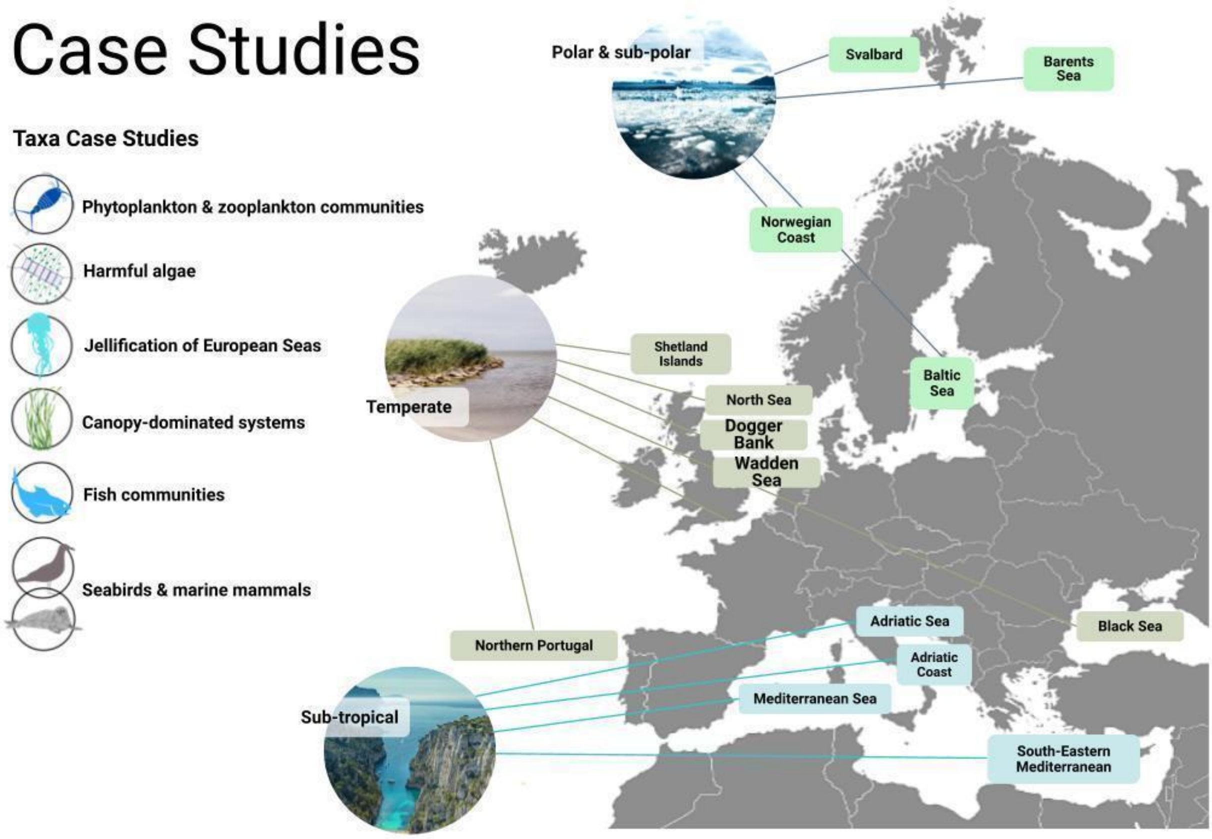
Case Study 5
Temperate

North Sea Offshore Areas



ACTNOW

ACTNOW is an EU-funded research project aimed at understanding the cumulative impacts on European marine biodiversity, ecosystem functions, and services for human wellbeing. The project equips regulators and decision-makers with essential knowledge and tools to combat biodiversity loss in coastal and marine habitats threatened by climate change and other regional drivers.

Conducted across various Case Study Regions in Europe, ACTNOW focuses on delivering scientific support for adaptation and mitigation measures, sustainable blue economy expansion, and contributions to the UNFCCC.

The project is structured into six Workpackages: WP1 (Data, Indicators and Scenarios), WP2 (Marine Organisms under Multiple Drivers), WP3 (Community, Food-Web and Ecosystem), WP4 (Cumulative Risks & Biodiversity Assessments), WP5 (Synthesis, Impacts & Solutions Options), and WP6 (Communication and Dialogue).

