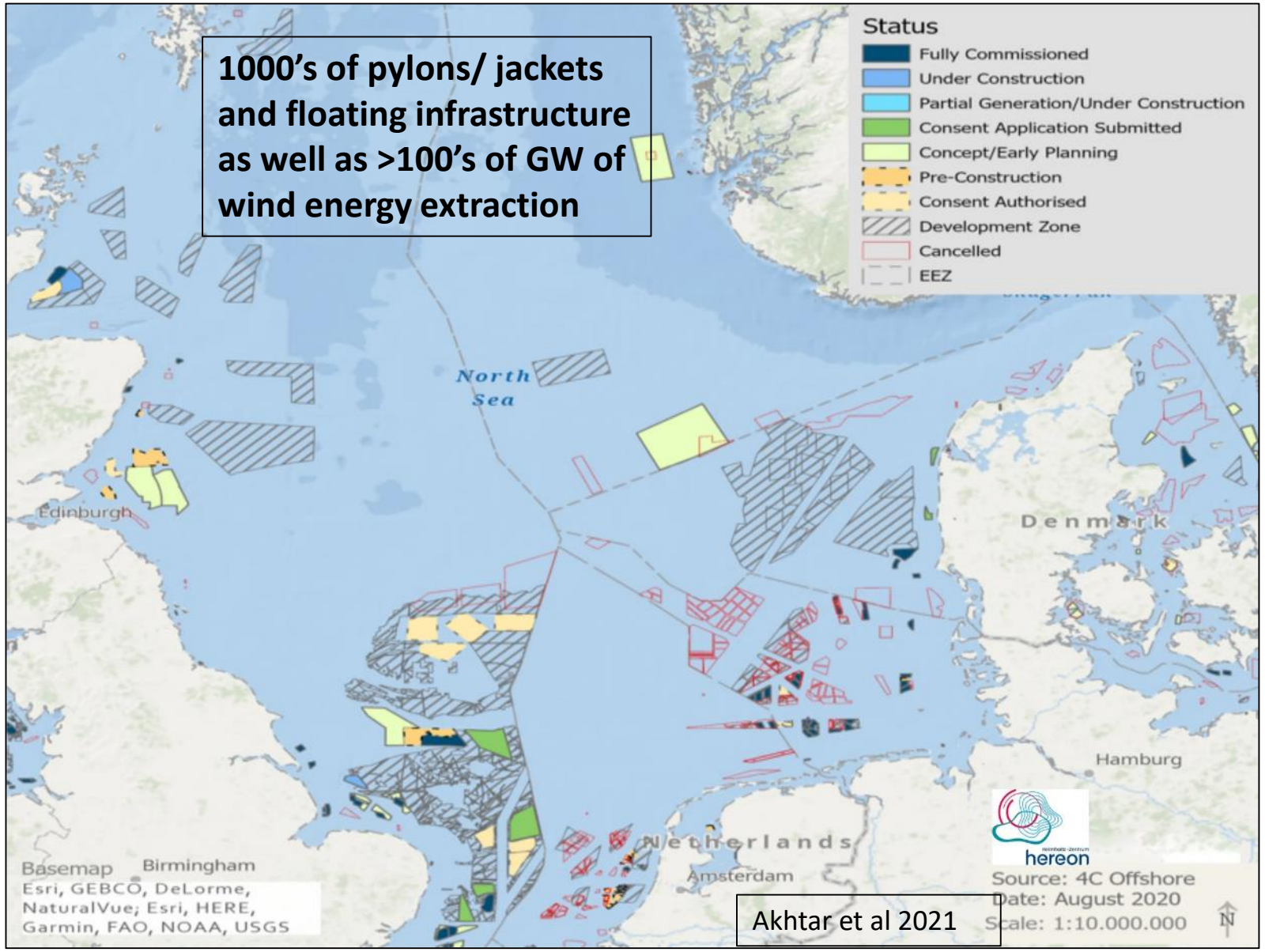
Ecosystem effects of offshore windfarms:

How to understand and use them for a sustainable future.

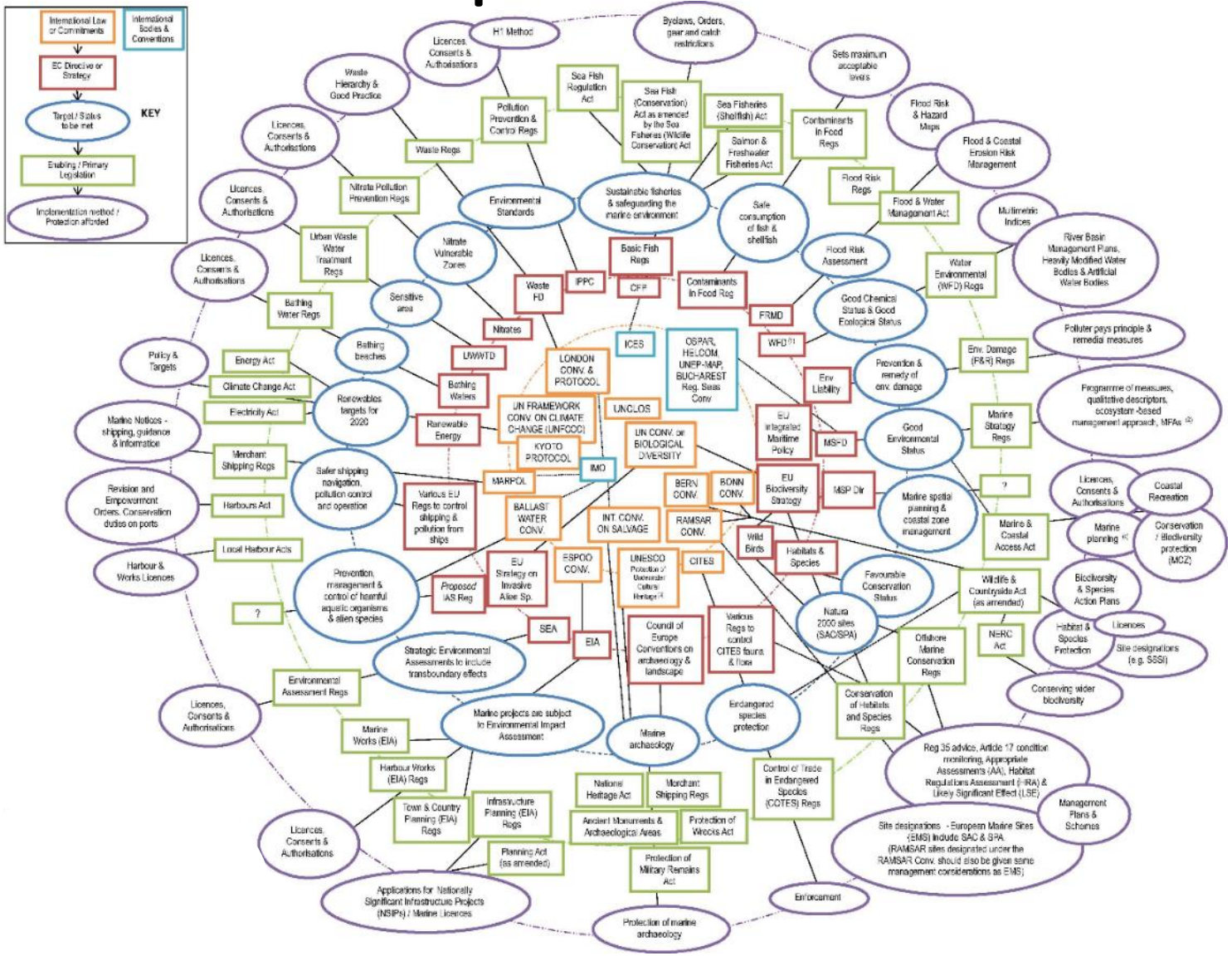
Prof Beth Scott
b.e.scott@abdn.ac.uk



Akhtar et al 2021

How to deal with ecosystem effects – when the regulations mostly focus on one aspect at time?

Horrendrogram of laws affecting 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

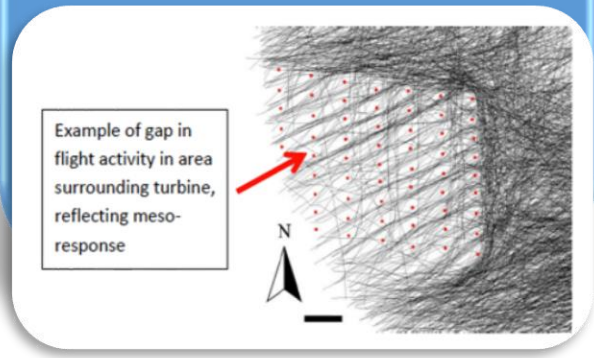
3 D's of Environmental Impacts

Disturbance

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

Displacement

Large scale (permanent) changes in movement/dispersal: daily foraging routes, annual migrations



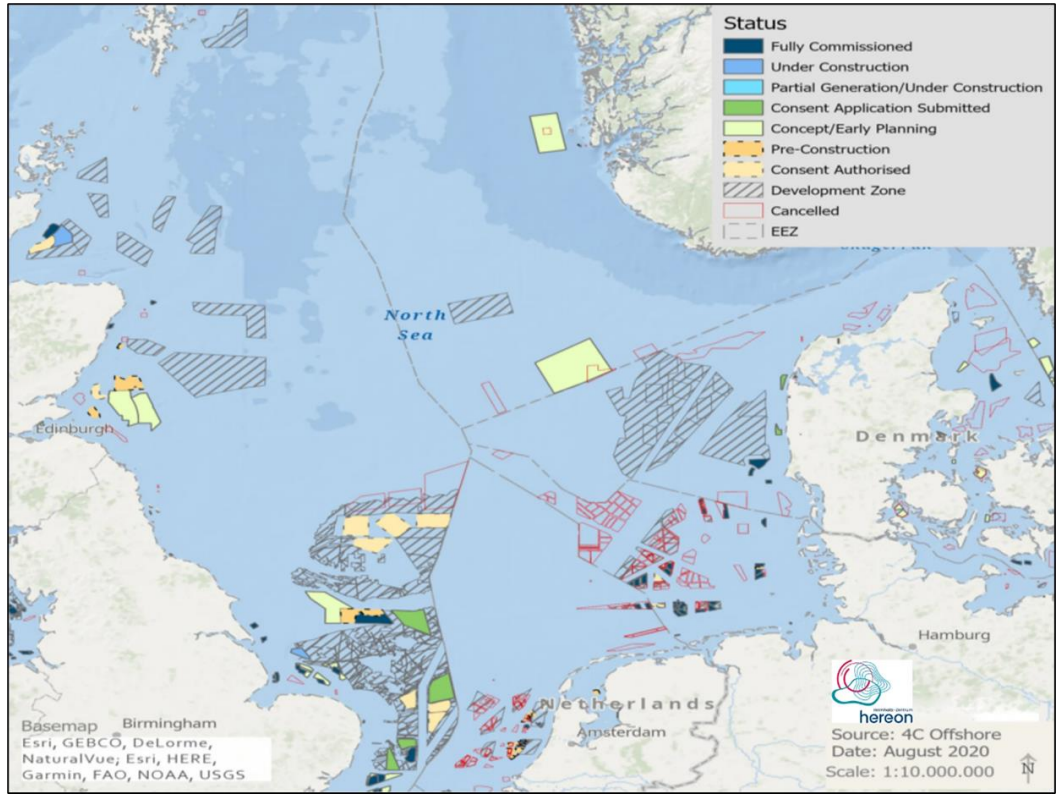
Death

Collision,
Entanglement,
Seabed habitat destroyed

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

Very difficult to produce accurate Cumulative Effects one species at time…

trophic levels effect each other – so how to deal with combined effects?



