# Using models to anticipate ecosystem and food-web consequences in the North Sea

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# Understanding 'connectivity' ...

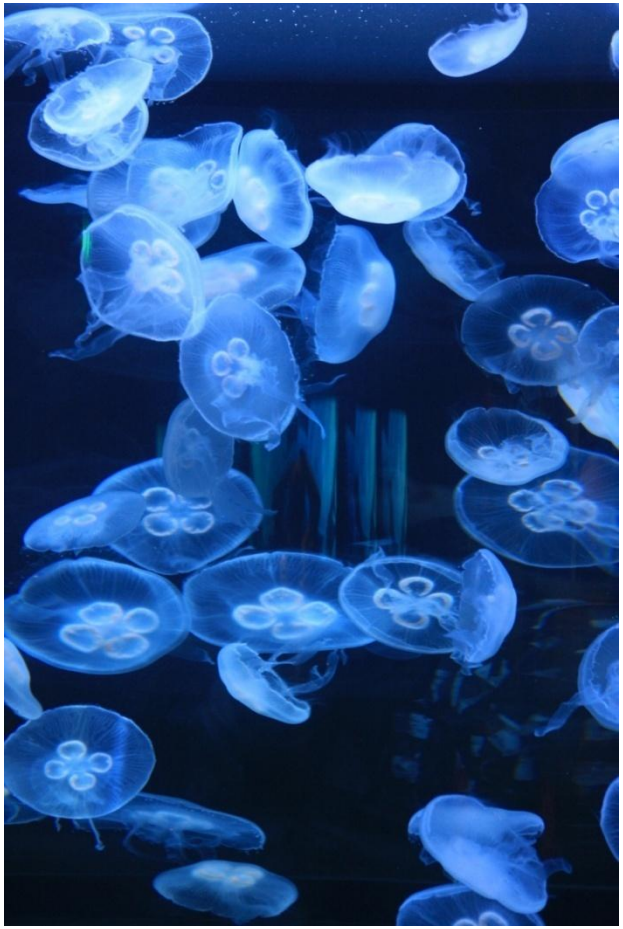
A key issue when thinking about offshore structures is whether they can act as **a 'source' or 'seed' locality** for populations of desirable or non-desirable species

**What is the connectivity between sites?**

If an animal is present at one site, will it be able to use **offshore structures as 'stepping stones'** to spread throughout the region.

Key issues:
- **Fish eggs and larvae** (can they replenish the sea)
- **Non-native, alien species**
- **Jellyfish** (will populations explode)
- **Biological diversity**

Cefas has developed a number of tools to look at connectivity between sites....



# Connectivity between North Sea MPAs

- **Marine Protected Areas (MPAs)** are being defined all around the UK

- MPAs should form **a coherent network** that affords protection to key species

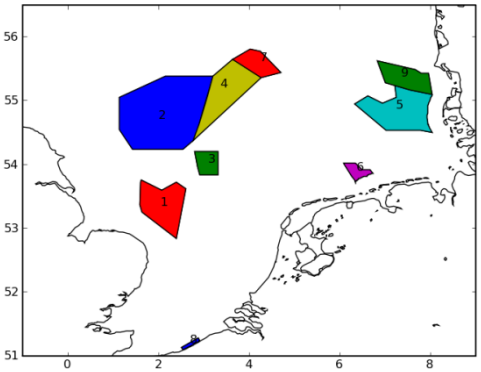
- **They should also be 'connected',** i.e. species should be able to travel between them, either by advection through currents (i.e. natural dispersal) or by active swimming behaviour.

- Cefas were employed by Defra to investigate connectivity using **a three-dimensional hydrodynamic model and an Individual Behaviour, particle tracking Model (IBM)**

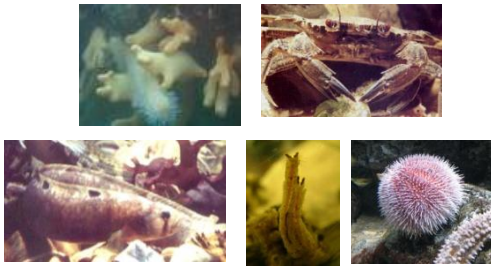
- The modelled propagules were tracked until they settled, and their origin and destination were compared.