Objectives include developing 'what if' scenarios, understanding combined impacts on ecosystems, employing advanced biologging and molecular methods, and enhancing awareness of the links between marine biodiversity and human health.

ACTNOW has 17 CSs, 11 are regional CSs while 6 are pan-European (group / taxon) CSs. All are designed to deliver a cause-and-effect understanding, build predictive capacity in models, and to develop indicators and tools for decision-makers charged with the stewardship of European marine biodiversity under threats from multiple drivers (stressors in call) (see fig below). In each case, drivers examined represent the local/regional priorities from regulators who co-create what-if scenarios of interacting drivers including envisioned management actions.

1. Case Study 5: The Greater North Sea

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Description

The region is experiencing, arguably, the most rapid and intense proliferation in offshore wind farms anywhere in the world. Other anthropogenic activities are many and varied (e.g., oil & gas exploitation, hydrogen generation, tidal energy, carbon capture and storage). All Temperate region CSs apply big data statistical approaches to identify patterns and trends of marine communities (benthos, plankton, fish, seabirds and marine mammals) and associated stressors to identify thresholds above which significant biodiversity impacts are exerted. Changing patterns of species distribution in the past and future are modelled using biogeochemical hindcasts and forecasts with scenarios on human pressures. ECOSPACE will be used in a mechanistic and empirical study across systems (rivers to open ocean) and spatial scales to explore how external subsidies (nutrients, detritus, migrating prey species) and contaminants affect ecosystem structure and function.

This case-study aims to address challenges in marine ecosystem management through three major activities:

2. **Big Data Analysis**: Apply big data approaches to observe marine communities and stressors, identifying thresholds of impact. This includes spatial mapping of present and future changes due to factors like climate change and fishing, and modelling biodiversity impacts at various scales.
3. **Field Work**: Conduct fieldwork and experiments in key regions to collect data for conservation and restoration efforts. The data produced will be used to predict future spatial relationships under different scenarios.
4. **Ecosystem Modelling**: Use ecosystem models (ECOSPACE and mizer) to study energy flow and pollutant impacts in marine food webs. Focus on marine predators to understand stressor impacts and inform conservation strategies.

Regional Context

The North Sea is a highly productive shallow shelf sea supporting substantial biodiversity, including globally significant populations of seabirds, grey seals and harbour seals, that are of global significance. It is also an area harboring unique assemblages of seabed fauna mediating globally significant ecosystem processes such as carbon and nitrogen cycling, that affect the ability of the ocean to serve as a sink for greenhouse gases. The region has also been heavily exploited for many centuries with a long history of commercial fishing including bottom trawling and inshore fishing by small vessels. Oil exploitation, one of the most intense offshore wind industries in the world, hydrogen generation, tidal energy, and carbon capture and storage add to a catalogue of human activities important in the region. In parallel, this is one of the most comprehensively studied marine systems in the world: there are uniquely strong data sets and time-series in this region as well as a suite of state-of-the-art, numerical modelling tools that can be used for impact assessment. Indeed, considerable long-term impacts of trawling on the benthic ecosystem, impacts of fishing on size spectrum spectra of fish, and recovery of seal populations following protection after centuries of intense hunting are well understood, and European legislation has led to interesting case-studies of ecological recovery. Crucially, alongside this history of human activity impacts and management, the North Sea is one of the world's warming hotspots, and concomitant changes in its species distributions are well underway. These changes affect our ability to sustain effective biodiversity conservation in the region affecting marine protected areas and jeopardizing advances made in fisheries management. These impacts in turn limit the ability to continue to use the region to support food security, climate regulation and biodiversity in the medium and long-term

A key study site – the Dogger Bank in the Central North Sea– presents areas of remarkably high biodiversity with high abundances of forage fish, and apex predators (including cetaceans, birds and seals) which aggregate in order to exploit this area. This is also an area of intensive past, present and forecast change in human activity, moving from previously crucial fishing grounds to plans for large-scale construction of many new wind turbines, and offshore hydrogen generation.

Services

Services include:

- Provisioning: fisheries, sea food and relevant products from aquaculture, oil and gas, renewable energy (wind farm)
- Cultural: coastal and marine tourism (sailing, fishing, diving, and beach tourism), culture heritage, sense of place, aesthetic values, educational values
- Supporting: biodiversity, species habitat, nutrient cycling
- Regulating: climate regulation, coastal protection
- The information in this document should help inform key stakeholders such as Dutch and UK authorities taking decisions on ecosystem management. This includes Rijkswaterstaat (NL); Department of Energy Security & Net Zero, Natural England, JNCC, Defra, MMO and Marine Directorate (UK).

