Centre for Environment Fisheries & Aquaculture Science

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Cefas

Marine Ecosystems Research Programme

Project briefing to Defra: Integrating data and models to better understand the consequences of changes in marine ecosystems for the services they deliver to society (MB0130: NERC Marine Ecosystems Research Programme)

1. Purpose of the briefing

NERC and Defra jointly fund two R&D programmes that address key knowledge gaps in marine ecosystem research, the 'Shelf Seas Biogeochemistry' (SSB) and 'Marine Ecosystems Research' programme (MERP). Both programmes emphasise:

- The critical importance of robust ecosystem science related to marine biogeochemical cycles (SSB) and marine food webs (MERP) to help us balance our relationship with a changing planet.
- The need to manage ecosystems to continue providing the benefits we rely on (i.e. focus on ecosystem services throughout).
- The benefits of partnership working when commissioning, collecting, delivering and using scientific evidence.
- The value of sharing resources (incl. data).

Despite an increased emphasis upon evidence-based environmental policy, on many occasions there is too little information flow between scientists and policy makers. As a consequence, scientific results that are produced by programmes such as SSB and MERP might not be used to the extent that they could be to inform decision-making. It is also desirable that research is more clearly directed at issues that influence policies.

The purpose of this briefing is to discuss MERP research activities with policy customers at Defra (i.e. communicate policy needs and science information) and highlight some examples of existing and planned policy-relevant MERP outputs. Collectively, we aim to:

- Provide opportunities for policy-makers to influence the direction MERP science is taking.
- Examine the utility of MERP science outputs to policy-makers.
- Help the MERP consortium to maximise policy-relevance of research products (i.e. ensure that appropriate and accessible outputs are delivered).
- Identify opportunities for the MERP consortium to provide scientific advice proactively to policy-makers.

2. Preparation for the briefing on 23rd February 2016, Nobel House, Defra

In order to make best use of the 2-hour meeting, we ask Defra policy customers to:

- Familiarise themselves with this briefing note and visit the MERP website (http://www.marine-ecosystems.org.uk/).

- Come prepared for a discussion on the types and formats of scientific information that is useful in their policy area.

Usefulness and uptake of existing and future MERP outputs are the main focus of the briefing rather than scientific detail.

1. What is the problem?

Human activities and environmental change can have wide consequences for marine ecosystems and the benefits they provide such as supplying food and supporting leisure and recreation. The significance of such consequences is difficult to predict because of our limited understanding of marine food webs, and in particular how interactions and changes in feeding relationships between organisms affect the delivery of ecosystem services.

1.1 Marine food webs

Food webs are complex networks of interacting organisms through which energy and materials move. They are often studied and modelled in terms of the flow of energy between different organisms through the feeding of one organism on another (Figures 1 and 2). These models are basically a snapshot of "who eats what or whom" in the ocean. Change may be driven from the bottom of the feed web, for example increased nutrients may increase plant growth, and in turn increase the amount of fish. Alternatively, change may be driven from the top of the food web by reducing the numbers of predators through fishing or other mechanisms, and therefore allowing larger numbers of prey to survive.

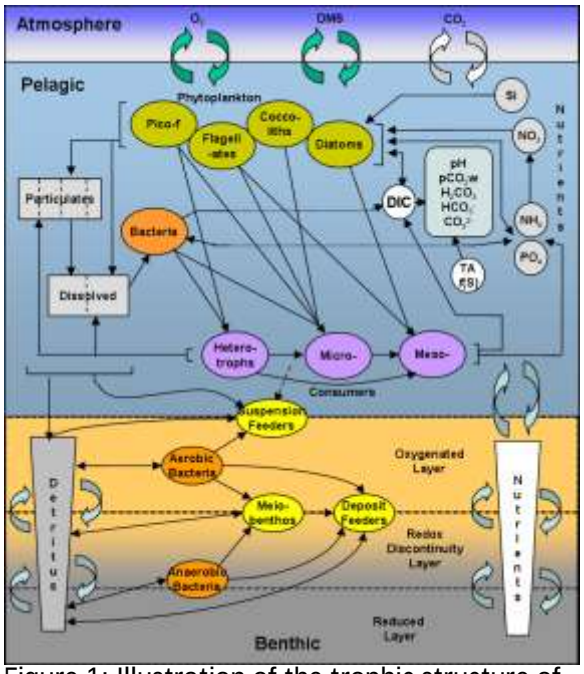


Figure 1: Illustration of the trophic structure of the European Regional Seas Ecosystem Model (ERSEM).

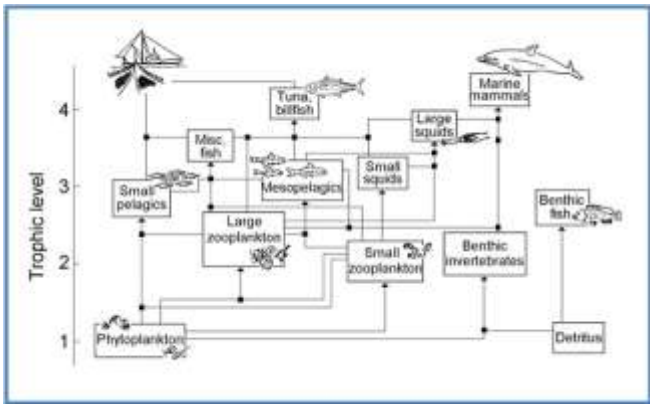


Figure 2: Schematic illustration of a food web, produced with the Ecopath ecosystem modelling software.

A healthy and stable ecosystem is one that is able to sustain the energy flow between trophic levels within a food web. When positions in the food web are eliminated (as a result of natural or man-made change) trophic relationships are lost or put at risk and the ecosystem may experience

imbalance. This can have important knock-on effects on the delivery of ecosystem services. The exact nature and significance of such effects is largely unclear.

1.2 MERP aims

MERP is designed to improve our understanding of the processes governing the dynamics of marine food webs and how changes in them affect the sustainable delivery of ecosystem services. MERP does this from an ecosystem perspective.