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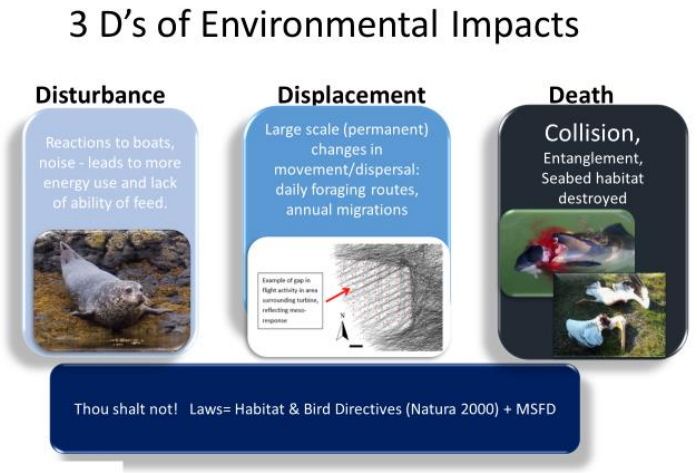
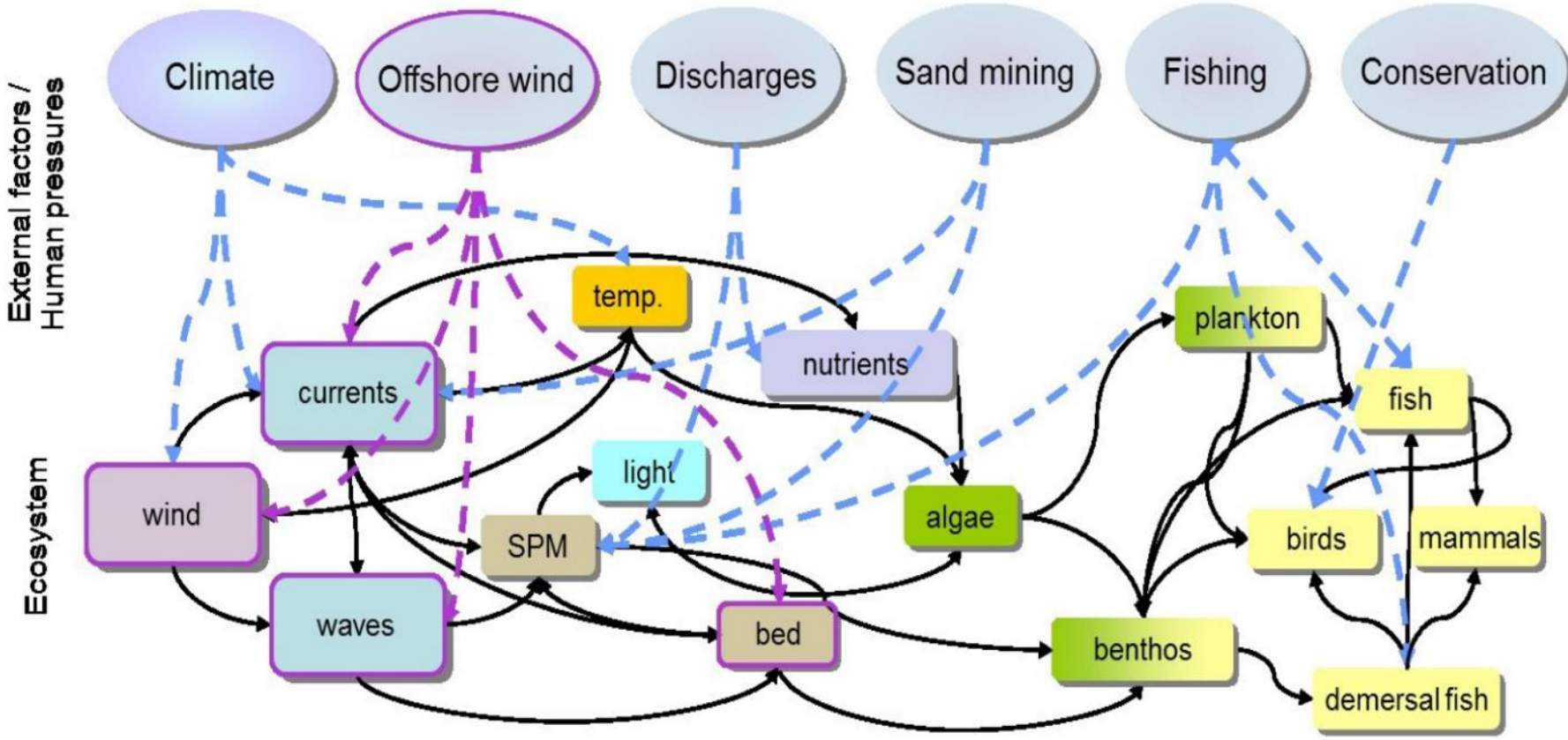


Ecosystems effects of offshore windfarms

Better Approach – accept connections and use knowledge of how ecosystems function



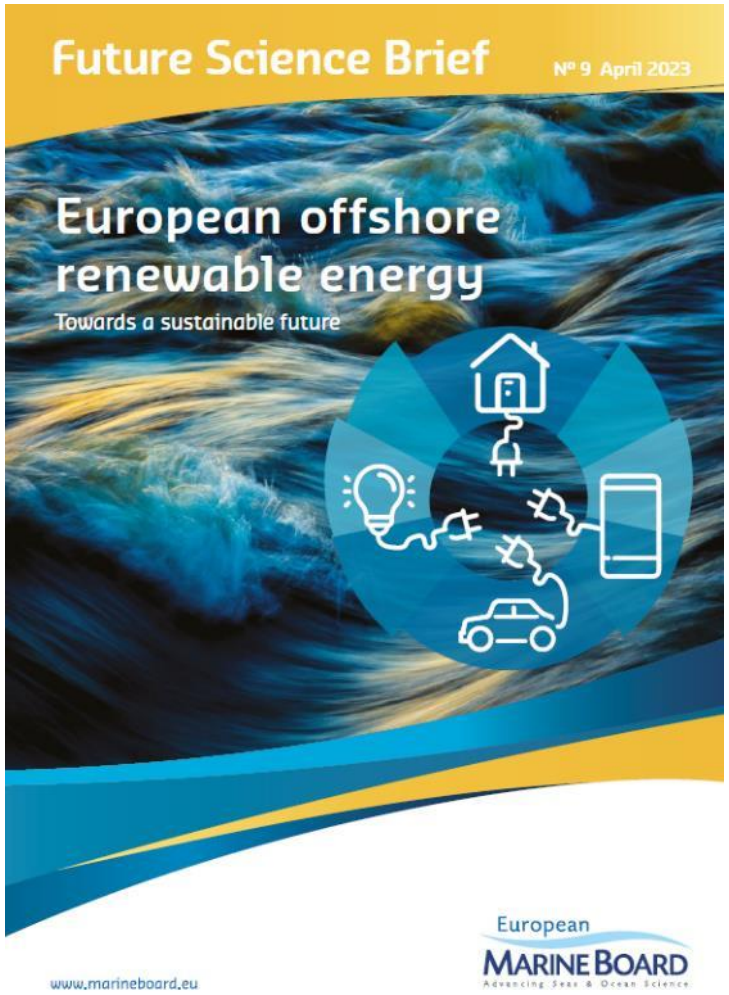
Boon et al 2018

Deltares

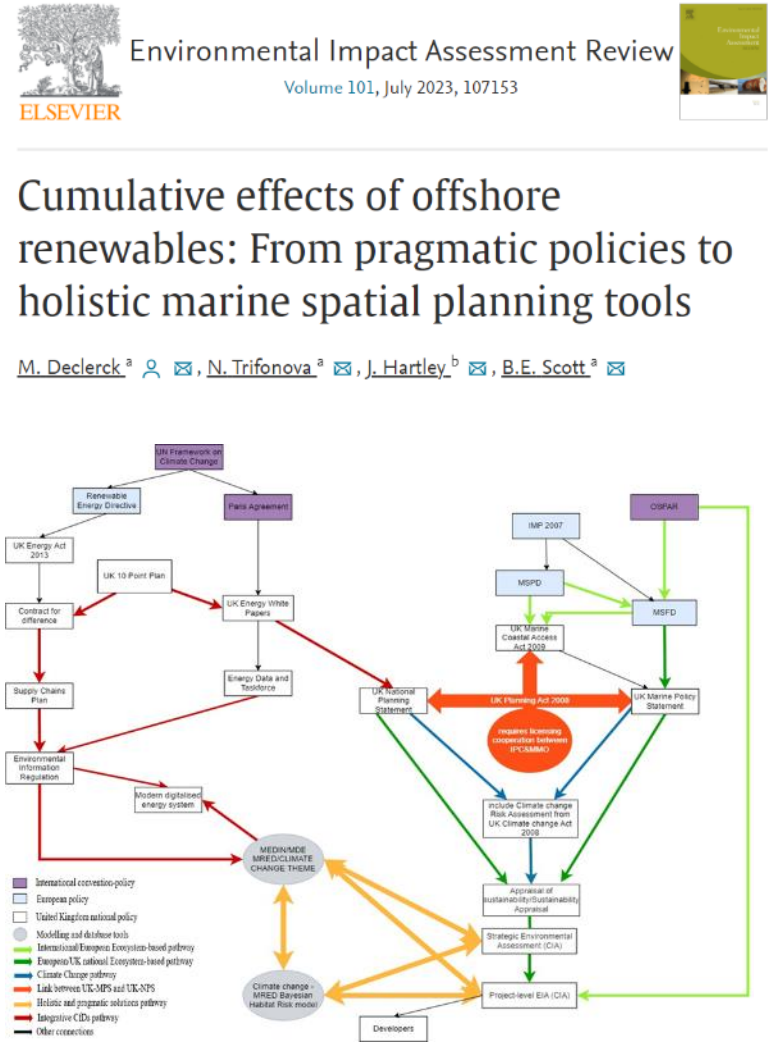
WHIFFLE

WAGENINGEN UNIVERSITY & RESEARCH

New background/overview information: Integrating Ecosystem Approaches and MSFD/GES Policies



https://doi.org/10.5281/zenodo.7561906



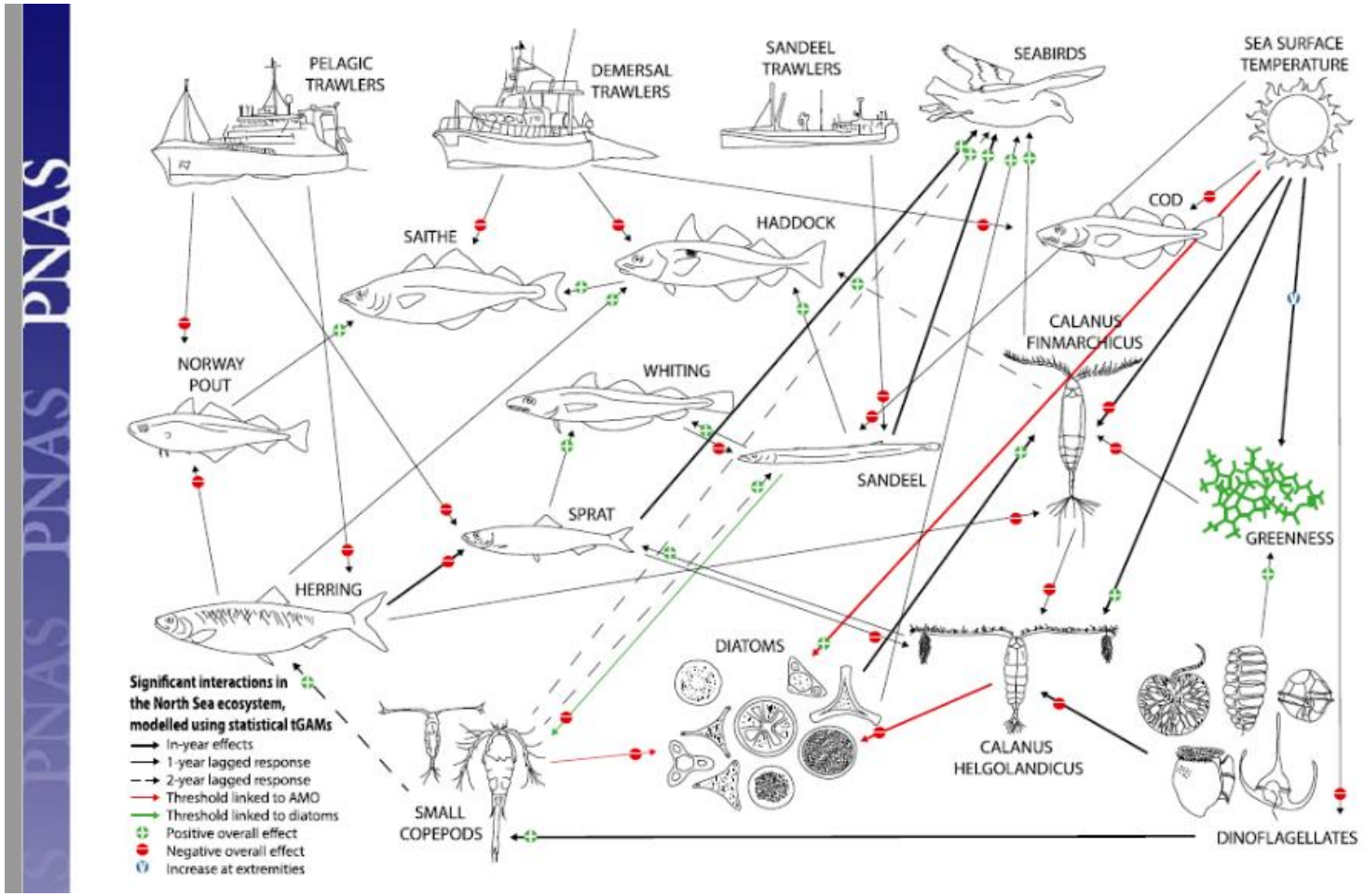
https://doi.org/10.1016/j.eiar.2023.107153