- **The model included 7 life-history parameters**

8 North Sea MPAs




Reef-associated species



Sand-associated species

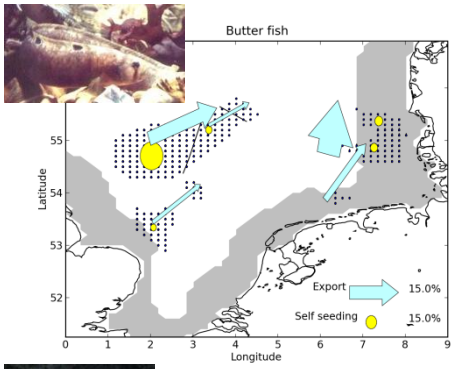
# Connectivity between North Sea MPAs

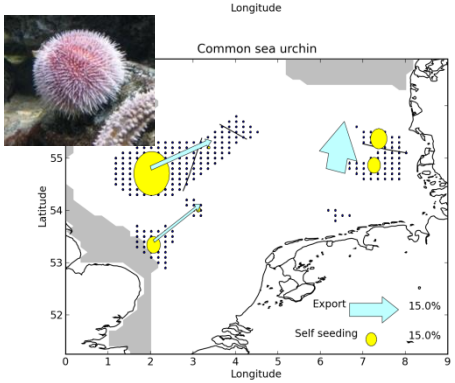
The results showed **similar trends in connectivity between the species**, but with **variations because of differences in life-history** characteristics.

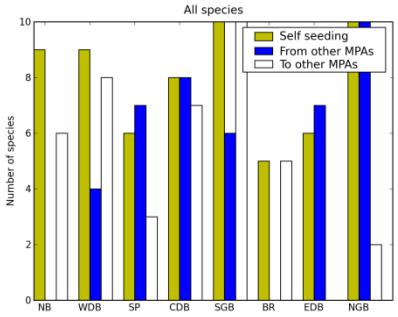
The modelled **connectivity mainly followed the uni-directional stream lines**, thus separating the proposed MPAs into three distinct groups that had little connectivity between them.

Some of the sites contained many propagules, suggesting that their ecosystems **have the potential to support (self-seed) themselves**.

**Others seem to be more reliant on propagules from other proposed MPAs**, and some received only few propagules either from themselves or from other sites and hence would seem reliant on non-MPA areas.



# Other uses of particle tracking models...

**Cefas have used similar modelling techniques for 'tracking' other objects, including....**

•Items that fell off the ***RV Napoli*** **and** ***RV Ice Prince***
•Bodies that wash up on beaches (for the Police)
•Fish eggs and larvae

*MSC Napoli*
Jan 2007
Lyme Bay

*MV Ice Prince*
Jan 2008
off Sussex

We used a coupled physical-biological model for the Irish Sea to simulate **dispersal of eggs and larvae of five species** with contrasting early life histories: cod, plaice, witch, sprat and pogge.

**Modelled larval distributions** and settlement areas **corresponded favourably with observations** from field sampling.

Settlement destinations were affected both by their **initial spawning location** and by the **species-specific development rates and behaviours** coded into the model.

# Emerging threats...

**Non-native species:**

•Will offshore structures act as ‘stepping stones’ for problematic alien species?

•If so – which species should we worry about?

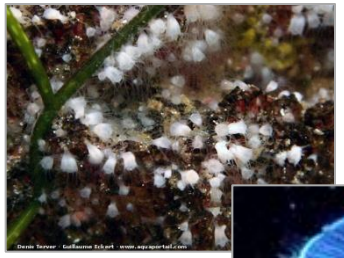
•Should we try to eradicate non-native species from offshore structures, to prevent them spreading?

**Jellyfish:**

•Many jellyfish species have a polyp stage and it has been suggested that rigs could help them proliferate

•Jellyfish numbers seem to be increasing in the North and Irish Seas, is this due to climate, fishing or structures?