Specifically, MERP aims to

1. Understand how marine food webs and the services they provide (e.g. food production and recreation) are regulated by natural mechanisms or human pressures.
2. Integrate the improved understanding of food web regulation (see 1. above) with existing ecosystem models and explore the impact of environmental change on the structure, function and services associated with marine food webs.
3. Apply new model developments to test the impact of potential management solutions (e.g. Marine Conservation Zones) on the structure and function of marine food webs and explore the usefulness of specific indicators of Good Environmental Status (GES).

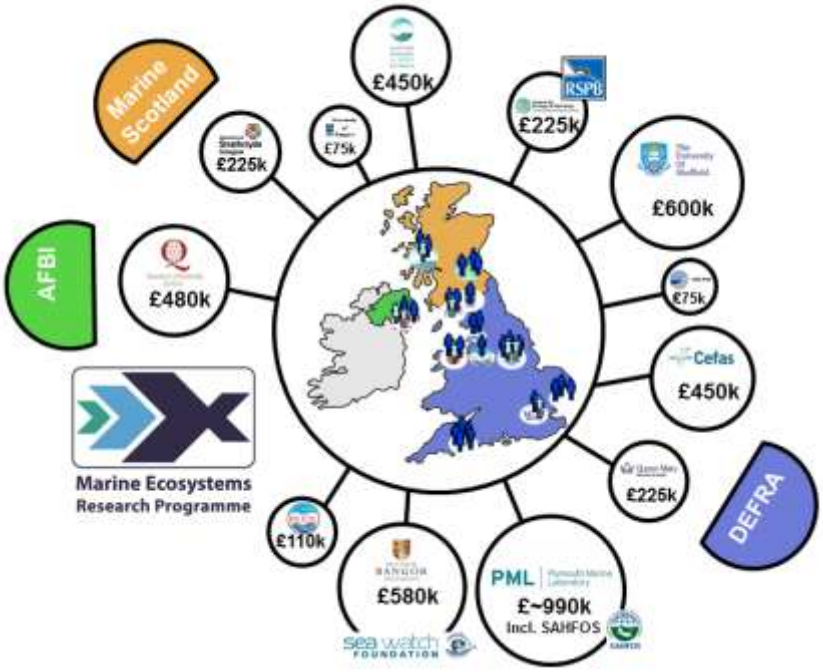
Identifying, describing, understanding and quantifying feeding relationships through space and time are key objectives. The existing and new observations and modelling results brought together by MERP allow us to show trends in the distribution of food web components under varying environmental regimes and future scenarios, and to understand how changes in one component affects others.

MERP science is designed in such a way that this knowledge can be used to assess, and ultimately manage, marine ecosystems toward desirable states. By addressing questions such as "What do natural and perturbed feeding relationships look like?", MERP will demonstrate when food web relationships go wrong, and inform managers of what restored or strengthened food web relationships look like and what needs to be done to achieve them. For example, MERP develops indicators of when key food web relationships are threatened, uses models to separate the effects of fishing practices and the implementation of the discard ban on Marine Strategy Framework (MSFD) descriptors and establishes how the removal or alteration of benthic habitat and fish prey affects populations of protected marine mammal and bird species (see specific examples on page 8 - 19).

MERP delivers ecological evidence that provides policy makers with recommendations regarding the impacts of anthropogenic activities on marine ecosystems in relation to natural change but this evidence alone cannot solve conservation problems of marine ecosystems. As the recommendations we provide will be weighed against socio-economic considerations before decisions are made, we study food webs within the context of the ecosystem services society derives from them. For example, we have been developing conceptual models that link ecosystem processes to key ecosystem services such as leisure and recreation, food provision etc. We use these models to highlight data sets which are needed to determine quantitative functional linkages between changes in food webs and changes in ecosystem services. Moving from qualitative to quantitative models in this way helps the MERP consortium to develop and deliver the coupled ecological, economic and social evidence needed to inform management measures (incl. for the MSFD, fisheries and marine spatial planning).

3.3 Programme Management

This £6m programme is co-funded by NERC (~ 85 %) and Defra (~ 15 %). Overall it will be active for 5 years. It consists of three major elements. The largest, led by the Plymouth Marine Laboratory (PML), has a budget of £4.2m, began in June 2014, and will last for 4 years. The first component is being delivered by a consortium of over 50 scientists working in 15 organisations from across the UK, including Cefas, NERC centres and affiliated research institutes, universities and Non-Governmental Organisations. It will deliver scientific understanding of how changes in food webs drive changes in ecosystem service provision at different scales of space and time. The second component currently funded (£0.5m), being delivered by PML, Cefas and NOC, is developing and improving NERC's marine ecosystem modelling capability. Funding for the third component, addressing how different management scenarios may influence ecosystem services, will be announced shortly.



4. Marine food webs and policy-making decisions

The MERP consortium compiled a list of policy questions from various sources including policy needs identified by the MERP Stakeholder Advisory Group (SAG) in December 2014, discussions at Marine Science Coordination Committee (MSCC) level surrounding the contribution of shelf seas models to policy development and a gap analysis by the Marine Management Organisation carried out as part of their Evidence Strategy 2015-2020.

We aligned current and planned MERP work with key policy questions identified by the MERP SAG and with Defra's evidence needs. This allows us to formulate and design MERP science in such a way that its outputs can feed into high-priority decision-making. MERP work is brigaded under the following research priorities, all of which have high policy-relevance (Table 1):

Table 1. MERP priority list of policy questions from various sources. The questions are directly linked to policy needs from Defra's perspective:

High-level Defra policy needs
1 Develop and implement Good Environmental Status under the MSFD.
2 Develop knowledge of marine ecosystem and food webs.
3 Develop more realistic marine ecosystem models.
4 Improve ability to advise and act on uncertainty in the marine environment.
5 Develop knowledge of marine ecosystem functioning and how to assess recovery.
6 Quantify and promote the value of goods and services provided by the marine ecosystem.