Outline: Understanding Ecosystems for sustainable futures

- How marine ecosystems function: 3 drivers
- How OWFs effect ecosystems: Mixing and primary production (PP)
- How understanding locations of new PP leads to predictability in fish available to predators
- Example of new project to assess ecosystem effects ECOWind - PELAgIO that combines at-sea sampling with oceanographic and ecosystem models and performs scenario testing

3 main drivers of marine ecosystems

>40 y for six plankton and eight fish groups along with one bird group (>20 y)



Lynam et al (2017) PNAS

1. **Bottom-up climatic** processes dominate plankton dynamics.

2. **Planktivorous fish** have a central role in food web - complex effects across and between trophic levels

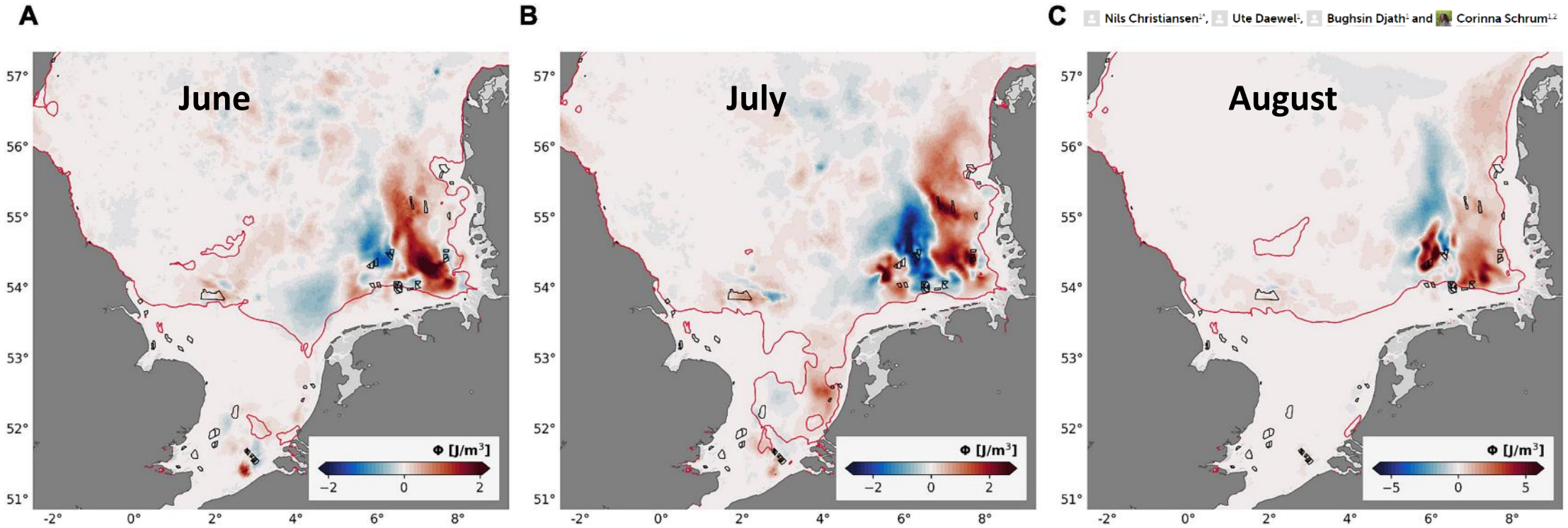
3. **Direct top-down Fishing** pressure on fish populations with Indirect effects altering plankton

Effects of Wind farms: New evidence - Extraction of wind energy changes mixing levels!

frontiers in Marine Science

Emergence of Large-Scale Hydrodynamic Structures Due to Atmospheric Offshore Wind Farm Wakes

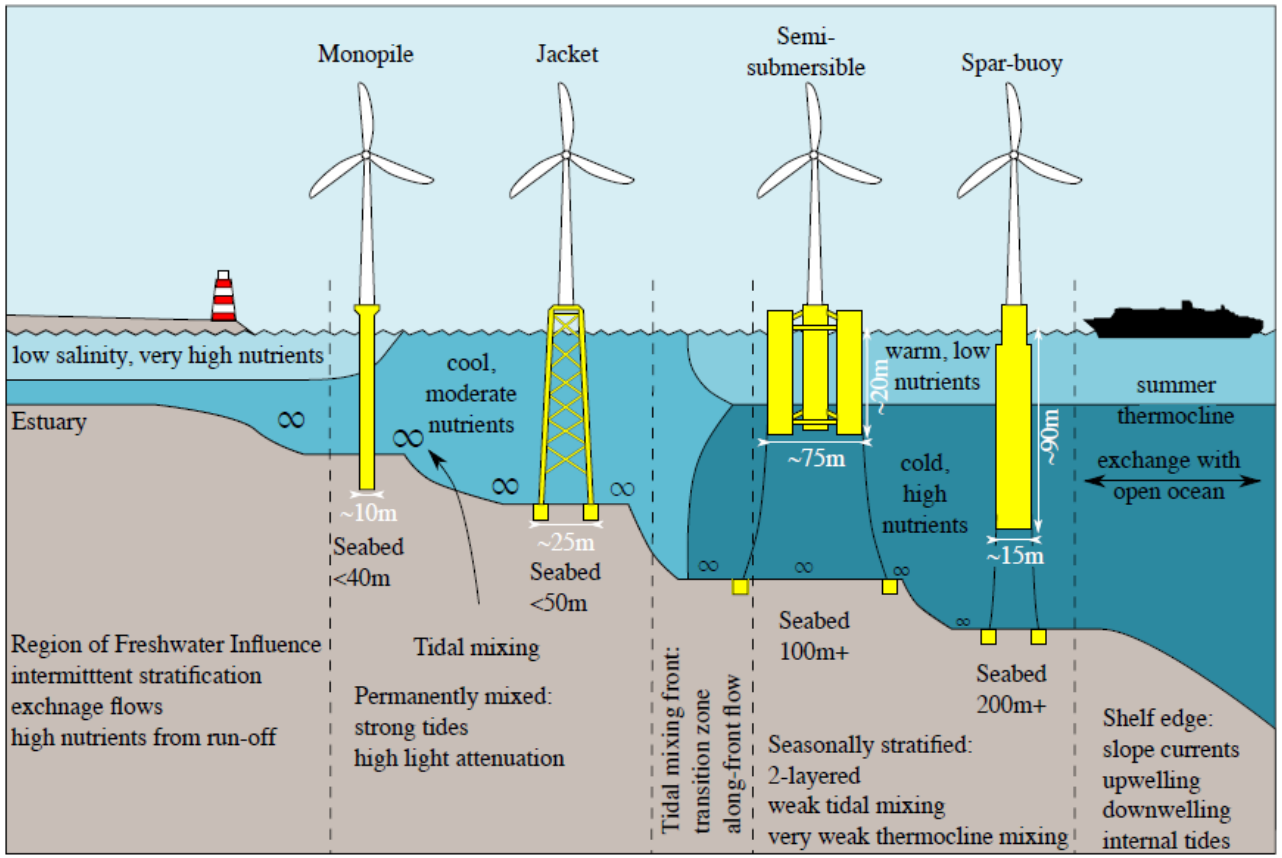
Nils Christiansen, Ute Daewel, Bughsin Djath and Corinna Schrum

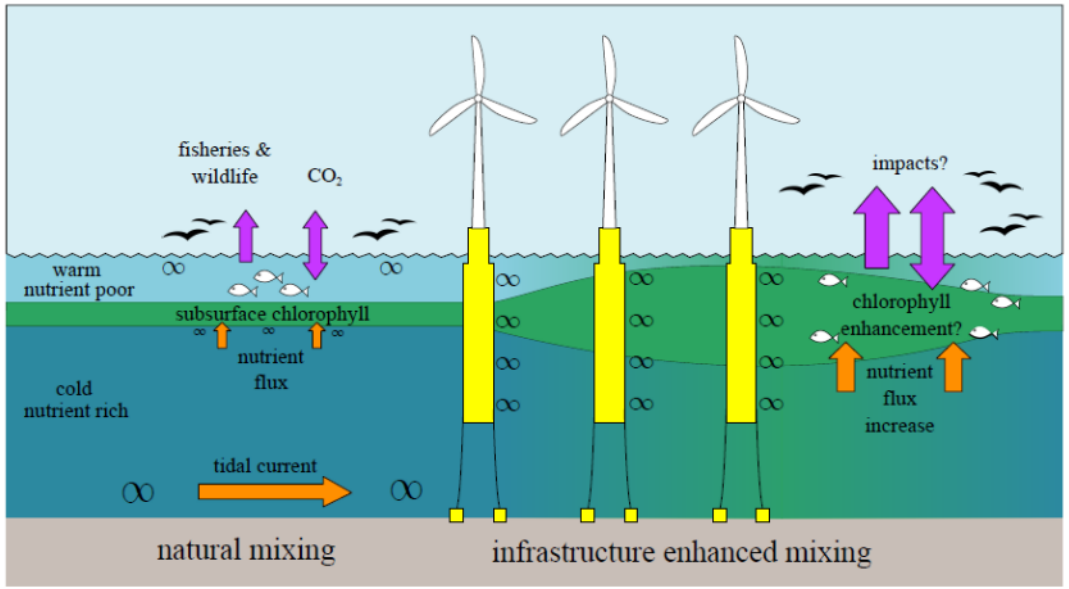


Monthly mean changes in stratification (potential energy anomaly) for the months of June (A), July (B), and August (C). The red lines indicate the location of the mean tidal mixing fronts within the respective months.