Interacting Drivers of Biodiversity Change

Several drivers can affect the North Sea over a temporal and spatial scale, with synergistic effects on marine biodiversity and related services. These drivers mostly include: climate change, overfishing, pollution, habitat destruction and usage (Fig 1) (e.g., Skjoldal and Sherman 2002, Andersen et al. 2020, Moullec et al. 2021).

Climate Change Rising sea temperatures affect the distribution and abundance of marine species. Warmer temperatures can also impact breeding cycles and migration patterns, which can lead to mismatches in predator-prey relationships with cascading effects on the food web.

Overfishing reduces the population of targeted species (cod, herring, and haddock) and leads to changes in the production and availability of crucial forage fish (such as sandeels) which are consumed by fish, marine mammals and seabirds. Changes in fishing effort also affect bycatch of Protected and Endangered Species (PETS)

Pollution including nutrient runoff, plastic waste, and chemical contaminants (metals and persistent organic pollutants). Nutrient runoff from agricultural activities can lead to eutrophication, causing algal blooms and related oxygen depleted waters. In some cases those blooms are classified as harmful algal blooms (HABs).

Habitat change due to coastal and offshore development, dredging, and bottom trawling. Coastal defence and development, and land reclamation projects also affect coastal habitats, while dredging and bottom trawling disturb the seabed affecting benthic habitats and communities.

Sea usage is linked to increasing maritime traffic and the expansion of offshore wind farms and oil extraction, cumulatively contributing to noise pollution, chemical spills and habitat alteration. This may impose costs to mobile marine organisms such as marine mammals and birds: increased mortality due to collisions with boats or turbines, or reductions in foraging efficiency that can affect health, reproduction and survival.

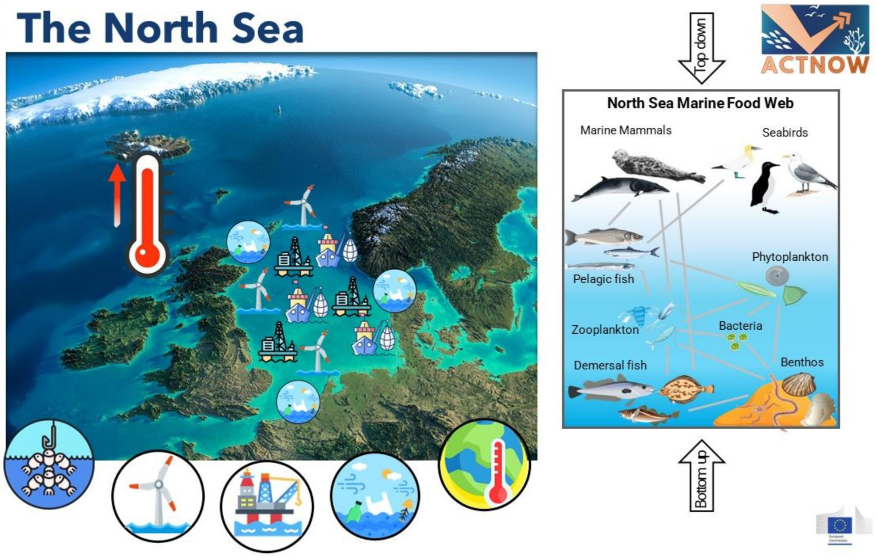

Figure 1 Schematic of the drivers affecting the North Sea marine food web

Research Needs

Further research is needed on the:

- Role of top predators in the response of the ecosystem, their impact on the whole food web and its resilience/vulnerabilities to stressors acting in combination.
- Future impacts of climate change and planned human activities on apex predator populations
- Relationships between biodiversity and seabed fluxes (now and under future climate pressure) affecting the ability of the ocean to serve as a greenhouse gas sink, supporting the use of EU marine conservation as a nature based solution for climate change.

Research Planned in ACTNOW

T2.1 Dogger Bank Cruise. The fieldwork for the cruise was accomplished in June 2023, and a range of samples still need to be analysed. Including: environmental DNA analyses or lipid composition of the plankton community.The fish stomach content analyses from the Dogger Bank Cruise were completed in June 2024.