Specific Defra policy needs
7 Develop, validate and operationalise remaining identified GES indicators.
8 Improve understanding of marine food-webs to better understand interactions.
9 How are prevailing conditions changing, and how are they affecting sea life, and the environment?
10 How is the status of UK seas progressing towards the objectives, and whether the measures taken to address the pressures are working?
11 Improve understanding on population abundance, distribution and biology of vulnerable species (cetaceans, seabirds, elasmobranchs etc.).
12 What are the benefits of the MPA network (contribution to GES, wider environmental benefits, valuation, carbon storage etc.?

State of food webs (or its components) in relation to specified targets
Are we achieving GES for MSFD Descriptors 1, 4 and 6 at regional scales?[1, 7, 10]
Are we achieving Conservation Objectives (COs) for species and habitats at local MPA scales?[12]
What is the relationship between ecosystem services and Good Ecological/Environmental Status?[6]
Identification of areas of particular importance to fish populations[2, 3, 5, 8]
How can we define and describe biodiversity hotspots?[2, 5, 8]
How are populations of vulnerable species (cetaceans, seabirds, elasmobranchs etc.) distributed in space and time?[8, 11]
Where do key foraging areas for sea birds occur in space and time?[8]
Effects of natural and anthropogenic change on the state of marine food webs and the services they provide
How does the removal (e.g. by tidal lagoon projects) or alteration (e.g. by towed fishing gears) of benthic habitats affect populations of marine mammals and birds (those mammal and bird species included in Habitats and Birds Directives)?[5]
What are the impacts of removal or change of fish prey species on marine bird and mammal populations (Habitats and Birds Directives)?[8, 9]
How to evaluate cumulative impacts, especially for mobile species (to ultimately create the ability to carry out strategic assessments through marine planning or SEA that consider the capacity of marine mammal and bird populations to cope with cumulative impacts across their biogeographic range)?[10]
How do impacts on rare and/or threatened habitats and species affect ecosystem services (especially for BAP/OSPAR habitats and species but also Habitats Directive/SSSI habitats and species)?[6]
Future state of marine food webs and ecosystem service provision under scenarios reflecting management situations in UK waters
What are the effects of changes in fisheries management on the environment, in particular through food web effects?[2, 3, 4]
What are the responses of indicators to specific management measures for MSFD descriptors?[1, 7, 10]
What are future changes in ecosystem services in response to different management scenarios?[6]
What is the impact of (multiple) MPA closures on fisheries and recreation?[12]

4.1 What is the state of food webs (or its components) in relation to specified targets?

Considerable progress is being made in MERP to develop tools to bring together existing data on all components of the UK marine ecosystem, from plankton to birds and mammals. Combining analyses of freely accessible data with data newly collected in MERP (i.e. new observations from cruises; data sets put together from the literature; previously restricted or separated data sets) will provide a more complete picture of how food web components are distributed and how they interact in space and time with pressures and environmental variables. Because of its whole-ecosystem nature, this evidence (incl. new maps and other data products) directly underpins advice on the state of food webs and the environmental conditions required to maintain them. It also improves understanding of natural variability in space and time. This understanding has direct applicability to assessing state of food webs (or its components) against specified targets (e.g. GES under the MSFD).

Policy-relevant outputs: New maps and other data products and indicators that underpin advice on the state of food webs and the environmental conditions required to maintain them.

4.2 What are the effects of natural and anthropogenic change on the state of marine food webs and the services they provide?

Negative impacts resulting from human activities can increase ecosystem and food web vulnerability or reduce their resilience. A major approach to adaptation policies for marine ecosystem resilience is to develop effective policy responses that regulate, manage and mitigate these activities. To achieve this goal, it is important to understand the individual and combined effects of pressures on marine food webs.

Extensive fieldwork and controlled experiments in the laboratory are gathering empirical evidence on the effects of natural and man-made pressures on food web components. We combining this evidence with analyses of existing data and modelled distributions of food web components (e.g. top predators) in relation to environmental conditions and anthropogenic activities to support statements regarding the state and vulnerability of marine food webs.

Policy-relevant outputs: Information that helps to identify which aspects of the marine environment are most at risk and where, and informs management measures to mitigate risks. It also informs effective marine spatial planning of human activities.

4.3 What are the likely future states of marine food webs and ecosystem service provision under scenarios reflecting management situations in UK waters?

Attributing the cause of change in food web structure or function is complex, and will be the result of pressures which act both directly and indirectly on different components of the ecosystem. There is no single approach currently available that includes the complex links within and among food webs needed for projections of future states. Consequently, there is low confidence in the quantitative projections of such changes and the effect they have on the provision of ecosystem services.

Understanding what future is desired, and what futures are possible, is critical to informing management decisions about complex ecosystems. The MERP consortium will consider future states of marine ecosystems in the context of a coupled social-ecological system, with the socio-economic

system influencing the ecological system, and vice versa. We will be using management and policy relevant scenarios (climate change, land use, fisheries management) on different spatio-temporal scales in our models to (i) examine alternate futures for the UK marine ecosystem, (ii) highlight the trade-offs inherent in these scenarios and (iii) draw connections between future scenarios and management strategies, including the importance of setting targets and deriving quantitative measures of progress towards these.

Policy-relevant outputs: Information on the impacts of future scenarios on food webs and ecosystem services that informs development of appropriate management measures for MSFD and fisheries and effective marine spatial planning of human activities.

5. List of specific examples

Here we provide a number of brief examples of policy-relevant outputs. The intention is to:

- give policy-makers a flavour of what is being done within the consortium and, based on policy needs, what could be done in the future and
- present tangible outputs from ongoing work that policy-makers can use in specific policy contexts.

These snapshots of MERP activity focus on current work where policy-relevant outputs begin to emerge rather than future aspirations or ambitions. We tailor examples to specific policy relevance, rather than present them in a more general sense. For example, by focussing on distributions of breeding birds in summer, our analysis can be used specifically to meet marine protection requirements under the Birds Directive. In contrast, the policy links to a single example on a more general theme of top predator distributions would be less coherent.