•Cefas have ongoing programmes looking at jellyfish



# Modelling the behaviour of fishermen...

(Dr Alex Tidd)

Many factors influence a fisher's decision where and when to fish.....

Marine protected areas (MPAs), and **spatial closures may force fishers to seek new fishing grounds**

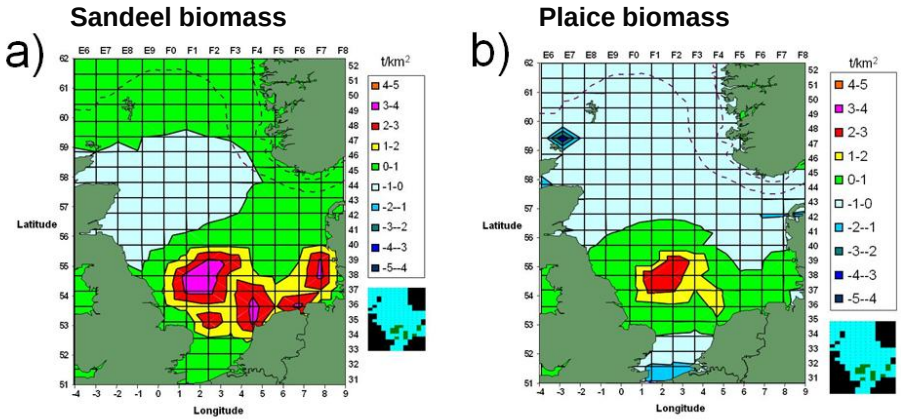
**Fishing vessels are not allowed to enter within 500m of offshore structures** – could they act as small MPAs? Where will the displaced fishing effort go?

Cefas has particular **expertise in predicting fisher location choice** by applying 'random utility' methodology and 'discrete choice models'

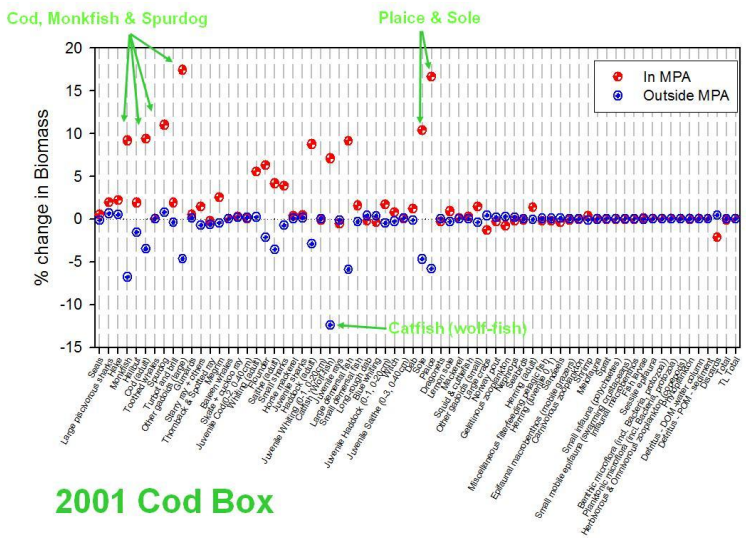
We have applied this techniques to look at:

1. **Proposed MPAs in the North Sea** and their impact on vessels fishing for cod.
2. **Aggregate extraction sites, MPAs and shipping traffic in the Channel** and their impact on scallop vessels

# ‘Ecospace’ – modelling food-web consequences...




Simulated impact of proposed SACs




**‘Ecopath with Ecosim’ (EwE)** has emerged as one of the most widely applied modelling approaches in the marine environment.