T2.1 Dogger Bank Cruise: laboratory analysis completed during June 2024 of fish stomach contents, using samples collected during North Sea cruise. Data validated and uploaded to the Cefas DAPSTOM database. Outputs compared to historic records from the same locality.

A draft paper was submitted: Hunt G., Pinnegar J.K. et al,. Long-term changes in fish diets in the North England region. Fish and Fisheries. We used unique stomach content data spanning 1896-present to examine multi-decadal changes in the diet composition of six dominant bottom-dwelling fish species in the North Sea, and in particular an area of sea spanning from north-east England to the Dogger Bank. Three of the six predators exhibited significant diet shifts between the late 19th century and 21st century. Bivalves dominated plaice, dab and haddock diet in the early and mid-20th century, but their importance declined in subsequent decades. Conversely, polychaetes increased in importance overtime and were the main prey resource for plaice in the 1970s and 2000s by number and mass. These diet shifts are attributable to changes in the benthic prey-base of the North Sea, linked to increased beam trawling in the 1960s-1970s, eutrophication, but also climatic processes. This work underlines the value of historical diet data to elucidate broad-scale and long-term changes in marine food-web structure. It further provides a benchmark for improving ecosystem status and implementing management plans aimed at the recovery of benthic and fish communities on continental shelves in the future.