Specific examples are listed below in no particular order and include (but are not limited to):

- Compiling and analysing UK marine data from plankton to large predators
- Trophic cascades in marine food webs and their role in determining environmental status
- Modelling the whole ecosystem impacts of fishing
- Seabird hotspots and predation pressure in UK coastal waters
- The effects of displacement from offshore wind farms on seabird populations
- Distributions of top predators in space and time
- The usefulness of operational indicators of GES for ecosystem services assessments

Compiling and analysing UK marine data from plankton to large predators (R Vergnon & T Webb, University of Sheffield)

The MERP consortium is filling gaps in available data for UK marine ecosystems (e.g. distributions in space and time of species, abundance, biomass etc.). Records are either entirely new data (MERP field work) or existing data that was either inaccessible to the wider scientific community, or available in suboptimal formats requiring personal correspondence with data providers. Our focus is on western and southern UK seas. The current collection and cleaning phase will be followed by an integration phase where data for plankton, invertebrates, fish, birds and mammals will be combined and linked to changes in both the physical environment and marine management.

Headline findings and significance

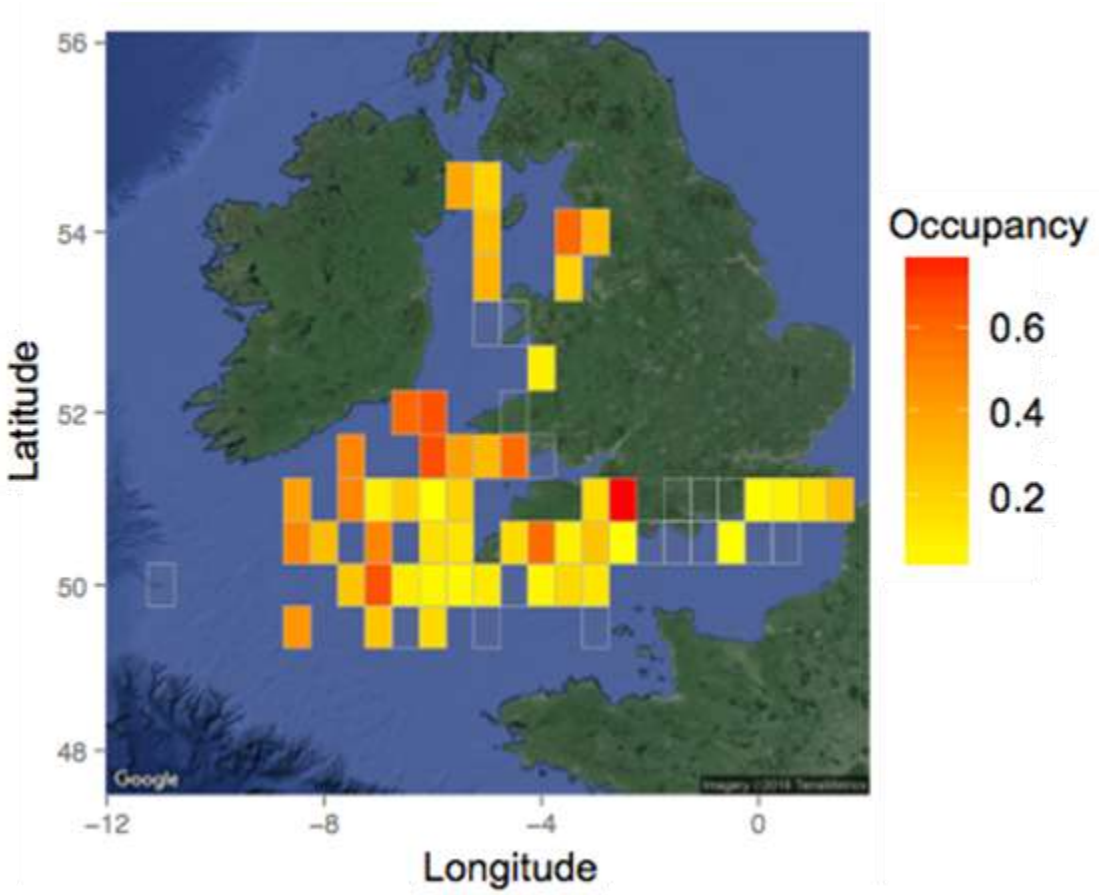
- More comprehensive data: We have collected tens of thousands of additional biological records that are not currently part of the Ocean Biogeographic Information System (OBIS), the largest existing bank of marine records (see Figure). This has particular significance for important but relatively poorly monitored groups of species (e.g. invertebrates inhabiting the sea floor).
- Enrichment: We have enriched information on each major group of species with additional data documenting the relationships between these groups (typically predator/prey relationships and will continue to link distributions of an increasing number of species with information on their relationships with their living and physical environments.
- Ease of access and integration: We have concentrated our efforts on easing access to and integration of relevant data (both biological and physical) from within a flexible and powerful tool (using open source software).

Policy implications

- Improving and integrating data on interacting components of the marine ecosystem has direct relevance to questions involving the study of species distributions and questions involving the study of food webs (see Table 1):
  - How can we define and describe biodiversity hotspots?[2, 5, 8]
  - How are populations of vulnerable species (cetaceans, seabirds, elasmobranchs etc.) distributed in space and time?[8, 11]
  - What are the effects of changes in fisheries management on the environment, in particular through food web effects?[2, 3, 4]

Type of products policy-makers could use

See below.



Distribution map for the benthic species Phaxas pellucidus (Razor shell) over 0.5 degree grid cells. The data combines four Cefas datasets made available via MERP: the Unicorn database, the Celtic Sea size spectrum data set (Defra project MF 1001), and two epibenthos data sets (Ellis et al. 2013, 2007 [ICES CM]). Here occupancy is the number of samples the species was observed in over the total number of samples. Only cells with at least five samples have been considered. Similar maps are available for approx. 1500 species, and composites mapping species richness or other synthetic measures are also straightforward to generate from the newly compiled dataset.

Trophic cascades in marine food webs and their role in determining environmental status (A G Rossberg, Queen Mary University of London)

As shown by the collapse of Nova Scotia cod, taking away animals from the top of the food web, for example by overfishing, can lead to long-lasting disruptions of marine ecosystems. Susceptibility to such disruption varies among marine ecosystems. Although it generally increases towards the poles, we cannot currently explain why or where it will be high. Different computer models sometimes give different answers. For assessments of food web status in the MSFD context (Descriptor 4), this leads us to question whether indicators used for national assessments and reporting should be sensitive to trophic cascades, and whether targets specific for their strength could be set. MERP is addressing these problems using an ensemble-modelling approach.