At it’s core EwE is a food-web model, and includes **all fluxes from detritus and bacteria up to whales.**

**‘Ecospace’** replicates food-web dynamics over **a spatial grid** and includes a simple ‘random utility’ model to predict **fisher behaviour**

Cefas has developed a validated model for the North Sea that includes **68 functional groups and 12 fishing fleets**

This model has been used to evaluate **‘winners’ and ‘losers’** resulting from proposed **MPAs and windfarms**

# ‘Ecospace’ – recent developments...

Cefas was funded by the Aggregate Levy Sustainability Fund (ALSF) to investigate **food-web consequences of aggregate extraction** in the English Channel

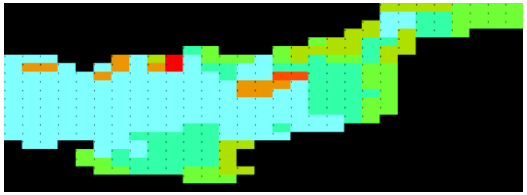
Changes in populations of benthic organisms were modelled **assuming a range of mortalities induced by dredging**

There were pronounced **direct (negative) and compensatory (positive) responses** that arise through feeding and competition.

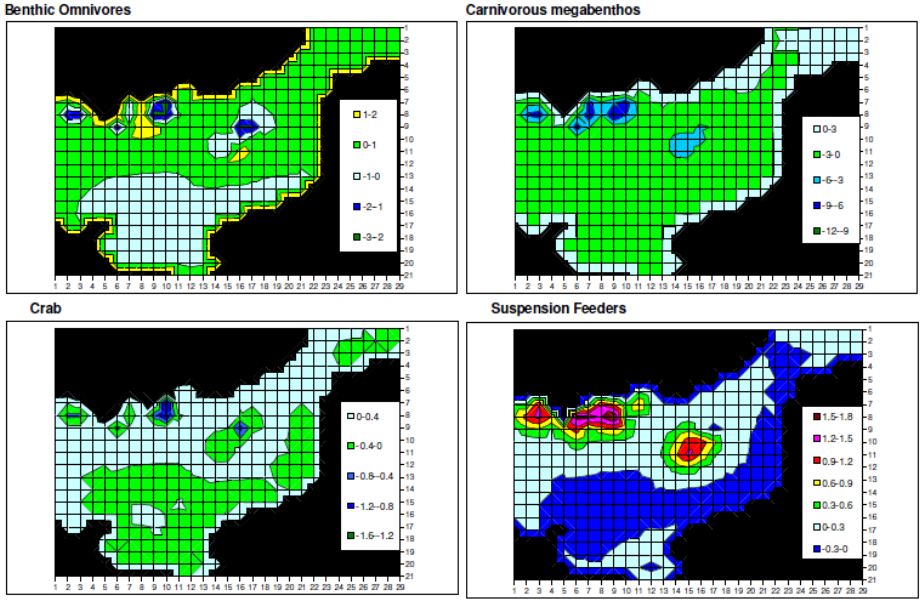
‘Ecospace’ is currently being modified (by Dr Jeroen Steenbeek) to **allow for habitat characteristics to change over time** – this could allow users to better **simulate the addition of offshore structures**

