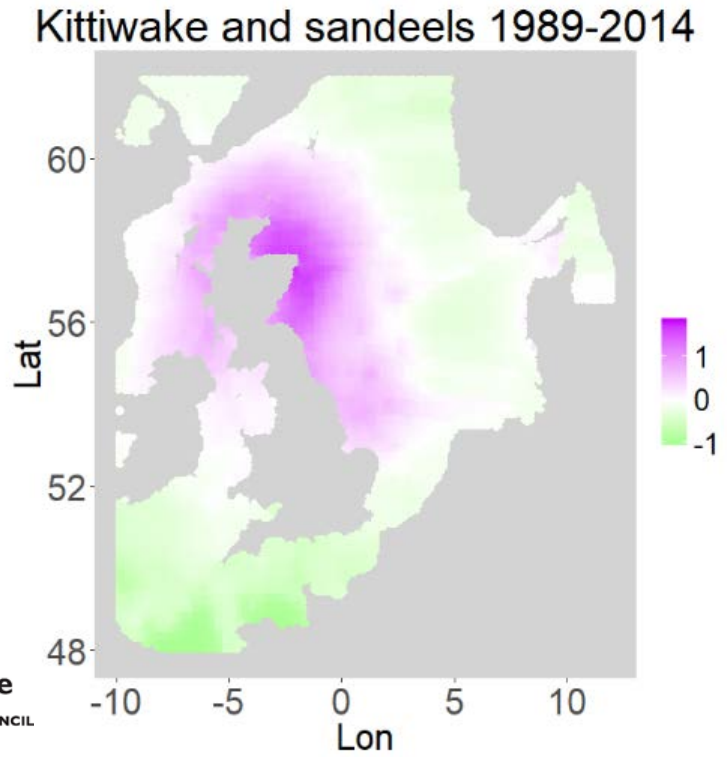
Common Spatial Trends:
Predators and prey have different relationships with critical habitat variables

+

~ **Net Primary Production(NPP)**

+

Potential Energy Anomaly (PEA)



High levels of common spatial trend = deeper purple.

Areas highly unlikely to occur together = deeper green.


ORIGINAL RESEARCH
WILEY
Bayesian joint models with INLA exploring marine mobile predator–prey and competitor species habitat overlap
Dinara Sadykova[1,2] | Beth E. Scott[1] | Michela De Dominicis[3] | Sarah L. Wakelin[3] | Alexander Sadykov[4] | Judith Wolf[3]