Christiansen et al. 2022 Frontiers

Effects of Wind farms: Bottom-up changes from structures - enhanced mixing and production?





frontiers in Marine Science

Anthropogenic Mixing in Seasonally Stratified Shelf Seas by Offshore Wind Farm Infrastructure

Dorrell et al. 2022 Frontiers

Primary production

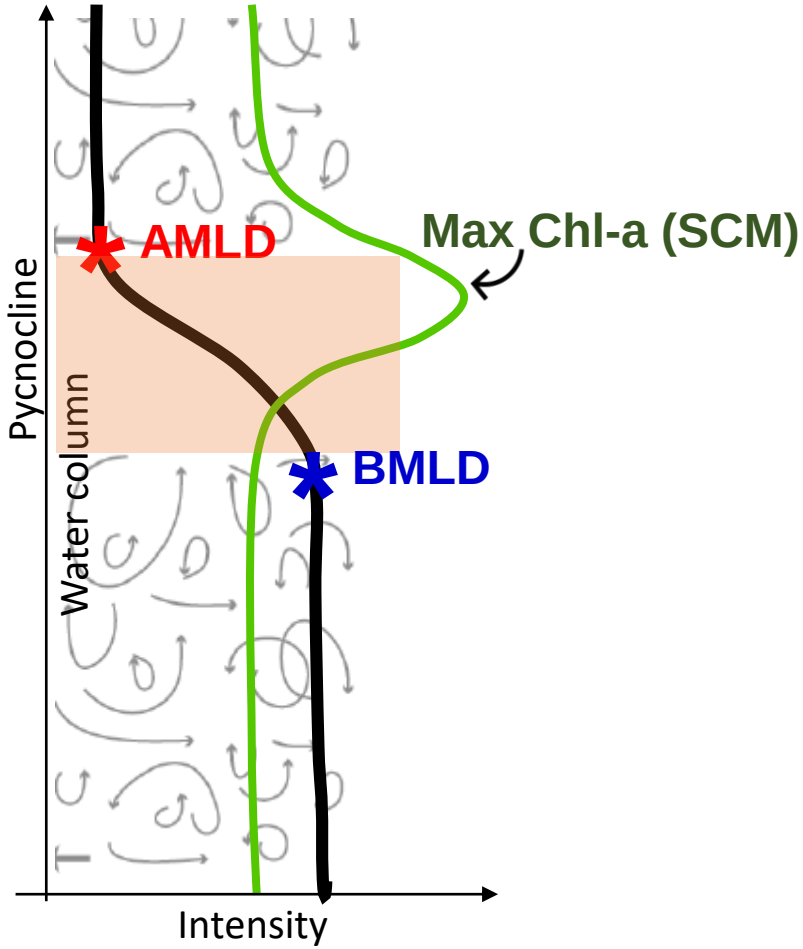
Wind farms

Link

Hydrodynamic processes

Arianna Zampollo

UNIVERSITY OF ABERDEEN

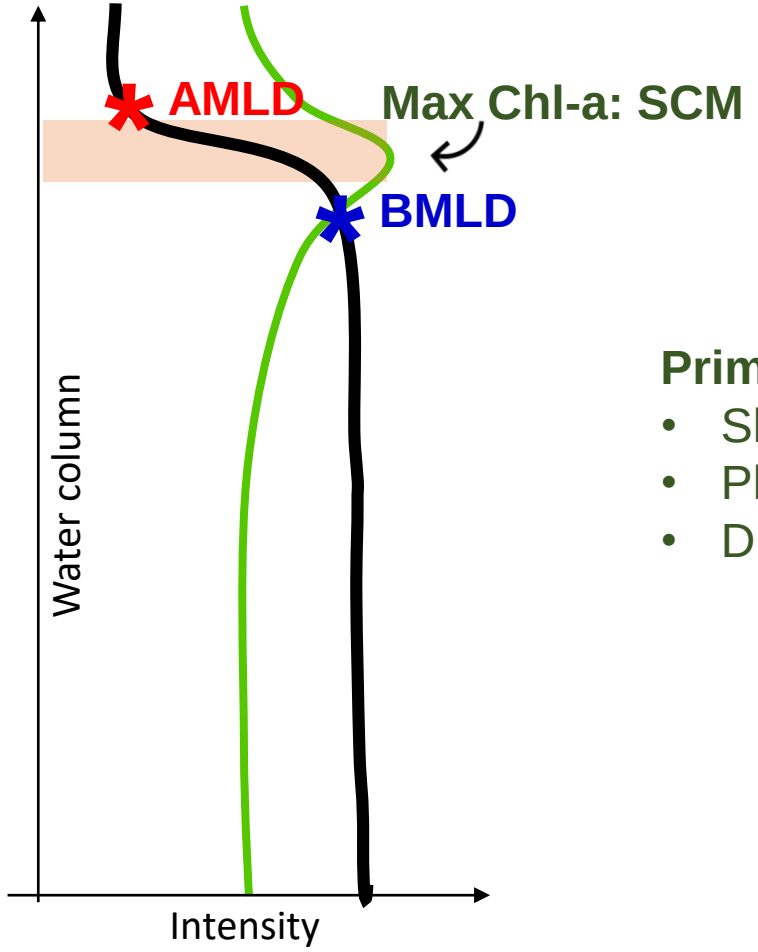


Primary production

Wind farms

Link

Hydrodynamic processes



Primary production characteristics:

- Shape of Chl-a vertical distribution
- Phenology (timing of blooms)
- Different community composition

Density

Chlorophyll-a

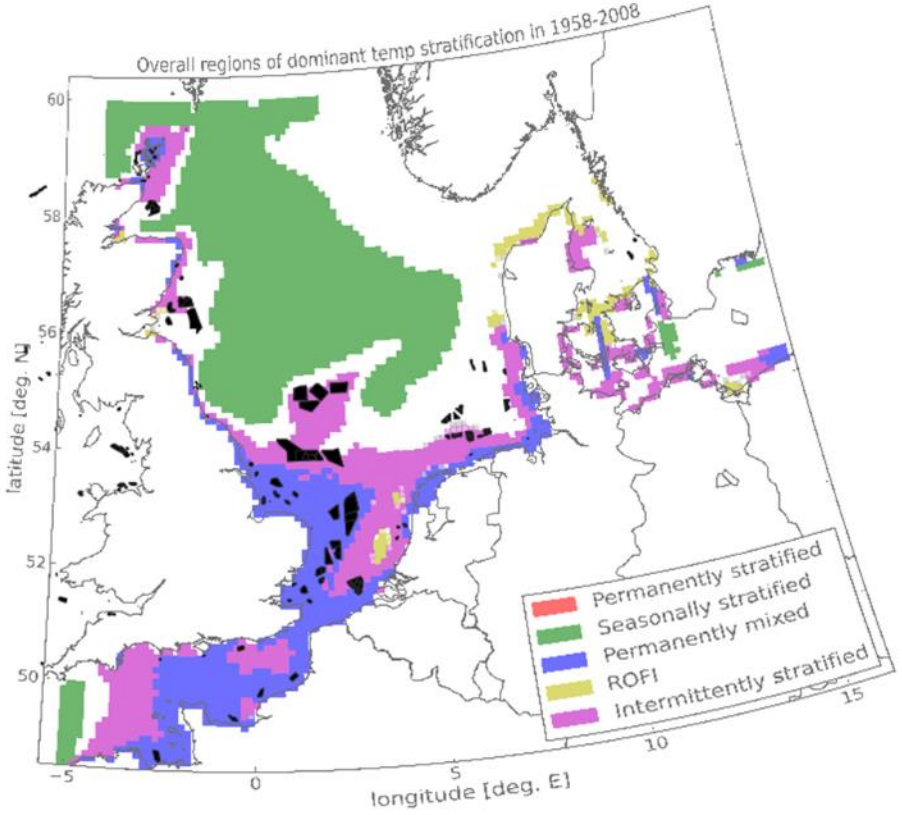
Primary production

Wind farms

Link

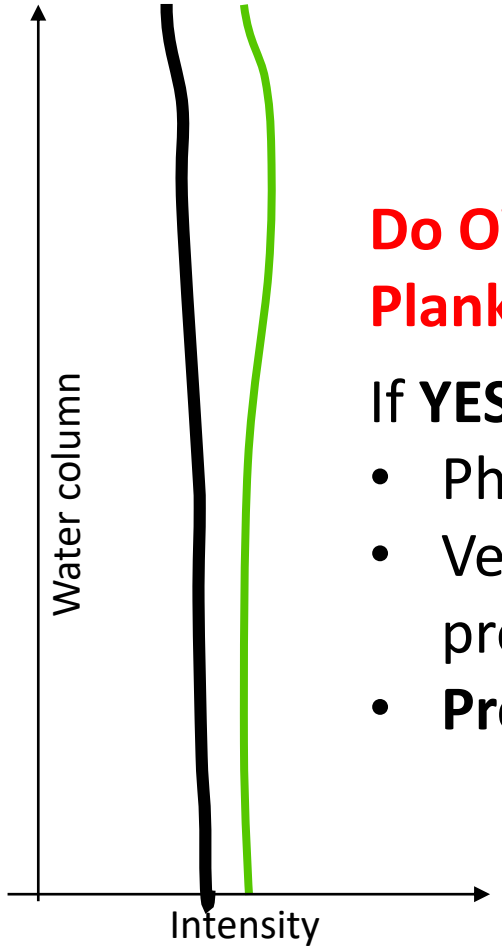
Hydrodynamic processes

Different hydrodynamic regimes



Van Leeuwen et al. 2015
Doi:10.1002/2014JC010485

■ Wind farms
@EMODnet



?

Do OWF affect the vertical distribution of Plankton?

If **YES**, those changes are likely to affect:

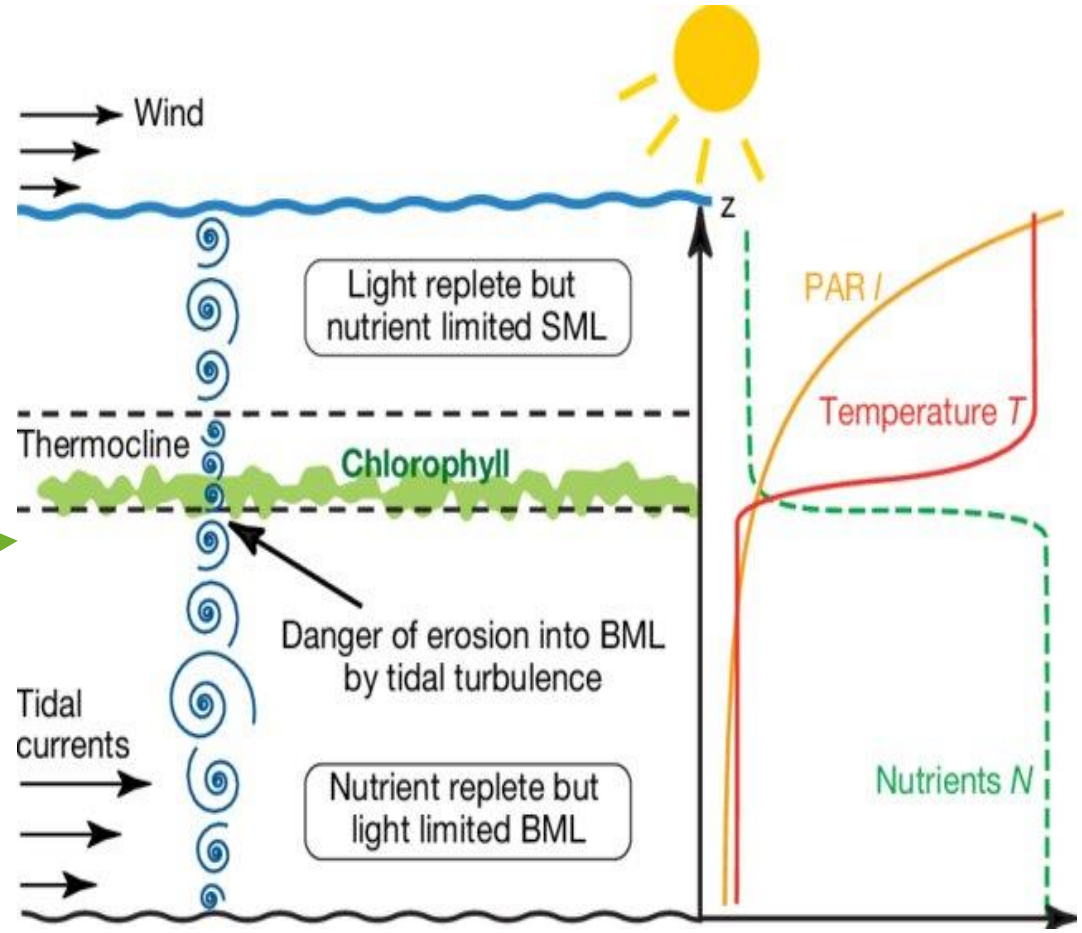
- Phytoplankton **abundance**
- Vertical **availability** of food patches for predators
- **Prey-predators** associations; ecosystems

Bottom-up processes driving Ecosystems: SCM

When/where the sea stratifies (warm water above cool)