Headline findings and significance

- No model in the MERP ensemble predicts strong trophic cascades in the Celtic Seas. Based on our current knowledge, strong and persistent top-down cascades are not expected in this system.
- Current marine food web models, as exemplified by the MERP ensemble, clearly differ in their specific responses to simulated overfishing, so uncertainty over the strength of possible trophic cascades remains.

Policy implications

- Descriptor 4 indicator suites could be structured to permit early identification of trophic cascades. This requires that abundances of groups at all trophic levels are monitored, e.g. phytoplankton, zooplankton, and planktivorous and piscivorous fish.
- A GES target should be set to prevent formation of trophic cascades spanning several trophic levels. It is likely that under prevailing conditions this target will be met.

Type of products policy-makers could use

The MERP mode ensemble can be adapted to other marine ecosystems to determine the expected strength of top-down effects and residual uncertainty.

Modelling the whole ecosystem impacts of fishing (M Heath, University of Strathclyde)

Many aspects of marine fisheries and environmental legislation are regarded as independent strands of policy. For example, the discard ban and setting of regional landing quotas are handled entirely under the CFP, whilst seabed disturbance is generally a habitats and species issue. Many of these strands potentially converge in the MSFD, especially in relation to the food web indicators. Firstly, this work disentangles the effects of harvesting rates, seabed ploughing by fishing gears and implementation of the discard ban on MSFD descriptors and shows which factors are the most important at the regional scale. Secondarily, the work provides evidence which is relevant to the ongoing judicial review of Defra policy on quota allocation between fishing fleet sectors as a result of the case brought by Greenpeace.

Headline findings and significance

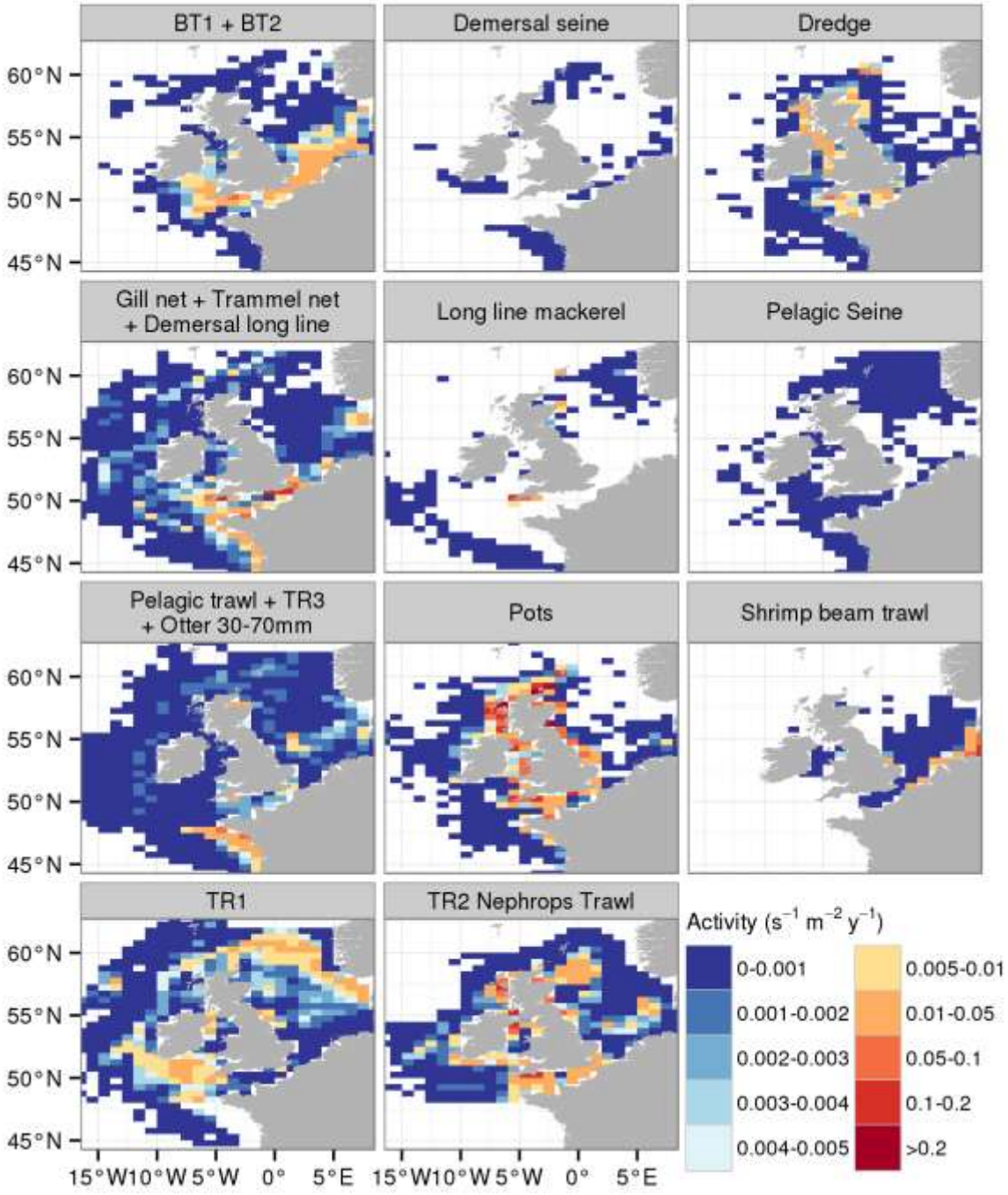
- The effects of seabed disturbance by trawl gears on regional scale food web indicators are small compared to the effects of harvesting and landing biomass.
- The food web in the west of Scotland region is more sensitive to seabed disturbance than in the North Sea because the trawling activity on muddy sediments is around 5-times higher than in the North Sea, almost entirely due to the activities of Nephrops trawling.
- Alternative strategies for implementing the discard ban can have very different consequences for food web indicators. Changing fishing patterns and gears to reduce unwanted by-catch can have significant benefits for the food web. Simply bringing unwanted by-catch ashore has only negative effects on food webs.