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

Large Scale issues: EcoWatt2050

Future Predictions of common spatial trend of mobile predators & prey

EPSRC
Engineering and Physical Sciences Research Council

NOW FUTURE with CC & EE DIFFERENCE

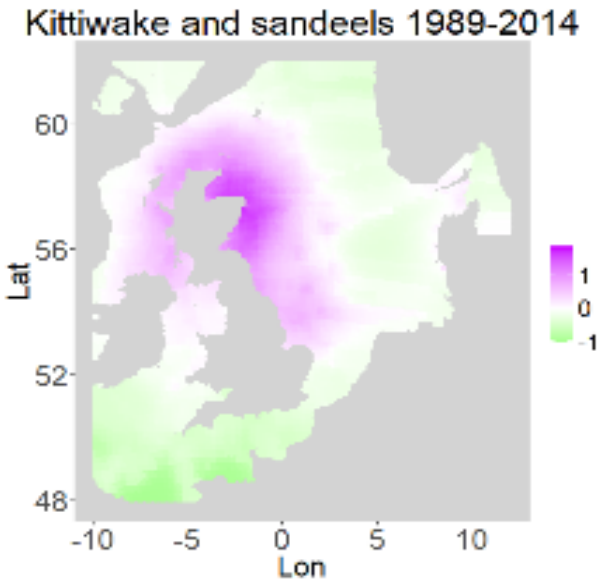
Kittiwake: current density

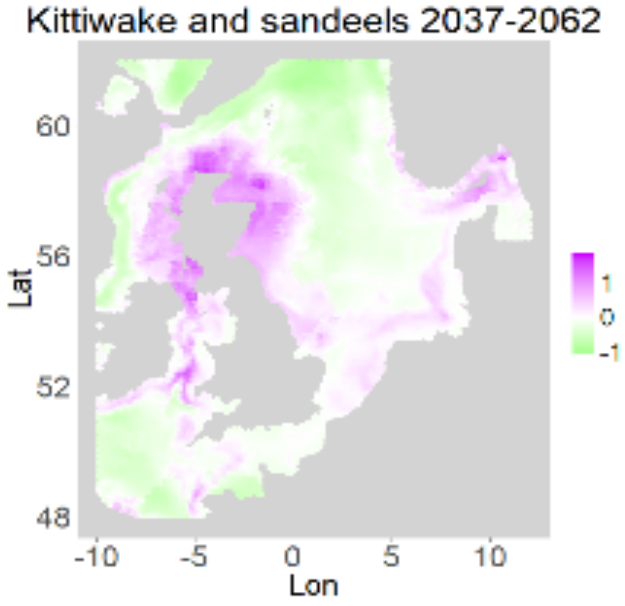
Sandeels: current density

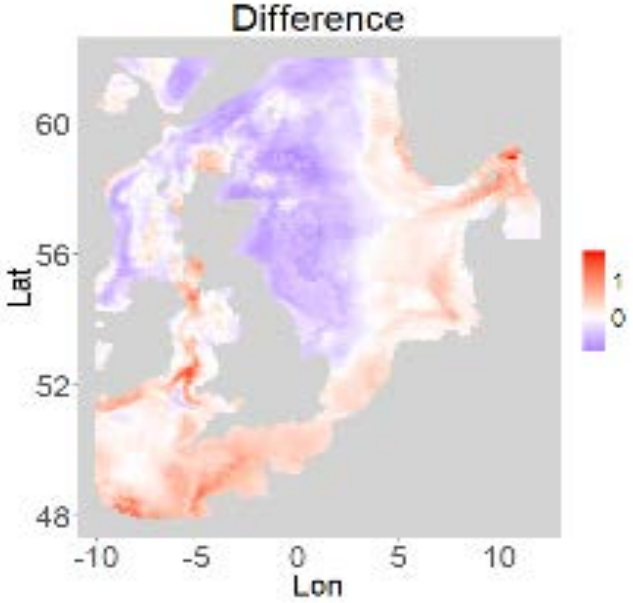
Kittiwake: predicted density

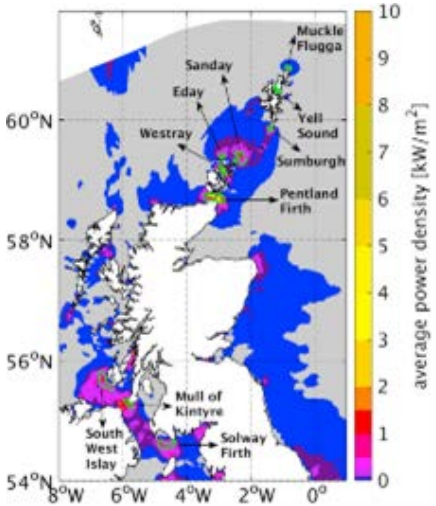
Sandeels: predicted density

Climate change 10^1 more effect than 6GW of Energy Extraction









National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

Is current SEA, EIA /post consent process fit for purpose?

An alternative method using ecosystem indicators

Offshore Energy Industry
Wind, Tidal, Wave, Decommissioning

EIA + HRA
(what species/ habitats/distributions)

≠

Post Consent
(population level effects)

Cumulative Issues

Data Products

COMET: Innovative Monitoring Methods & Instruments

1. Deliberate standardisation of focused questions and methods.
2. **Data products** based on agreed questions need to consistently build on information from EIA to Post Consent and Cumulative issues.
3. EIA/Post Consent **data products** also used for national needs for GES – allowing simpler/rapid assessment by Regulators as same data types.
4. Use of integrated autonomous vessels and platforms for both offshore energy industry (Bird/Habitat/Natura) and national MSFD (GES) **data**.