After spring bloom the **subsurface chlorophyll maximum (SCM)** can produce up to 50% of the annual primary production

production remains subsurface >20 m

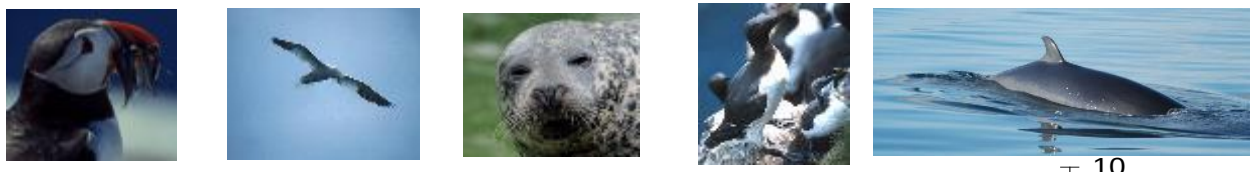


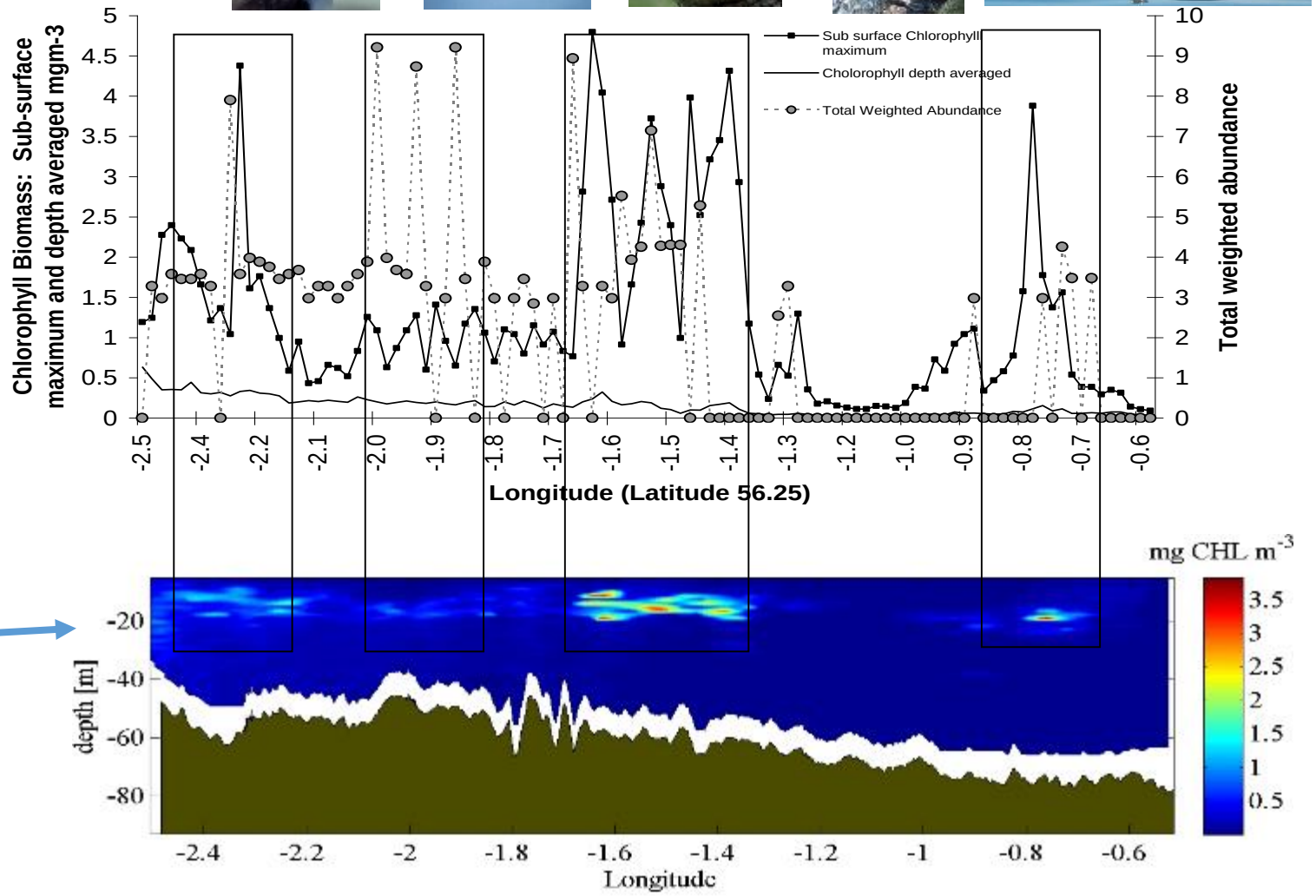
Ross and Sharples (2007) MEPS 347:21-38

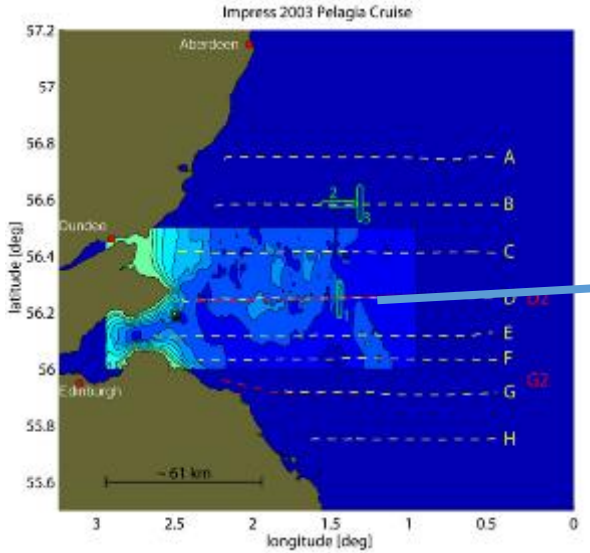
Patchiness of SCM

Evidence that areas of high sub-surface primary production can be use to predict ‘hotspots’ of top predators

All foraging animals grouped as one predator

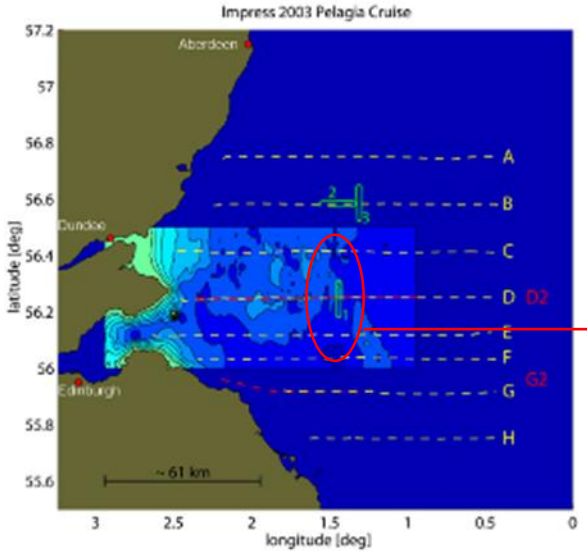


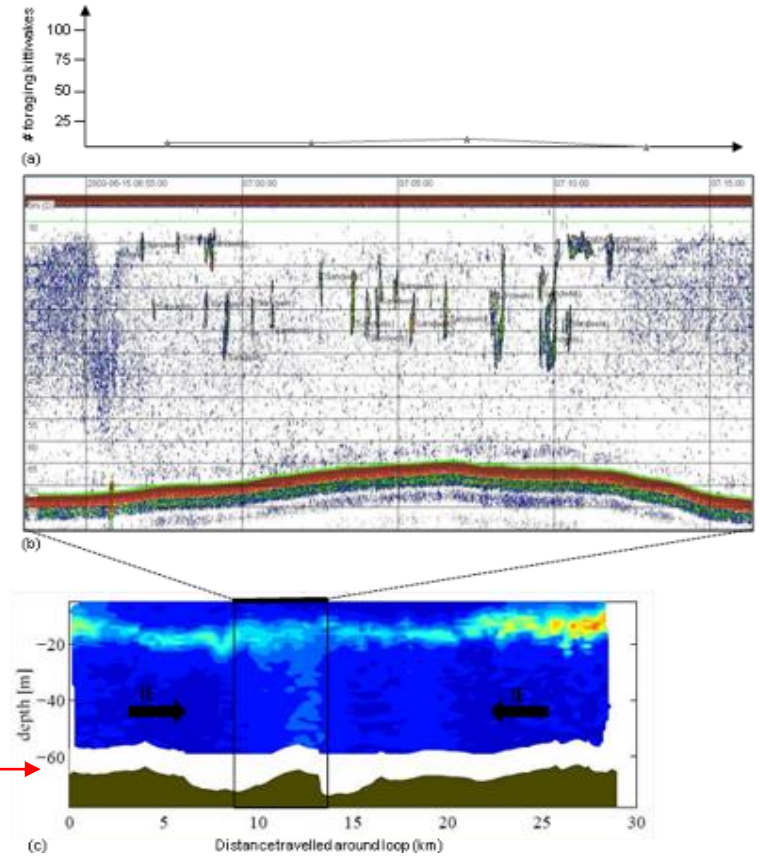


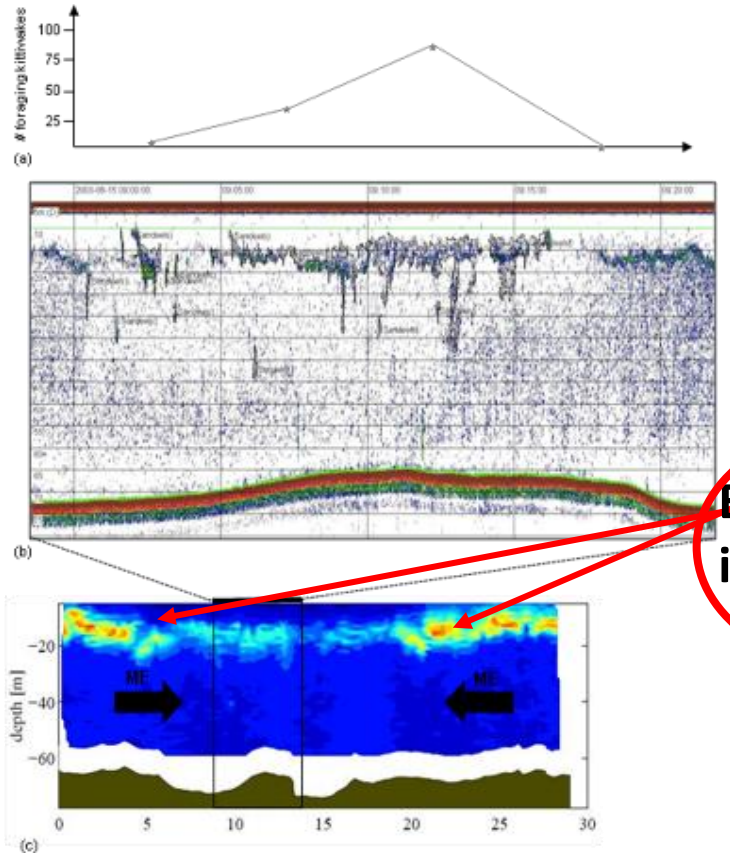


Scott et al 2010 (MEPS 408: 207–226)

Round in circles: Kittiwakes foraging at maximum ebb over bank edge (when sandeels number of schools are greatest and shallowest)



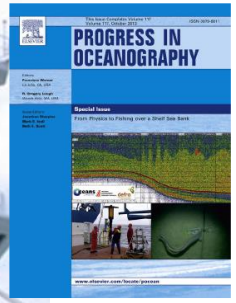




Evidence of internal waves

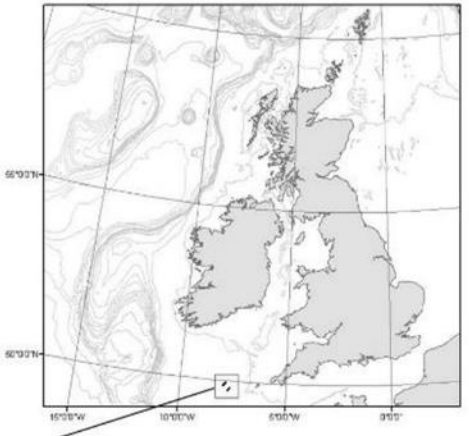
Embling et al (2012) J Applied Ecology 49:481-492