Policy implications

- At the regional scale the main benefits for ecosystem food web status are likely to come from managing the overall levels of activity, or the selectivity (power) of fishing gears, rather than focussing on specific gears which are perceived to be particularly damaging to the seabed.
- Notwithstanding the above, a key action point concerns the high ploughing impact of the Nephrops fishing gear, especially in the west of Scotland region.
- The work has specific relevance to a range of policy questions including (see Table 1):
  - Are we achieving GES for MSFD descriptors at regional scales?[1, 7, 10]
  - What are the effects of changes in fisheries management on the environment, in particular through food web effects?[2, 3, 4]
  - What are the responses of indicators to specific management measures for MSFD descriptors?[1, 7, 10]

Type of products policy-makers could use

See below.



The geographic distribution of international activity by the main fishing gears used in NW European waters. These gears target different food web components, and have distinctly different seabed ploughing and by-catch discard rates. BT1+BT2 refers to beam trawls mainly targeting flatfish; TR1 refers to the otter trawl gear mainly targeting demersal finfish; TR2 is the fine-mesh trawl used to catch Nephrops, and TR3 refers to a fine-mesh pelagic trawl mainly used to catch sandeels.

Seabird hotspots and predation pressure in UK coastal waters (F Daunt, Centre for Ecology and Hydrology)

The Centre for Ecology and Hydrology, the Royal Society for the Protection of Birds and the University of Glasgow are developing breeding season distribution maps of seabirds combined with data on diet and energetic budgets to derive predation pressure maps from seabirds on key forage fish species. The models comprise a significant component of the total seabird biomass in UK waters including several species of conservation concern (e.g. kittiwake, shag).

Headline findings and significance

- At-sea distribution of these species is linked to availability of suitable habitat in proximity to breeding colonies and competition among species.

Policy implications

- These maps will aid marine spatial planning by identifying areas that qualify as offshore SPAs or should be considered in assessments of offshore renewable developments. These maps, together with spatial information on diet, will be used to quantify the predation pressure on commercially important forage fish species and, in turn on the importance of these fish prey to protected seabird populations.
- The work has specific relevance to policy questions including (see Table 1):
  - How can we define and describe biodiversity hotspots?[2, 5, 8]
  - How are populations of vulnerable species (cetaceans, seabirds, elasmobranchs etc.) distributed in space and time?[8, 11]
  - Where do key foraging areas for sea birds occur in space and time?[8]

Type of products policy-makers could use

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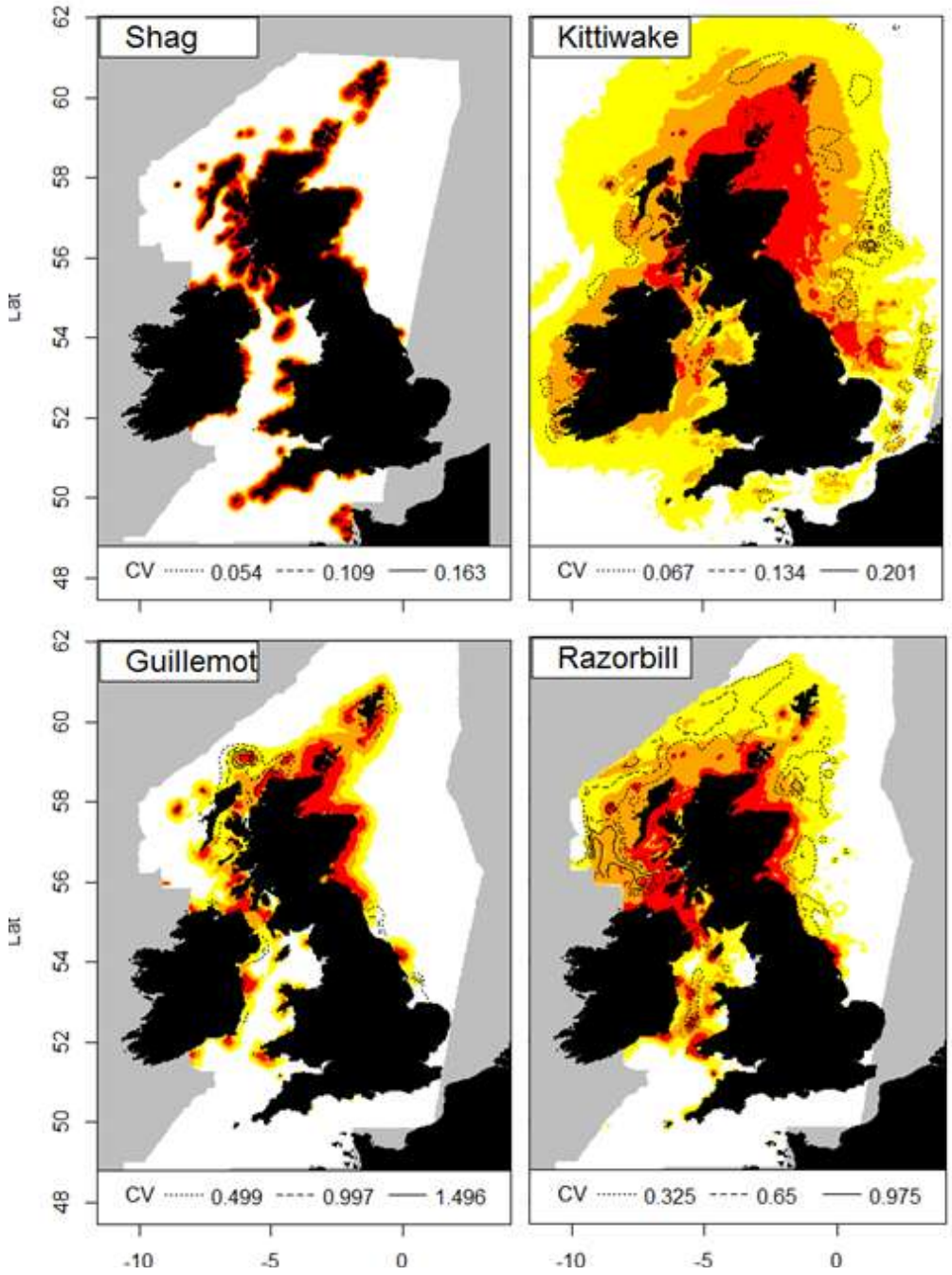

Figure: Predicted at-sea utilisation of four breeding seabird species comprising 35 % of the total breeding biomass of UK seabirds. Further species are being added with the aim of modelling 95 % of the seabird biomass.