Instrumentation Companies/Integrated Instruments

≈

Regulators / Advisors

Bird/Habitat Directives & Natura 2000 & OSPAR

MSFD (GES): Good Environmental Status 11 Descriptors

Data Products

Biomass Food web models show complex winners and losers

ELSEVIER

Ecological Indicators

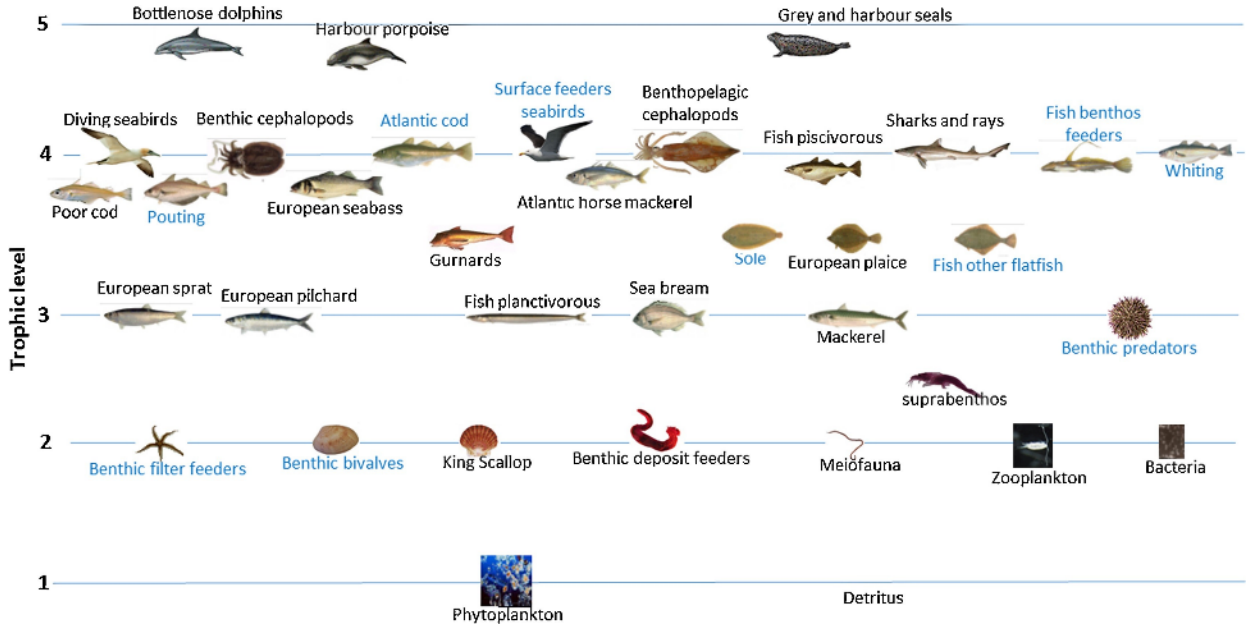
Volume 72, January 2017, Pages 33-46

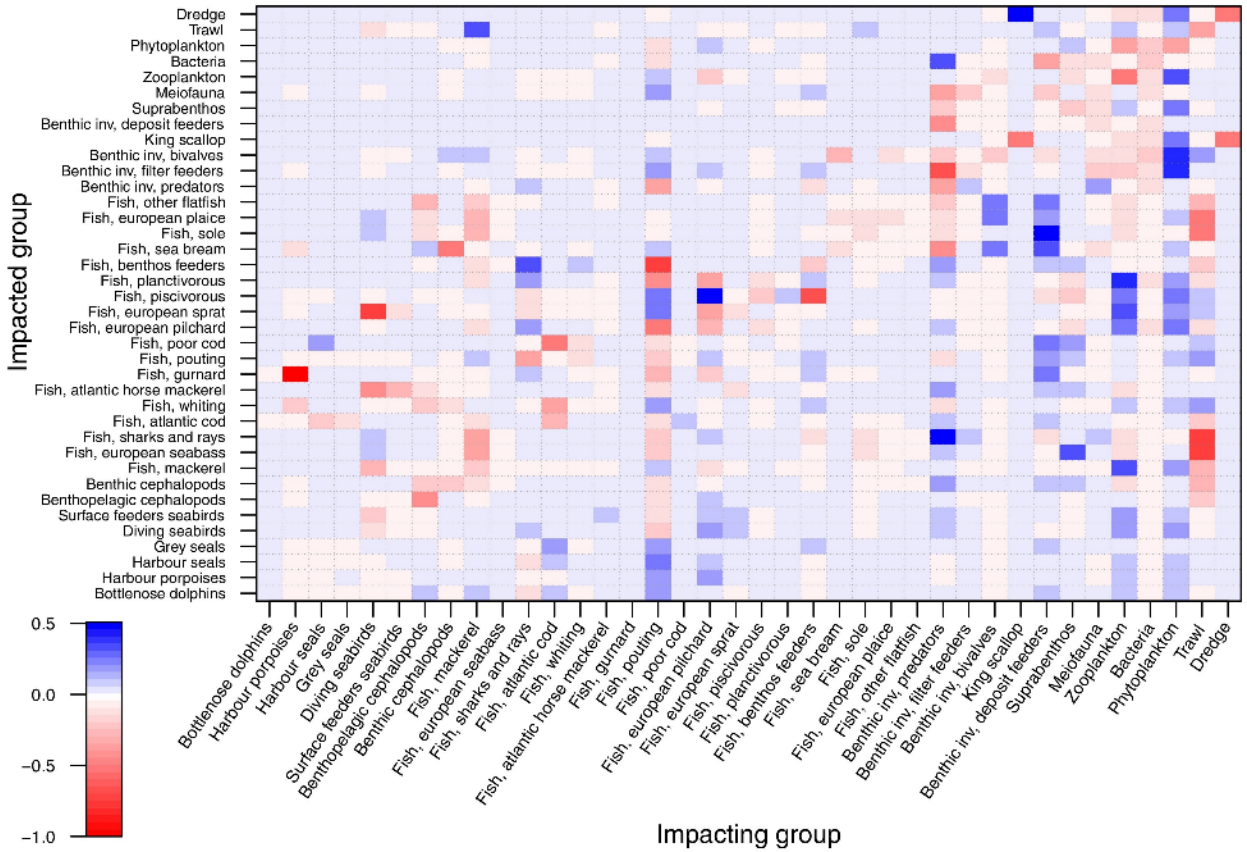
Original Articles

Benthic and fish aggregation inside an offshore wind farm: Which effects on the trophic web functioning?