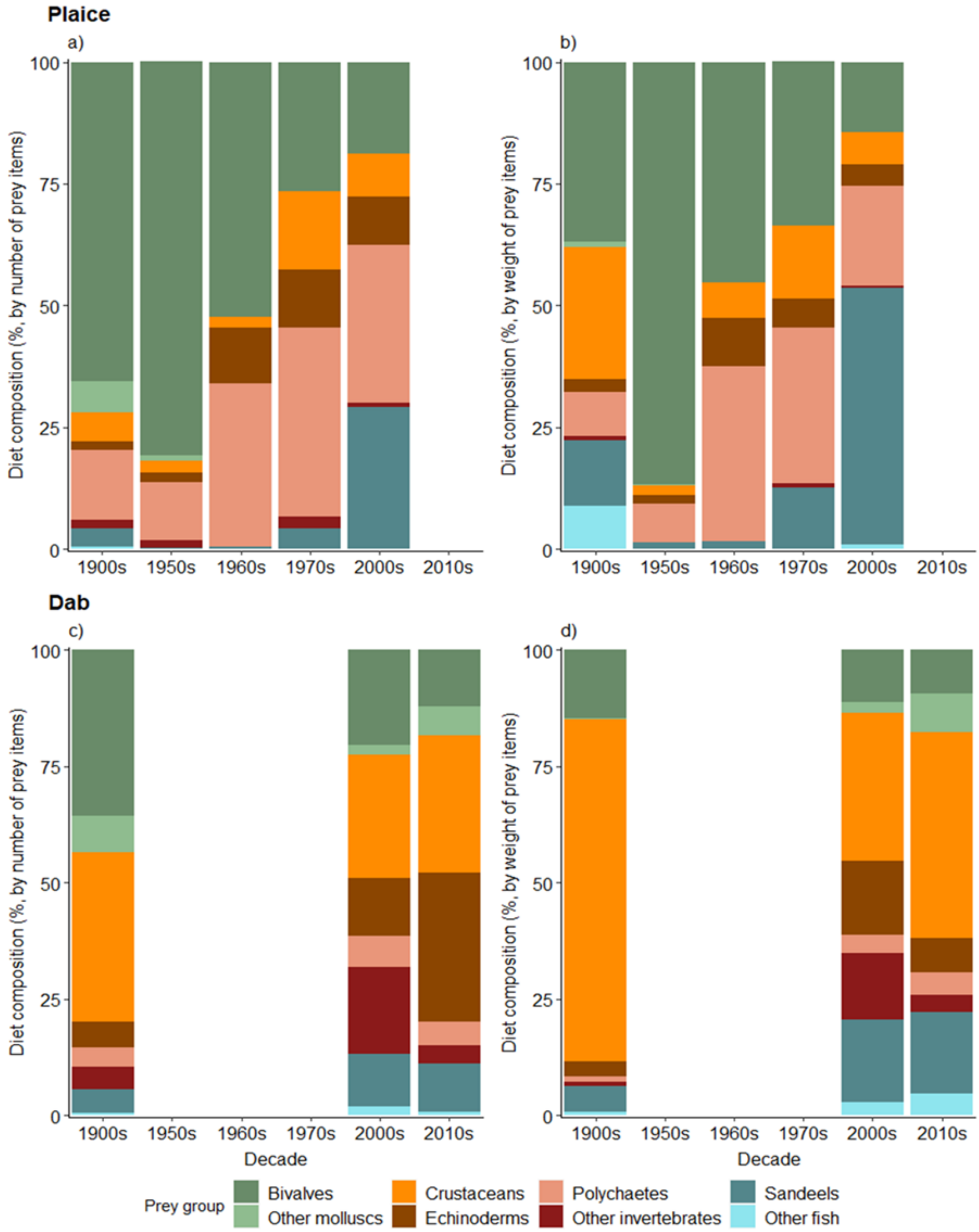

Figure 2. Diet composition of (a and b) plaice and (c and d) dab > 20 cm based on the number (left column) and mass (right column) of prey items consumed between April and September. [from Hunt et al. submitted]