The effects of displacement from offshore wind farms on seabird populations (F Daunt, Centre for Ecology and Hydrology)

The Centre for Ecology and Hydrology are developing a model of the population level consequences for seabirds of displacement from offshore wind farms (kittiwake, guillemot, razorbill, puffin and gannet). The model estimates variation in energetic budgets and knock-on effects on breeding success and survival of different wind farm scenarios, including cumulative effects of multiple wind farms.

Headline findings and significance

- Modelling work has shown that displacement and barrier effects have the potential to reduce the reproductive success and survival of breeding seabirds in the Forth/Tay region, with population-level consequences at SPAs.
- The most vulnerable species were kittiwake and puffin, because they have moderate foraging ranges so they interacted extensively with wind farm footprints. Shorter range species (e.g. guillemot, razorbill) interacted less with wind farms and the longer ranging gannet was less vulnerable to displacement because the footprints represented a small proportion of their foraging range.
- This modelling approach is flexible and could be adopted in other locations or species depending on the availability of input data. The evidence would suggest that the reproductive success and survival of any species that is displaced by renewable developments in situations where they constitute an important proportion of the summer foraging range may be affected.

Policy implications

- This model has been used in consenting decisions on Forth/Tay wind farms. The approach is flexible and could be adopted at other locations to inform Habitats Regulations Assessment requirements on integrity of the Special Protection Area (SPA) network of seabird colonies and recreational ecosystem services provision.
- The work has specific relevance to policy questions including (see Table 1):
    - How does the removal (e.g. by tidal lagoon projects) or alteration (e.g. by towed fishing gears) of benthic habitats affect populations of marine mammals and birds (those mammal and bird species included in Habitats and Birds Directives)?[5]
    - How to evaluate cumulative impacts, especially for mobile species (to ultimately create the ability to carry out strategic assessments through marine planning or SEA that consider the capacity of marine mammal and bird populations to cope with cumulative impacts across their biogeographic range)?[10]

Type of products policy-makers could use

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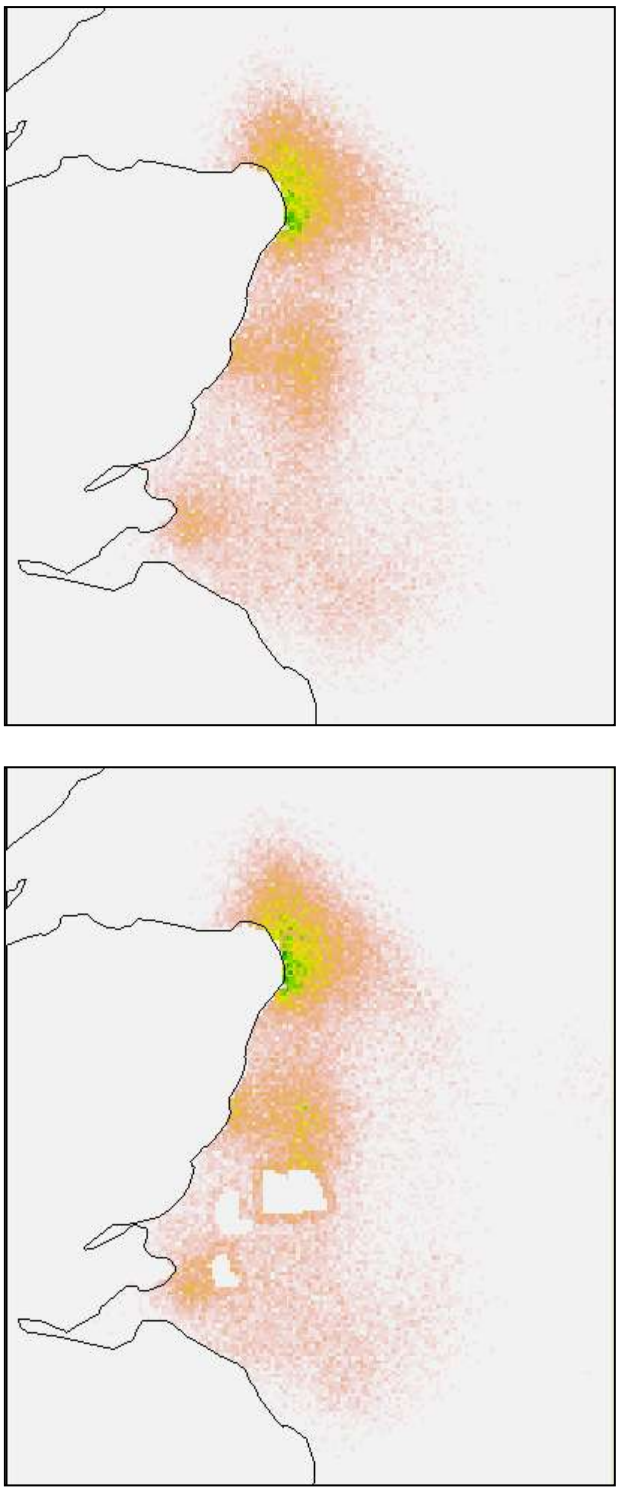


Predicted at-sea utilisation of black-legged kittiwakes breeding at SPAs in eastern Scotland in baseline conditions (top panel) and when displaced from multiple proposed offshore wind farms (bottom panel).