So far only BIOMASS transfer models (who eats who)

need MODELS WITH MECHANISTIC LINKS to predict effects via physical aspects through food webs



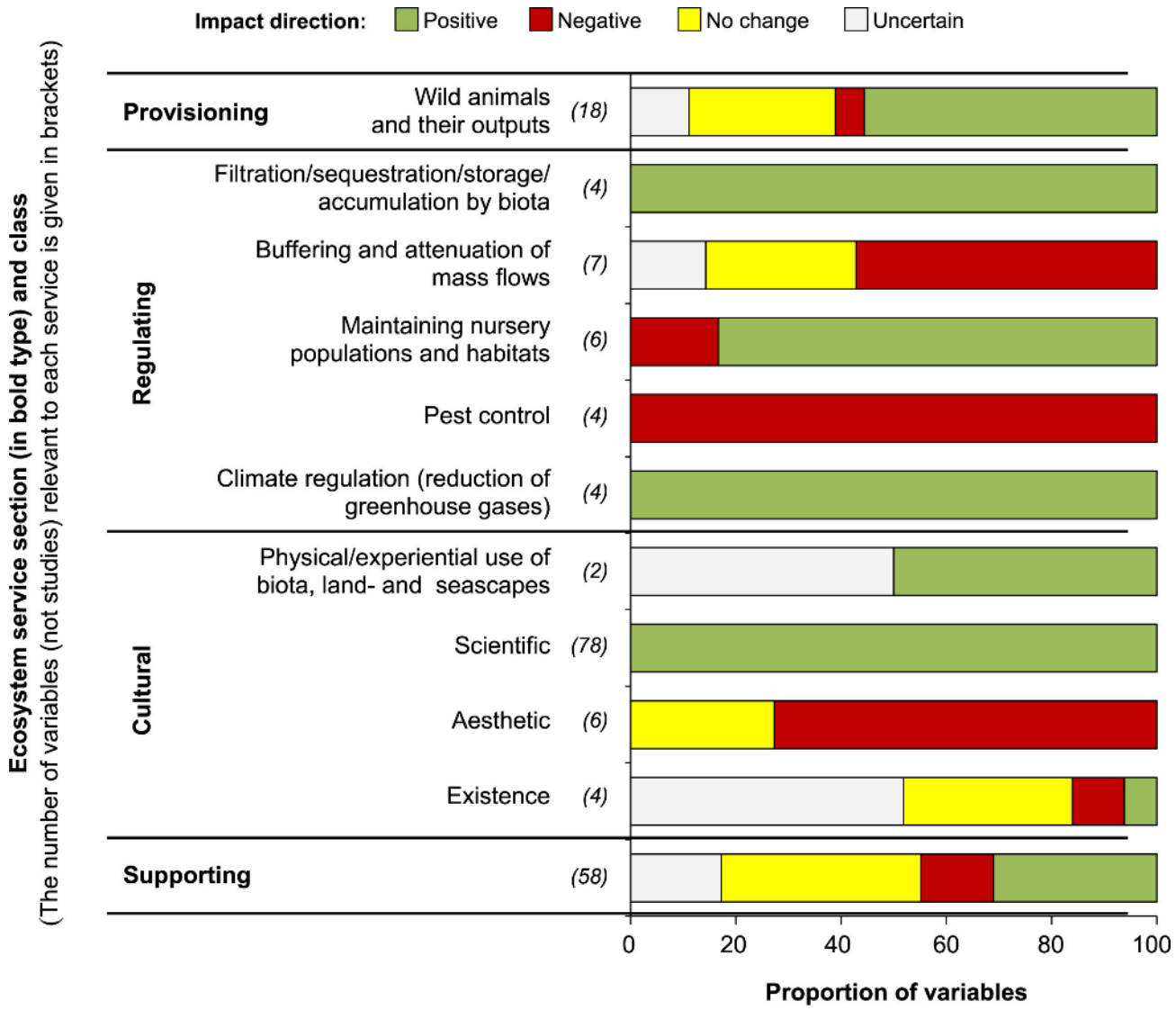


Ecosystem Services: Impacts for OWF mostly positive

Renewable and Sustainable Energy Reviews
Volume 70, April 2017, Pages 230-241

The implications of energy systems for ecosystem services: A detailed case study of offshore wind