‘Ecospace’ is now **interoperable with GIS**

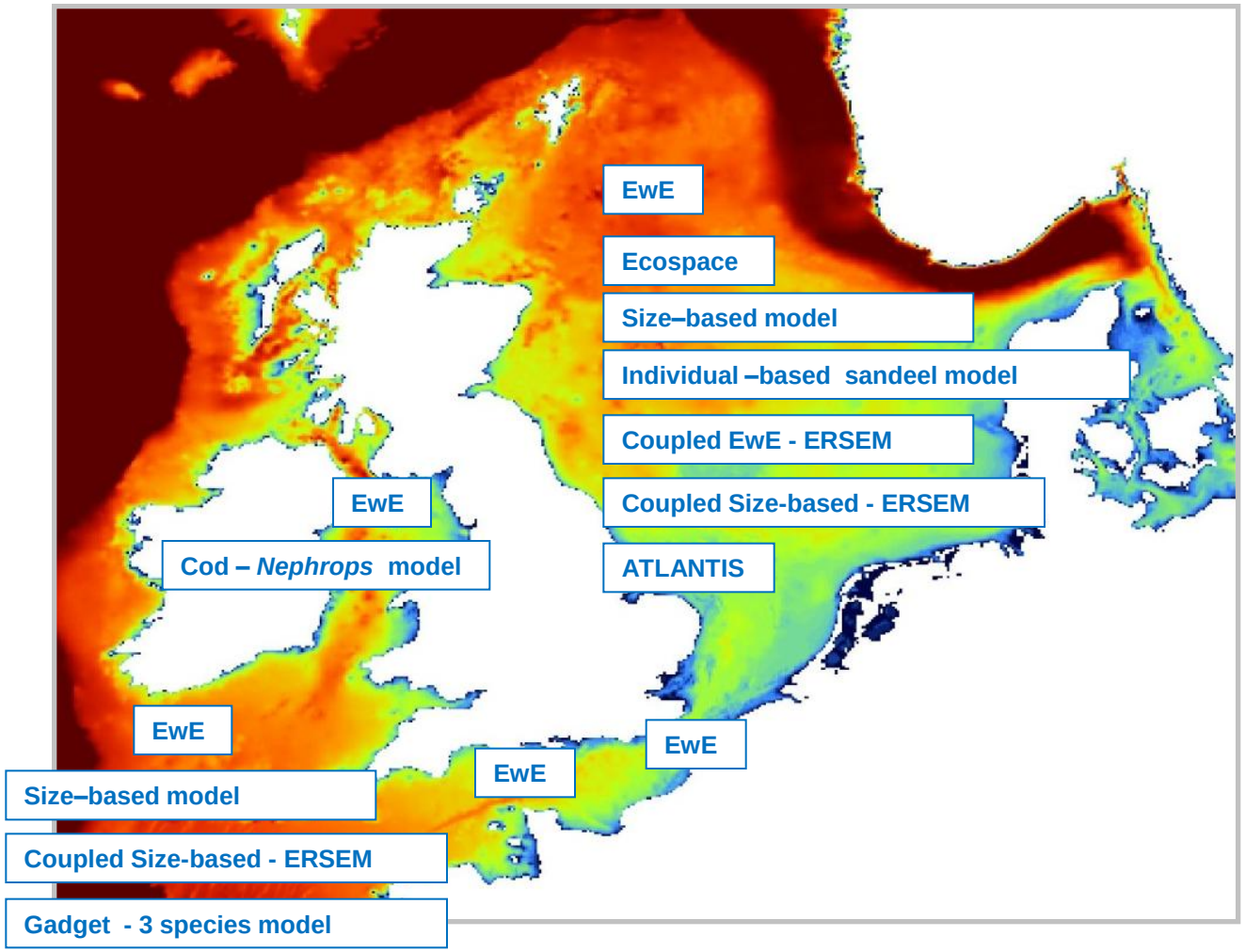
Ecospace Habitat Map – English Channel



(Dr Steve Mackinson)



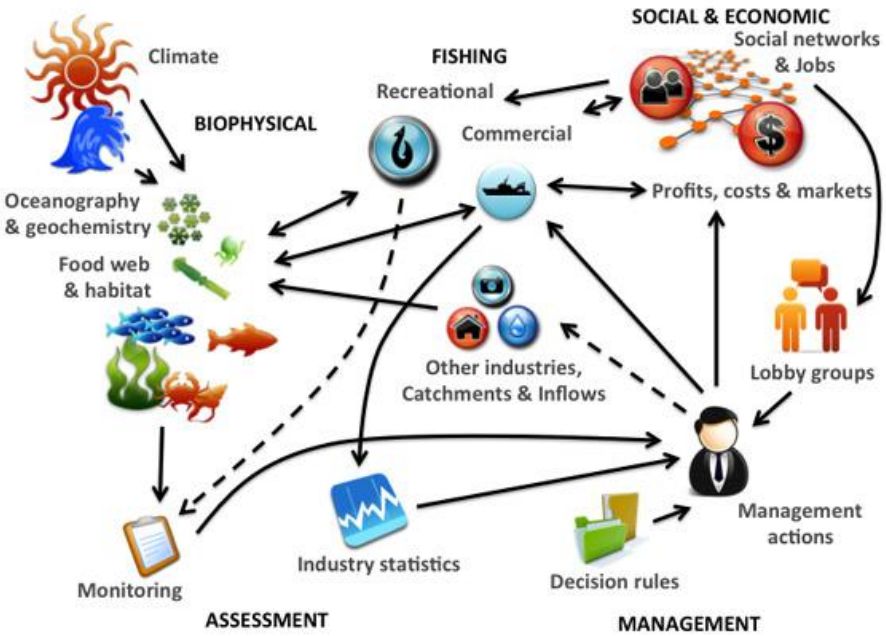
# We have applied a wide range of different models…….