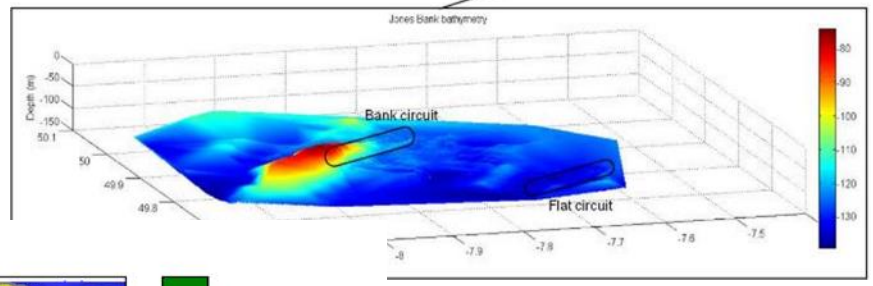
Physic to Fish (CMarHab)



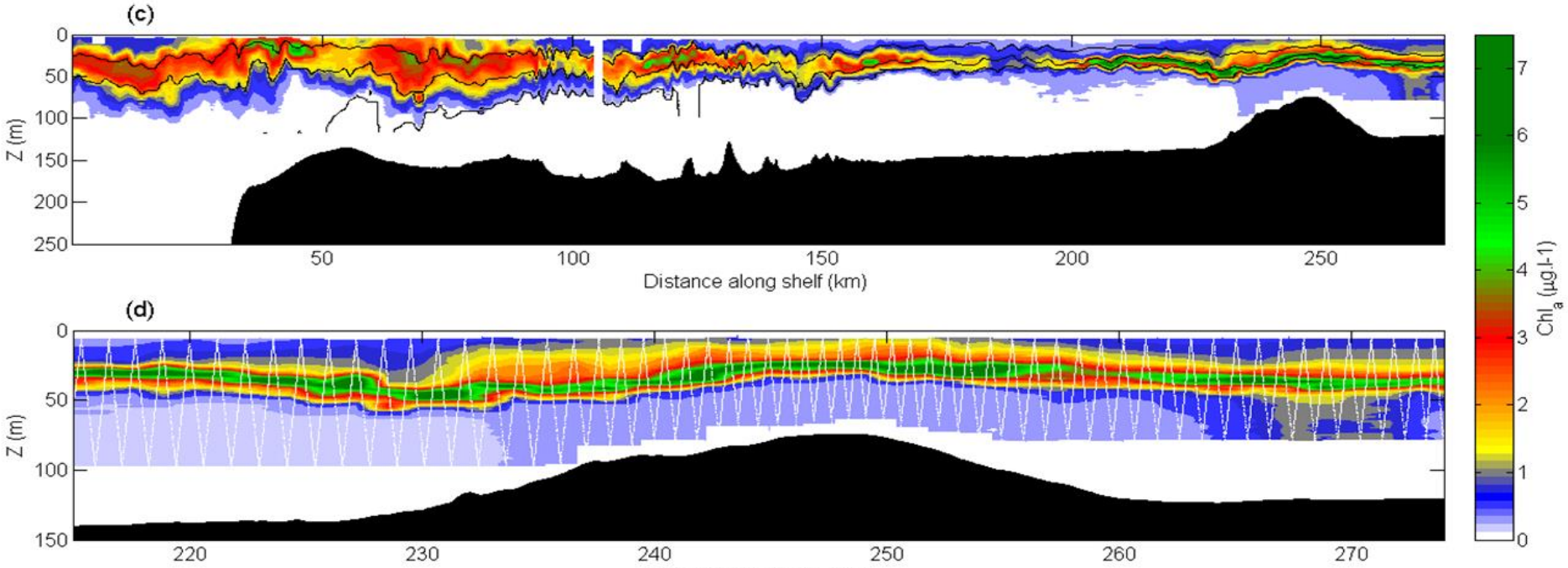
Special Issue
Sharples, Scott, Inall 2013

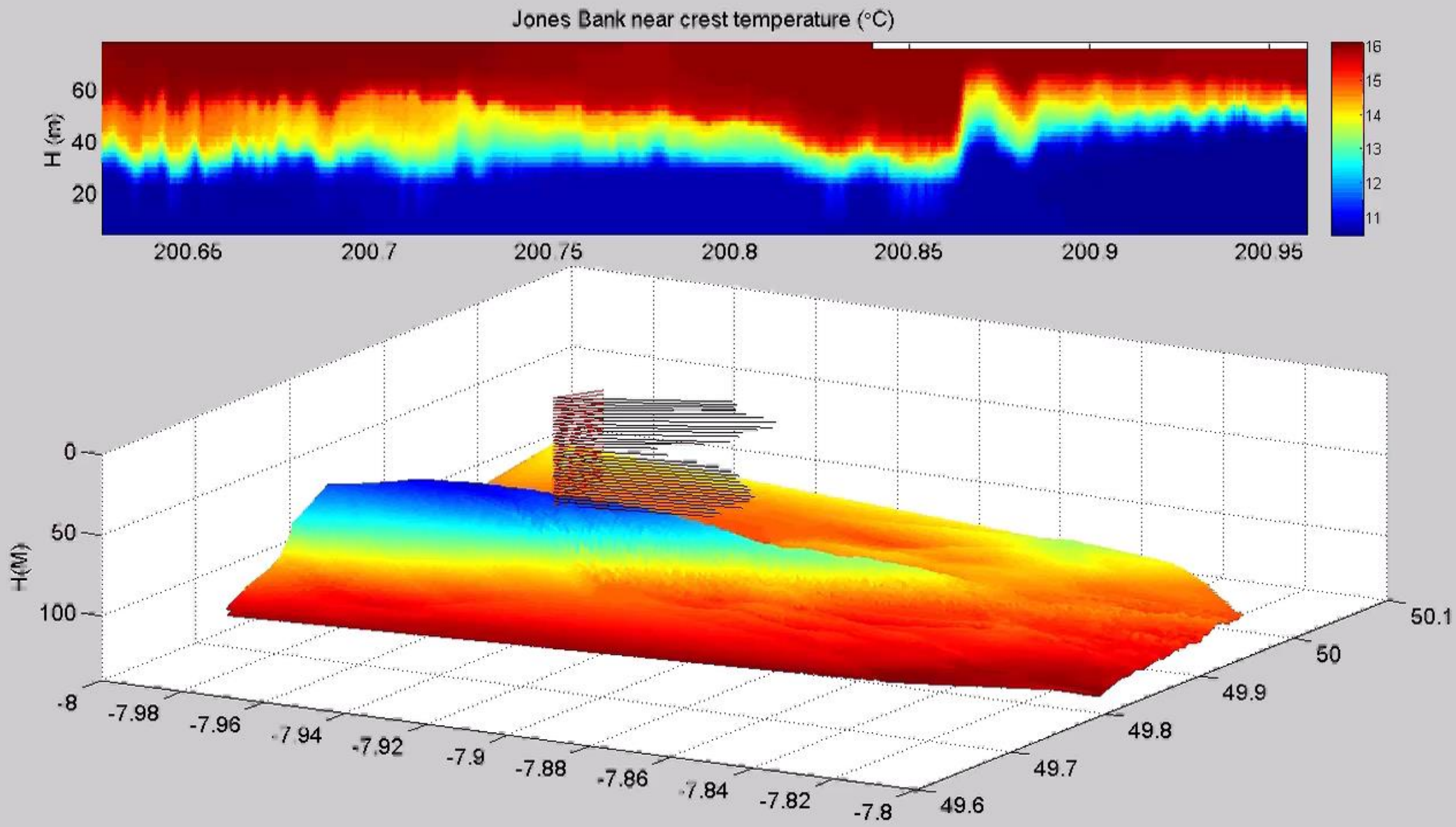
Contrasting
bank to flat area





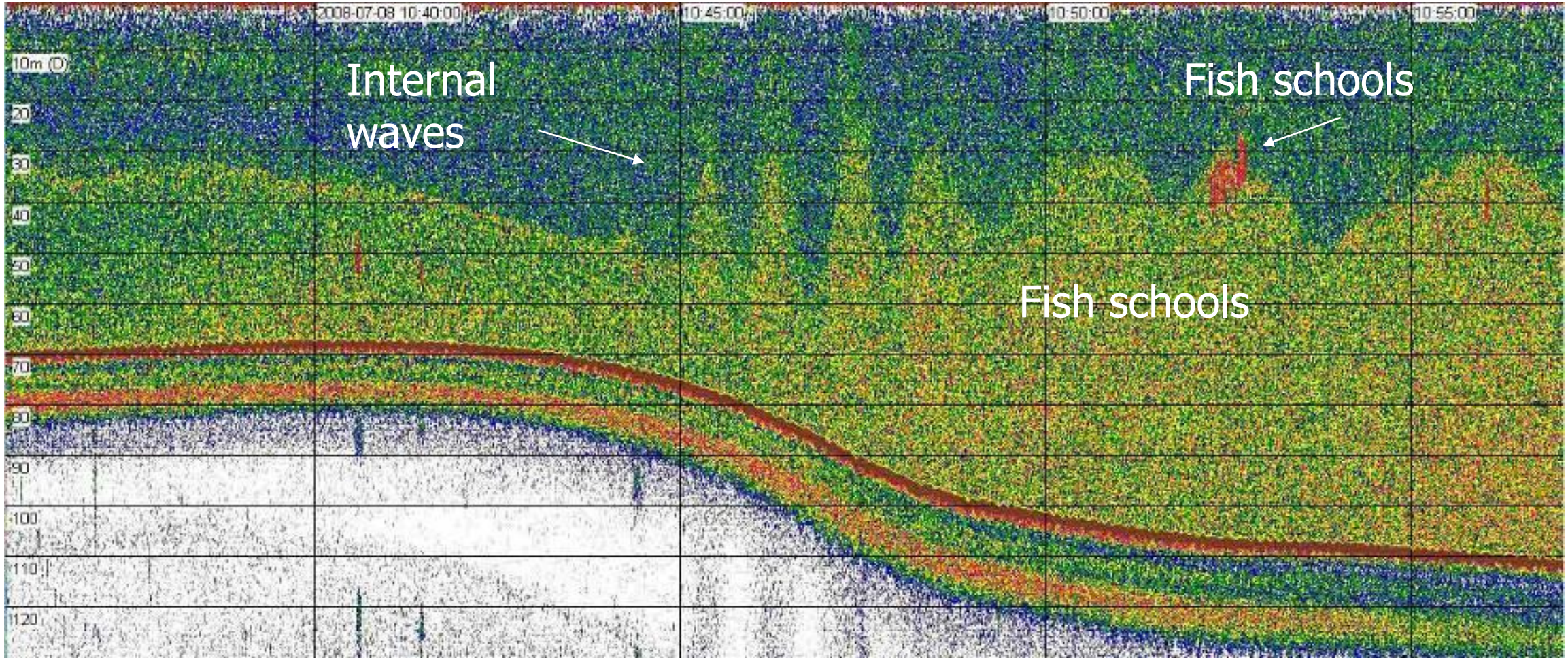
Creation of Internal
waves causing
patchiness at shelf
edges and over banks




Jones Bank near crest temperature (°C)
H (m)
60
40
20
200.65
200.7
200.75
200.8
200.85
200.9
200.95
16
15
14
13
12
11
H(M)
0
50
100
-8
-7.98
-7.96
-7.94
-7.92
-7.9
-7.88
-7.86
-7.84
-7.82
-7.8
49.6
49.7
49.8
49.9
50
50.1