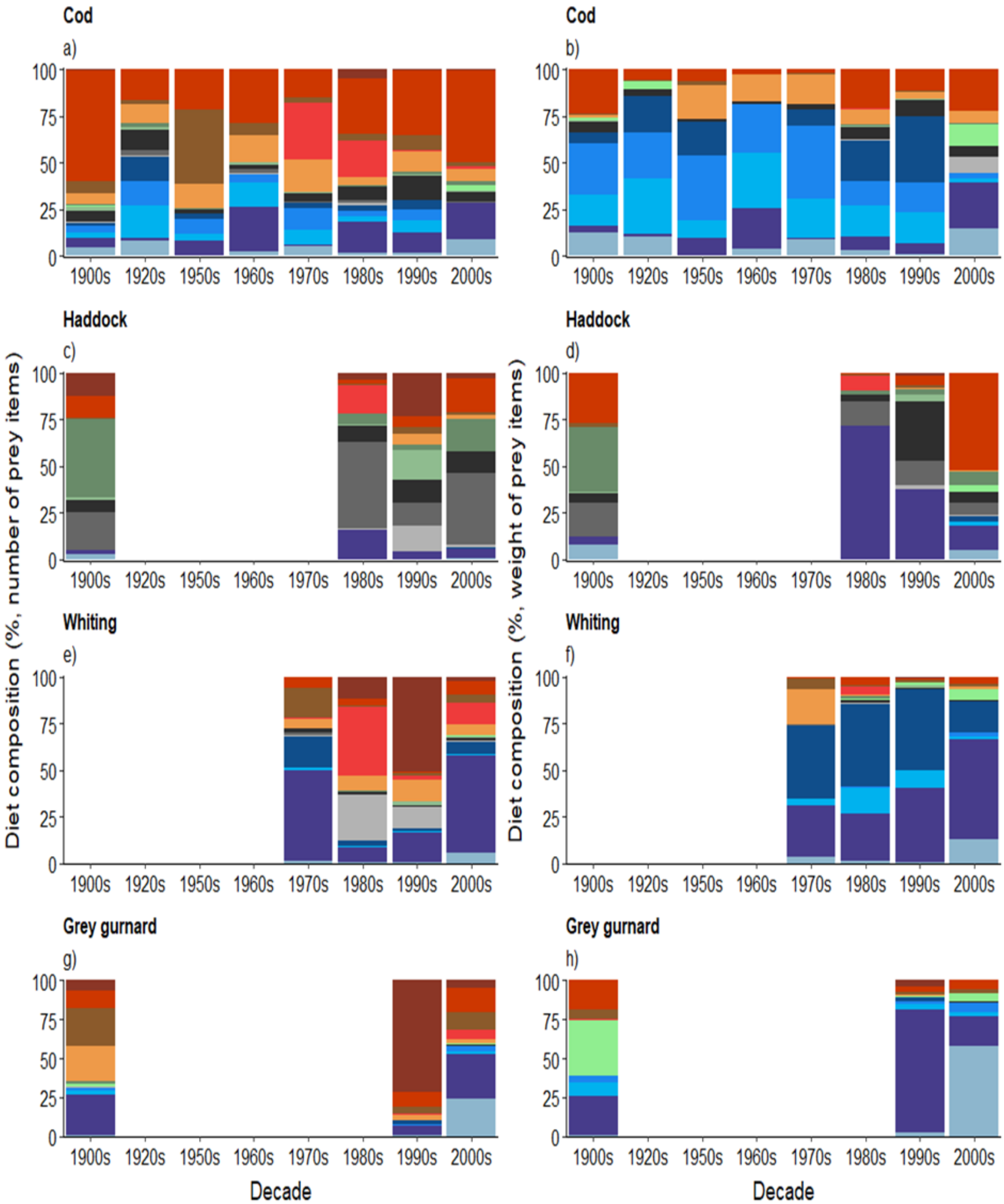

Figure 3. Diet composition of > 20 cm (a-b) cod, (b-c) haddock, (d-e) whiting, and (f-g) grey gurnard expressed as percent number (left column) and mass (right column) of prey consumed in quarters two and three by decade. [from Hunt et al. submitted]

● T2.2 Dogger Bank Cruise: statistical analysis of cruise predator sightings will be compared with environmental covariates in a statistical analysis, to explore habitat choice by the predators in relation to biotic and abiotic data. Together with habitat-preference maps based on telemetry, results will be examined to predict directions/impacts of future changes in habitat under different scenarios of human activity.

● T2.3 Dogger bank Cruise: agent based modelling (ABM) will be applied to seals using the Dogger bank area, to suggest likely changes in foraging efficiency under different scenarios of anthropogenic change in terms of energetic consequences for the individual animals.

● T3.1. A joint-species distribution model for North Sea and Baltic Sea fish communities is being setup and parameterized by DTU using the HMSC framework (which is adopted as the principal statistical modelling tool within this task). DTU expects to have a converged and validated model by early 2025. The model will provide improved process understanding of the drivers and assembly processes determining patterns and changes in species distribution and composition, as well as a means to forecast future changes in responses to climate change scenarios.

● T3.3 Ecopath with Ecosim and Ecospace model of the North Sea refined to incorporate change in habitat for epifauna due to wind turbines (Cefas). A scenario of change in presence of turbines across the whole North Sea in order to meet goals for energy development by 2030, 2040 and 2050 is in development (Uni of St Andrews). Change in habitat due to turbines and oil and gas infrastructure will be modelled under climate change projections building on work done in FutureMARES. Cumulative effects of fishing, climate (including temperature, salinity, primary production change), habitat change from structures and de-facto protected areas will be investigated. Outputs will demonstrate spatial and temporal change in biomass of functional groups from plankton to whales and in fishery yields for multiple fishing fleets.

● T6.2 Contributing to the development of the serious game "*Playing for change: Using experiential learning for bridging science and policy making to drive holistic understanding* "

Pictures, graphs and maps

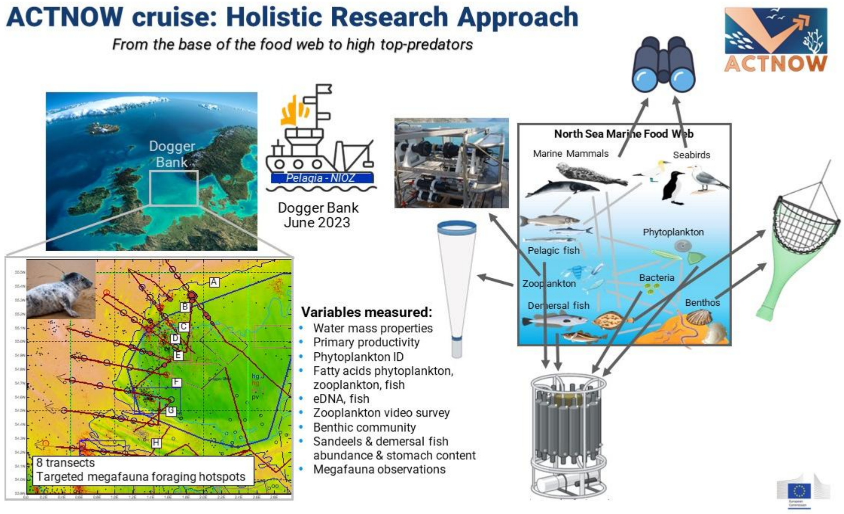

Figure 4 Research activities conducted in the Dogger Bank as part of the ACTNOW cruise in the North Sea in June 2023

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