Distributions of top predators in space and time (P Evans & J Waggitt, University of Bangor)

Bangor University in conjunction with the Sea Watch Foundation is collating marine bird and mammal survey data sets from the 1980s to the present from throughout the NW European continental shelf and adjacent deeper waters. One of the major challenges that past analyses have faced has been the spatio-temporal gaps in coverage. Following a strict validation and error checking process, and comparisons of results between datasets for cross checking, this should then form the most comprehensive database of these top predators in existence for NW Europe.

Headline findings and significance

- A series of density distribution maps will be produced for different species by season and by longer time period. These will result in regional density, abundance and biomass estimates for top predators to feed into a number of the ecosystem models.
- Examination of drivers of spatio-temporal patterns for the more regular marine bird and mammal species will be undertaken in 2016.

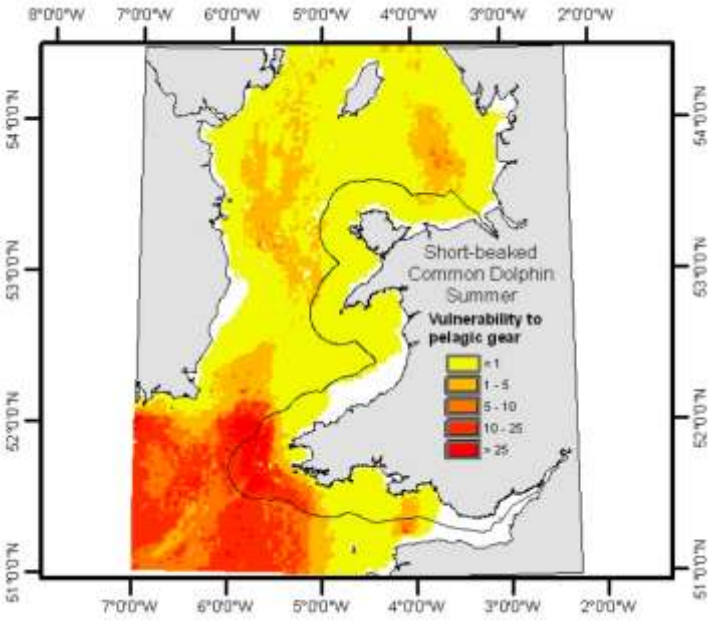
Policy implications

- The work has specific relevance to policy questions including (see Table 1):
  - Are we achieving Conservation Objectives (COs) for species and habitats at local MPA scales?[12]
  - How can we define and describe biodiversity hotspots?[2, 5, 8]
  - Where do key foraging areas for sea birds occur in space and time?[8]
  - What are the impacts of removal or change of fish prey species on marine bird and mammal populations (Habitats and Birds Directives)?[8, 9]
  - How to evaluate cumulative impacts, especially for mobile species?[10]
  - What are the effects of changes in fisheries management on the environment, in particular through food web effects?[2, 3, 4]

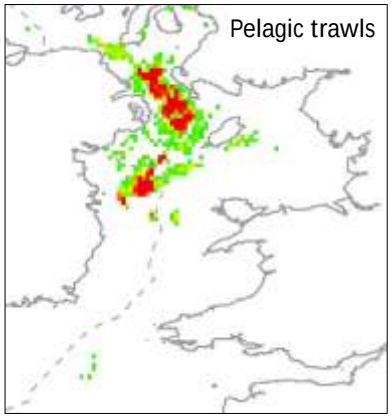
Type of products policy-makers could use

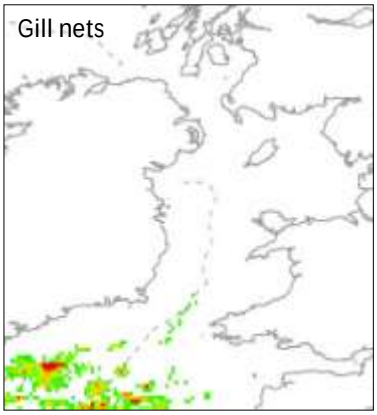
See below.

Vulnerability to bycatch in pelagic trawls



Distribution of fishing effort from VMS data





Mapping spatio-temporal patterns of usage of top predators (e.g. common dolphin) known to be vulnerable to fisheries bycatch against those of human activities can be used to identify risk. In this example, both pelagic trawls and gill nets are known to result in common dolphin mortality. However in this region, the species is more likely to suffer bycatch mortality from gill netting in the Celtic Sea than pelagic trawling in the northern Irish Sea.

The usefulness of operational indicators of GES for ecosystem services assessments (S Broszeit, Melanie A & N Beaumont, Plymouth Marine Laboratory)

Indicators are used for monitoring GES in the framework of the MSFD. Potentially some of the same indicators could be used to inform assessments of ecosystem services, such as will be required under the EU Biodiversity Strategy. MERP is assessing the extent to which currently proposed UK indicators of GES for Descriptors 1 (biodiversity), 4 (food webs) and 6 (seafloor integrity) can be harmonised with proposed indicators for assessment of ecosystem services, focusing on food provision, leisure and recreation, biological checks and balances, and bioremediation of waste. This comparison and integration of indicator sets will inform our capacity to assess ecosystem services and GES, provide validation of current indicators and highlight any gaps, and also enable efficiency in monitoring programmes. If indicators also match outputs from ecological computer models we can use them to explore how ecosystem services may change in the future.

Headline findings and significance

- Preliminary findings suggest that some UK indicators for GES are also useful for assessing ecosystem services. Several of these indicators measure variables concerned with top predators (birds and mammals) and relate to the services 'leisure and recreation' and 'aesthetic experience'. Others relate to food provision and bioremediation.
- Other GES indicators, that do not relate to ecosystem services directly, may be useful for understanding particular aspects of ecosystem services or the processes on which they are based.

Policy implications

- This work will aid understanding of how the provision of ecosystem services and the achievement of GES are related, and offers the possibility of joint assessments of ecosystem services and GES, thus increasing efficiency of monitoring programmes.
- Linking GES and ecosystem serviecs indicators with models will allow future consequences of policy choices to be modelled and compared.

Type of products policy-makers could use

Tables linking GES indicators to ecosystem services indicators for food provision, leisure and recreation, bioremediation and biological checks and balances.

The gaps in the pool of indicators necessary for ecosystem services assessment will be highlighted and can then be addressed within MERP.