Fisheries acoustics – can show structure in water column

EK60… more than just a pretty fish finder…



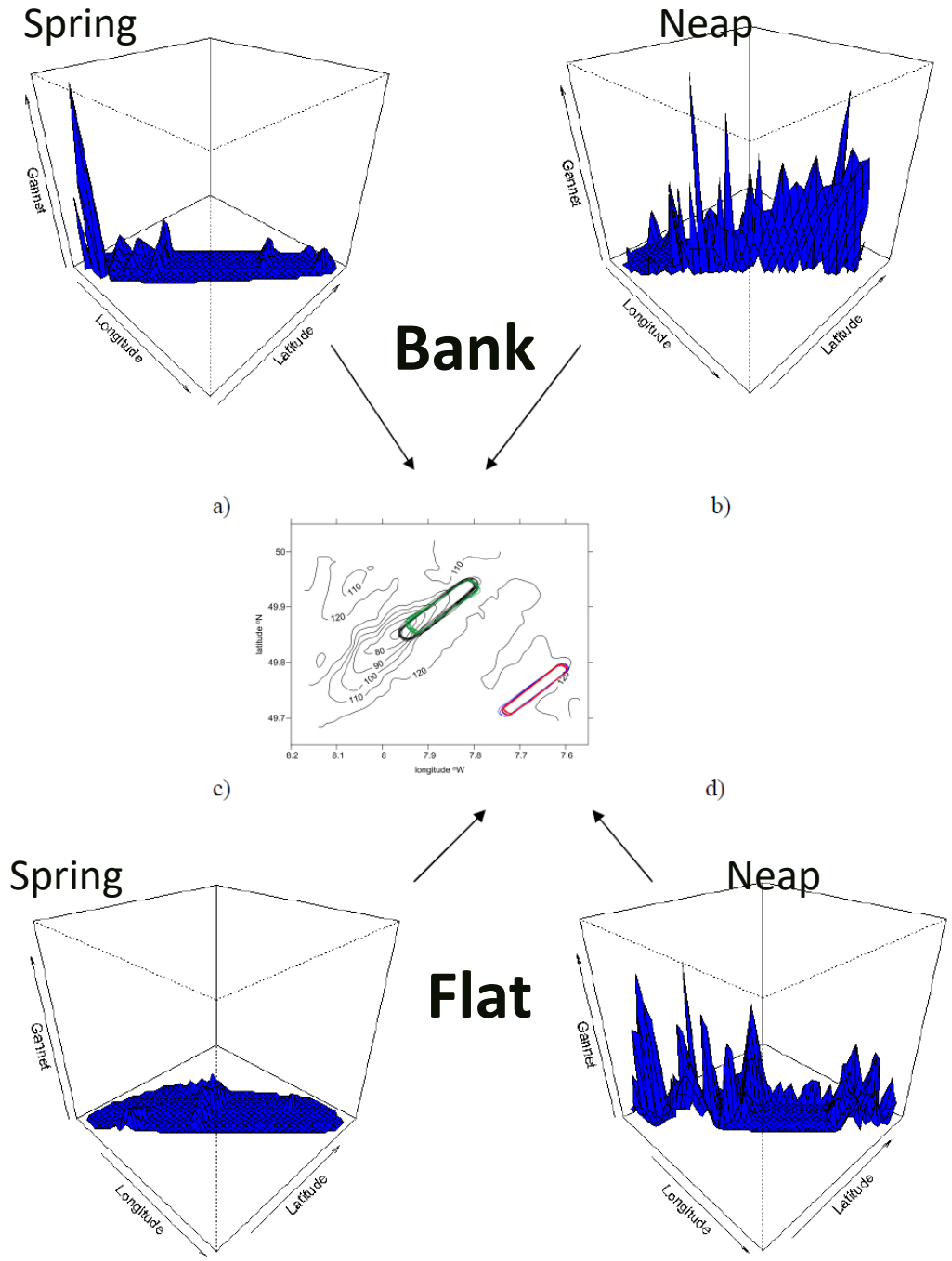
…great for showing internal waves!

Embling et al. 2013

Gannets only use <u>internal wave action site</u> on springs at the bank

Preferring neap tides in both areas

Scott et al. (2013)



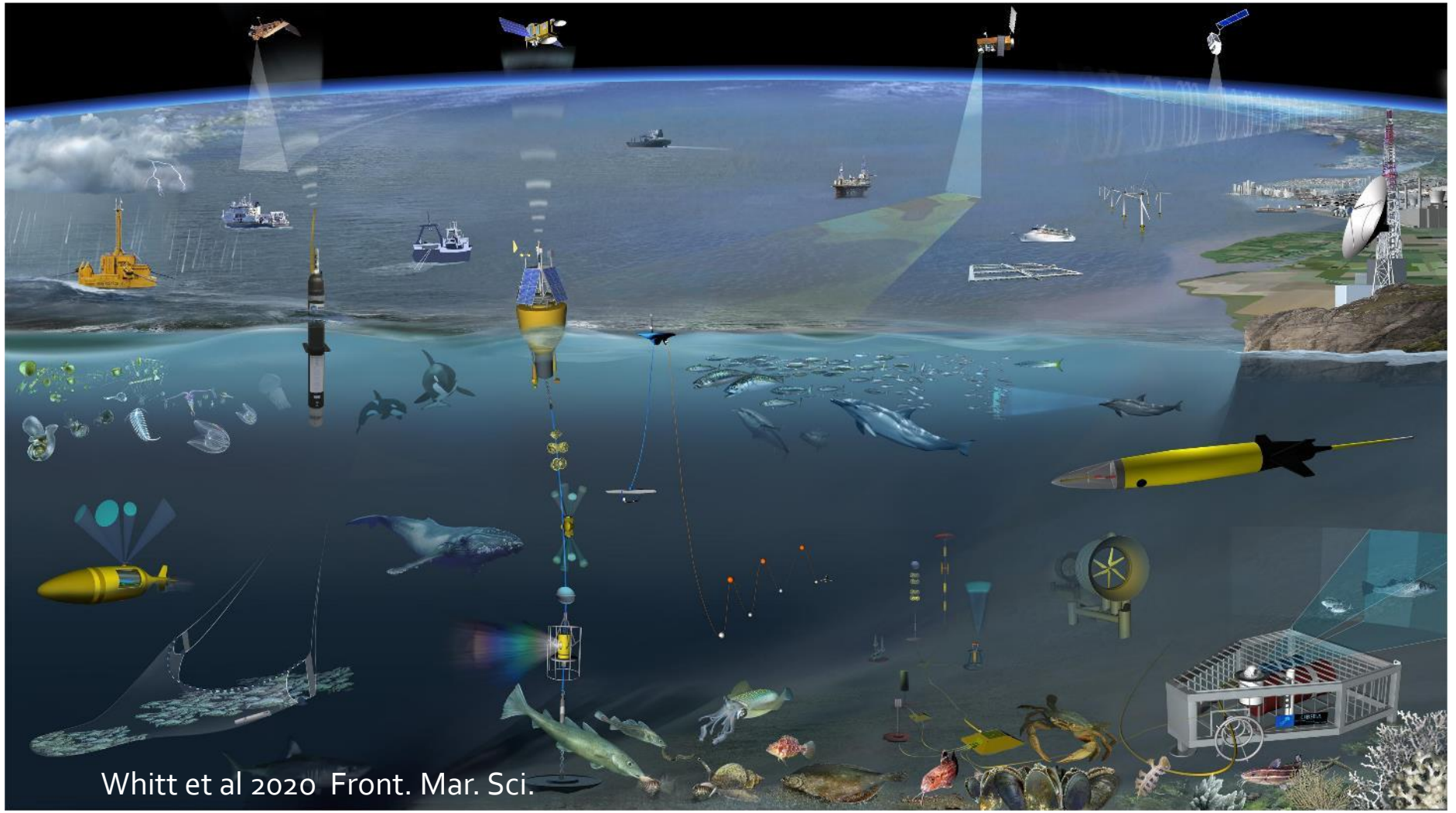
Story so far…

- Need to work at ecosystem level to understand cumulative effects
- OWF can change mixing and therefore primary production - a main driver of Ecosystem functioning
- Areas of new primary production driven by differences in mixing may be limited locations of higher trophic predator-prey interaction - **Not all locations are equal**

To come…

- Example project for assessing ecosystem effects

FIELD DATA: Need to understand linkage between layers & need to collect multiple data types simultaneously



Whitt et al 2020 Front. Mar. Sci.

For continuous, simultaneous monitoring across tropic levels/physics:

- gliders
- smart buoys and moorings
- upward facing platforms with acoustics
- Lower CO_2

ECOWind

PELAgIO
Physics-to-Ecosystem Level Assessment of Impacts of Offshore Wind Farms (OWF)

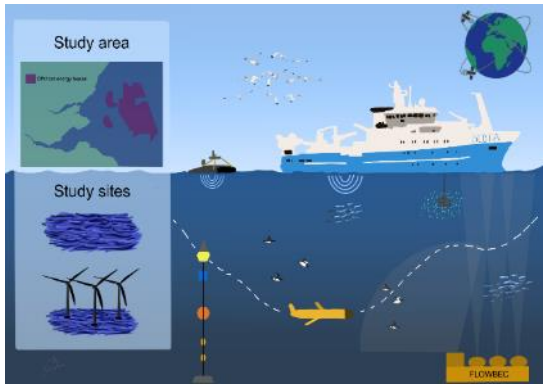
WP1: Impacts of changes in mixing from OWF on local, regional and shelf-wide scales. Determine if outside natural variability and relative to Climate change.

ECOWind

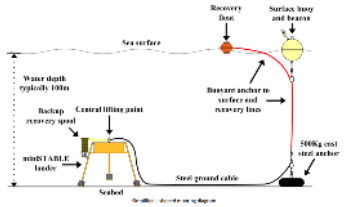
Field Data and Model Predictions at all (overlapping) Scales

Local

(AUV, Moorings, FLOWBEC)
(10 m-1 km)

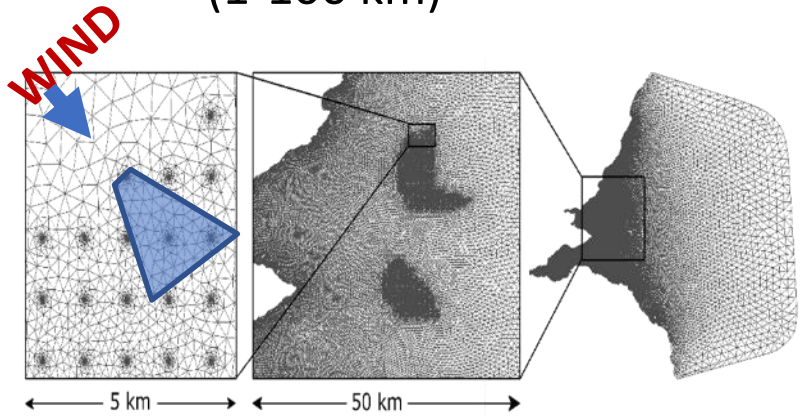


field data collection

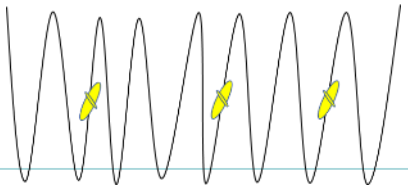


Regional

(AUV, FVCOM + ERSEM)
(1-100 km)



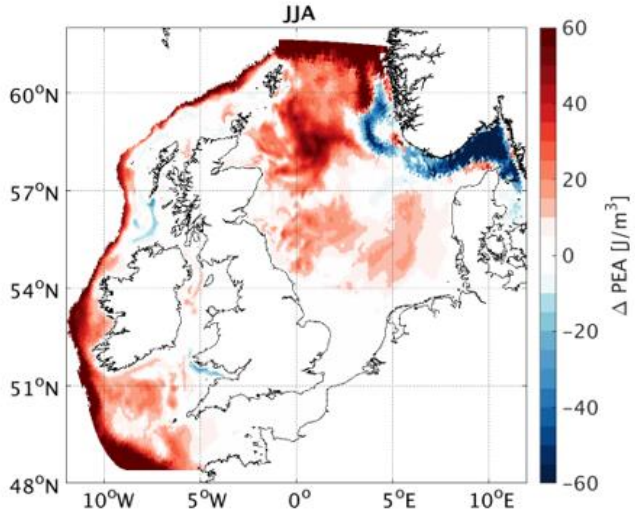
e.g. Firth of Forth



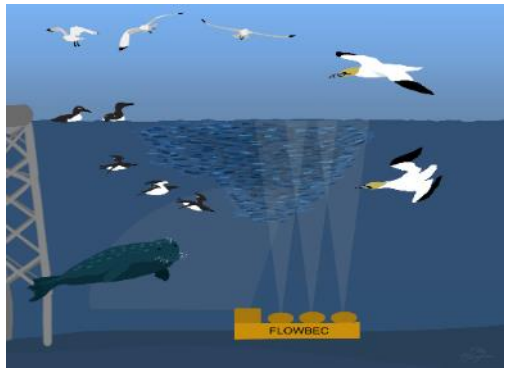
Shelf Wide

(FVCOM + ERSEM: OWF & Climate Change)
(>1000 km)