Tara Hooper, Nicola Beaumont, Caroline Hattam

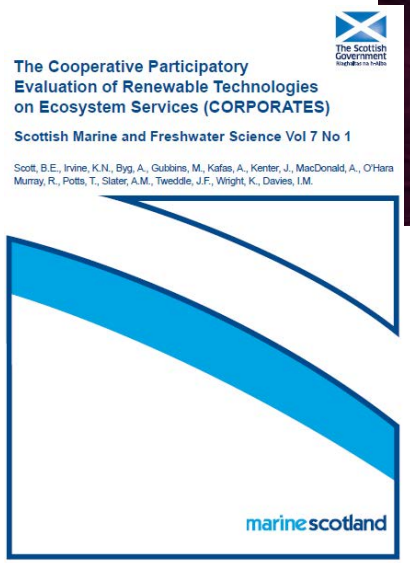


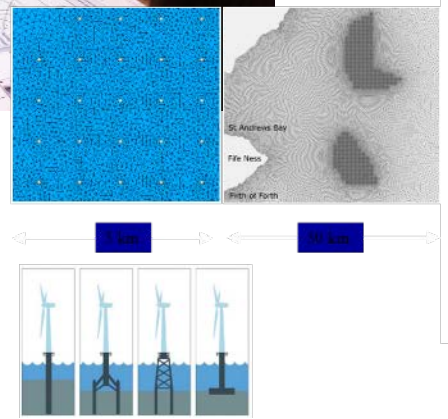
Social and Policy Aspects: CORPORATES

http://corporates.moonfruit.com/

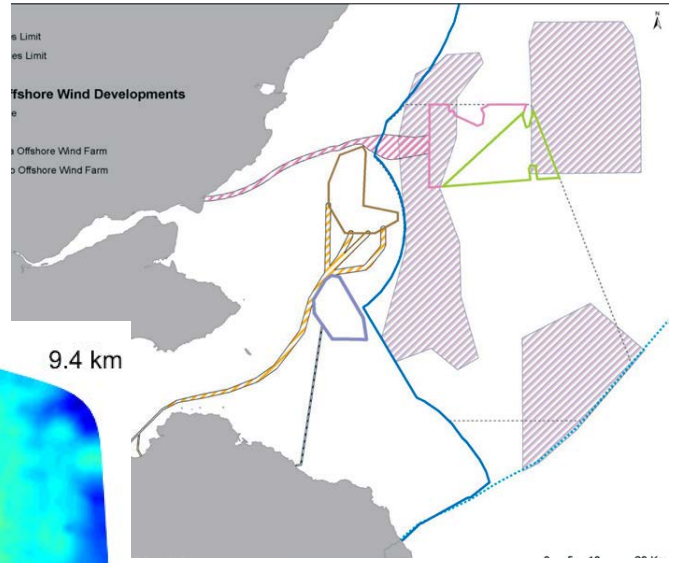
Cooperative **Participatory** Evaluation of Renewable Technologies on Ecosystem Services

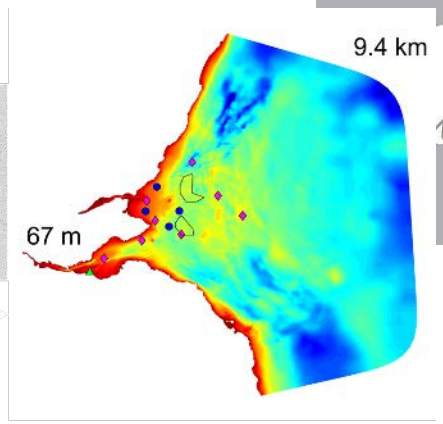
To design, with Stakeholders, methods (**a decision-support framework**) which address potential **ecological trade-offs** such as, climate change, marine renewable developments and MPAs





The Firth of Forth Windfarms and primary stakeholders





Let’s work together for a safer future.

OPEN ACCESS Freely available online

PLoS one

Win-Win for Wind and Wildlife: A Vision to Facilitate Sustainable Development

Supergen Offshore Renewable Energy

b.e.scott@abdn.ac.uk