# ‘ATLANTIS’ – is it the answer?

‘ATLANTIS’ is a modelling framework originally developed at CSIRO (Australia), that considers all parts of marine ecosystems - biophysical, economic and social (Fulton et al. 2007)

It has been rated by the United Nations as the most advanced ecosystem model in the world.




(Dr Beth Fulton)

A new parameterisation of ATLANTIS is being developed as part of the EU FP7 ‘VECTORS’ project

The model will be used to investigate the impacts of climate change, non-native species, and MPAs on North Sea fisheries and food-webs

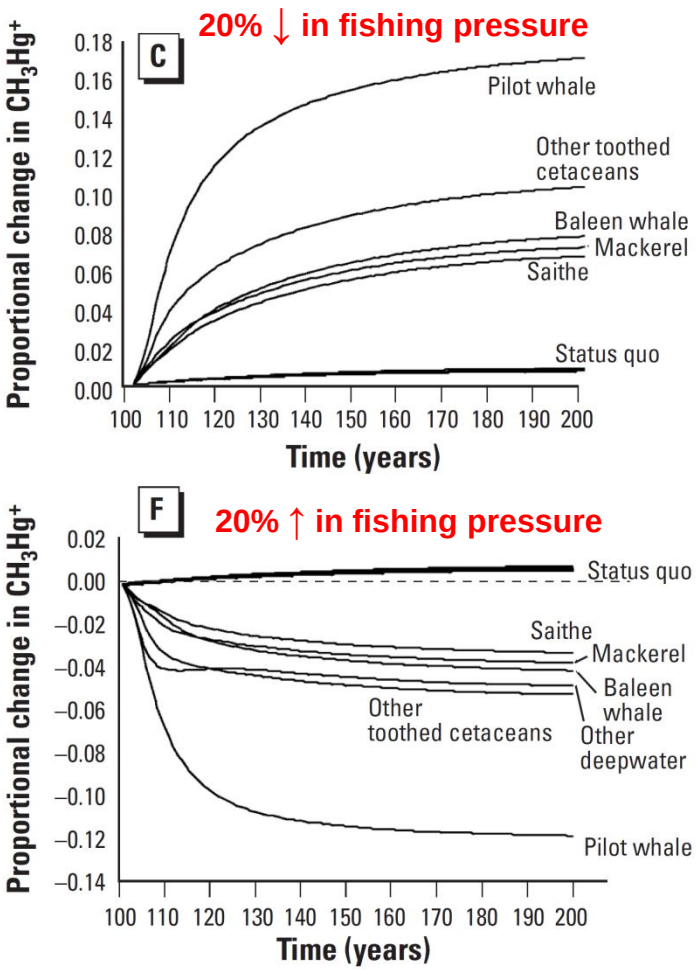
# ‘Ecotracer’ – modelling the uptake of chemicals...

A variant of the EwE software (called ‘Ecotracer’) can be used to **simulate the transport and accumulation of persistent chemicals** in marine food webs .

So far this technique has been used to:

1. Examine the uptake of **radionuclides** in the Baltic Sea (Sandberg et al. 2007)
2. Model the uptake of **methyl mercury** to mammals (including humans) and seabirds in the Faroe Islands (Booth & Zeller 2007)
3. Model the transport and accumulation of **polychlorinated biphenyls (PCBs)** in the eastern Bering Sea (Coombs 1994)

It could be used to look at the uptake of **‘legacy’ contaminants** (e.g. metals or petroleum hydrocarbons) from the UK oil and gas sector, or other industries.




(Booth & Zeller 2007)

# *Questions……*

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