Change due to future climate



WP2: The oceanographic processes that predict fish availability and how OWFs alter foraging opportunities



Two new metrics

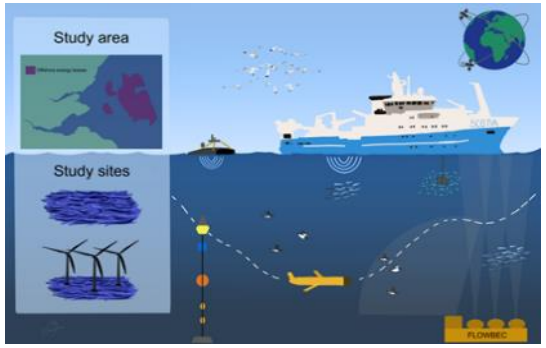
(i) **prey availability**: spatio-temporal variation

(ii) **probabilities of foraging opportunities** (per km^2/hr)

Local

(FLOWBEC, AUV, Moorings)

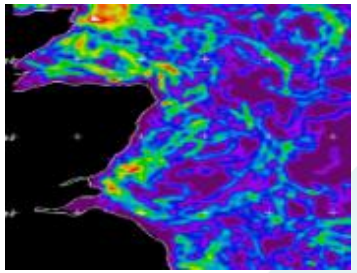
(10 m-1 km)

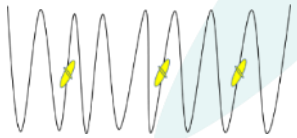


Regional

(AUV, NEODAAS/tag data)

(1-100 km)

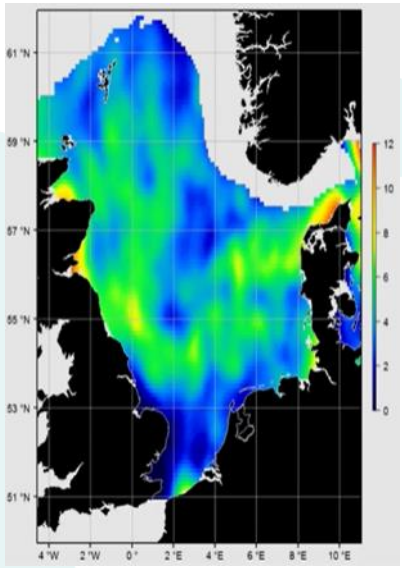




Shelf Wide

(ICES/HERAS/PREDICT)

(>1000 km)



PREDICT

Ørsted

WP3: New methods to assess Ecosystem-level cumulative effects and trade-offs with/ without windfarms, fisheries, climate change

ECOWind

SECTION ONE: Bayesian ecosystem model

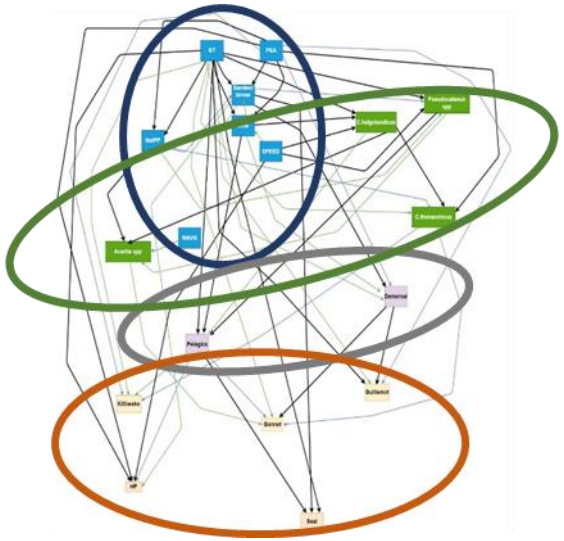
SECTION TWO: Ecosystem Services and Net Gain estimation

SECTION THREE: Socio-economic valuation: Natural Capital and GVA

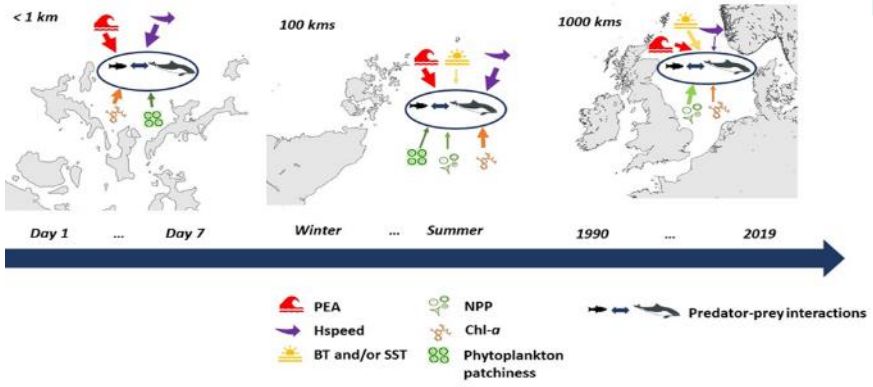
SECTION FOUR: ORE Deployment, climate change and fisheries scenarios

SECTION FIVE: Spatial planning decisions and energy policy

Dynamic Bayesian Network Model:
Outputs as Ecosystem Services, Marine Net Gain, Natural Capital, Gross Value Added (GVA)



Testing at different spatial scales

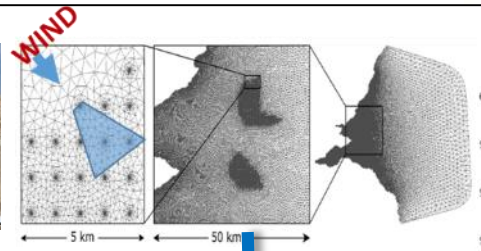


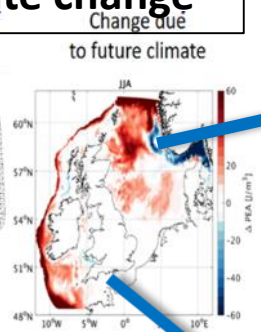
Trifonova et al. 2022 *Progress in Energy*

Trifonova et al. 2022 *Frontiers in Marine Science*

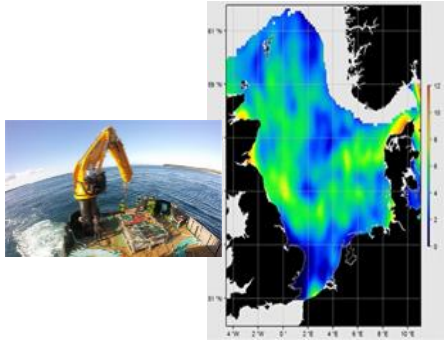
Main Outputs:

WP1: **New autonomous monitoring techniques** and predicted **fine and far field affects of OWF and Climate change**

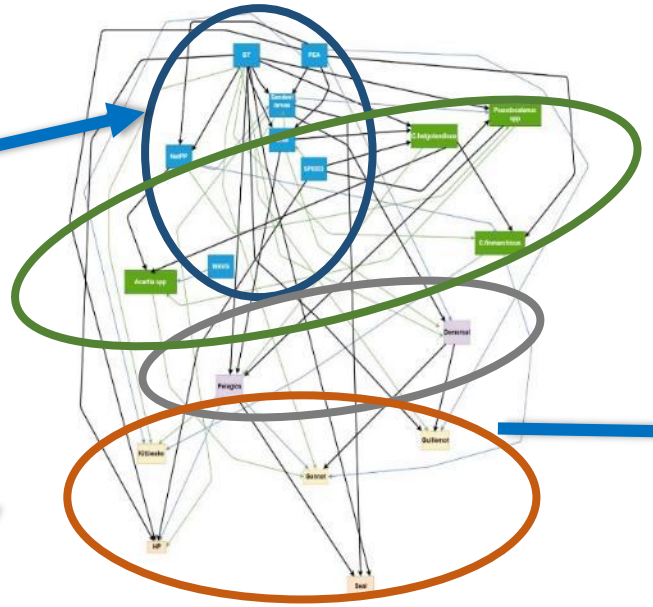




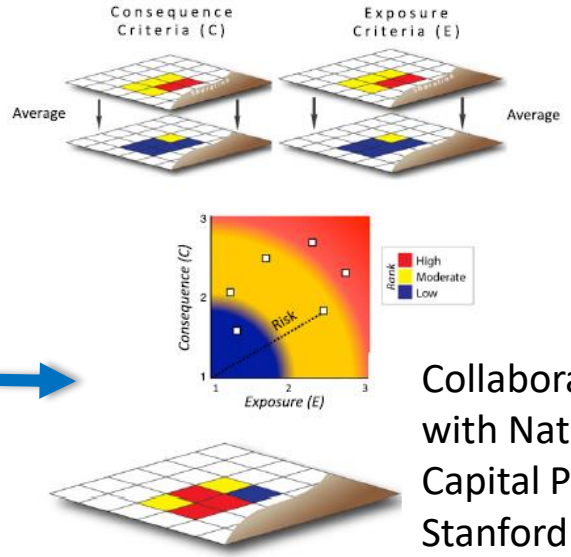
WP2: **Fish availability Metrics**: reasons for variation in predator spatial distributions



WP3: **Cumulative Population trends** - allows for dynamic interactions with all trophic levels



WP3: Modified HRA InVEST for finer scale (plan/development) output – **asses trade-offs in space use**



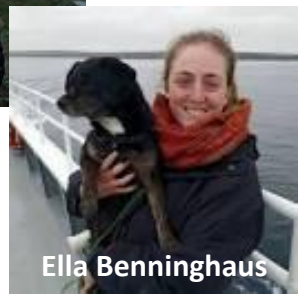
Collaborations with Natural Capital Project, Stanford

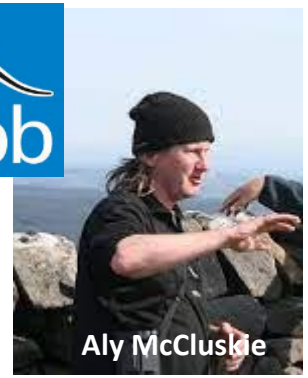
Scenarios – with/without-windfarms, fishing displacement and climate change at different spatial scales

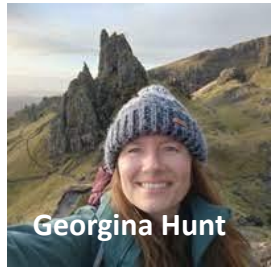
Fisheries displacement

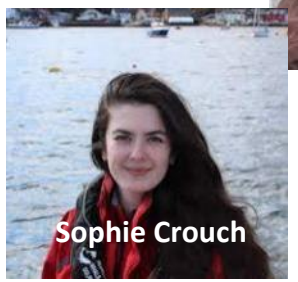
- Improves certainty in collision and displacement models- **prey availability**
- Assess levels of change in Marine Net Gain Ecosystem Services; **where are populations increasing/decreasing**
- Identifies which areas are **better/worse for OWF** and which are **more/less resilient to climate change**

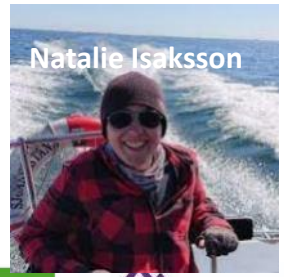
PELAgIO, PREDICT and EcoNEx collaborations

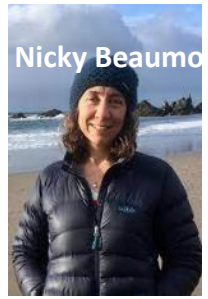












Ecosystem effects of offshore windfarms:

How to understand and use them for a sustainable future.

1) **Need to more fully understand bottom-up effects to understand all effects.**
   i. Change in plankton
   ii. Change in pelagic fish growth – whole food chain (good MPAs/essential fish habitat)?
   iii. Change in distributions/populations of seabirds and marine mammals linked to fish
2) **Make the most use of the use of our seas**
   i. Strategic pre-, but focus on long-term post-monitoring across trophic levels to understand species and ecosystem level issues (Good Environmental Status).

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Questions?