UK-EOF Statement of Need

Marine Observation Requirements

Alongside development of Towards a Statement of Need, the UK-EOF has also developed Observation requirements tables to capture information and help articulate:

- The UK's requirements for observing the natural environment
- Identify the questions that we need to answer
- How close we are to being able to provide the evidence via a balanced suite of observations.

For ease, information gathering has been split into environmental domains and for each domain, what the specific issues or sub issues that are of importance for the headline issues identified in the UK-EOF Statement of Need.

Information has been gathered from experts in their field via correspondence, a workshop and open consultation. The tables are not final and some gaps exist in the information. The UK-EOF will work to fill these gaps and revise the tables accordingly.

Some of the sub-issues identified fall under several fundamental issues and there are key dependencies with other environmental domains.

Observation requirements captured within the tables have not been prioritised in any way, nor has current capability been identified. Prioritisation will be addressed via a decision support framework which is also being developed under the UK-EOF and capability or current activities are searchable within the UK-EOF Environmental Observation Activity Catalogue (www.ukeof.org.uk).

Summary of Requirements (under each UK-EOF headline issue)

Pressure on all environments in the light of Population Growth and associated pollution.

Human population growth can impact the marine environment both directly via water from the land entering coastal waters or by expansion of our economic footprint into the marine environment. The consequences of polluted or nutrient enriched waters entering the marine environment (directly or via our river systems), are eutrophication, or the marine ecosystem polluted with hazardous substances. Increased intensification of uses of the sea for leisure and recreation as well as infrastructure development / extractive activities to support economic growth (aggregates, fishing, oil and gas, renewable energy) have to be managed to ensure there is minimum environmental damage. The marine environmental carrying capacity is a useful concept we need to understand and measure in order to inform our planning and management of marine and coastal waters. This will allow us to

assess our ability to sustain the human population without wholly compromising the marine environment's ability to sustain itself.

At present UK marine monitoring programmes supply information for management across all sectors and record changes to allow management action where possible. However, these data have yet to be deployed to answer the fundamental questions about marine ecosystem resilience and its ability to absorb impacts caused by population growth whilst maintaining critical ecosystem services (see Biodiversity and ecosystem functions below).

Support Economic Growth whilst reconciling with Sustainable use of natural resources

It is likely that development of marine renewable energy will be significant to economic growth in the UK in the future. This growth will impact on marine (spatial) use, biodiversity and ecosystem functioning in different ways depending on location and nature of renewable energy development (wind, wave, tidal or combinations of them). Although there is an important role – (ultimately) – for maintaining understanding of the impacts of individual projects and mitigating negative impacts effectively, the cumulative impact at regional seas level, and over time, of multiple renewable energy projects is vitally important to understand.

As direct exploitation of energy from the marine environment has the potential to change (enhance or reduce) the environment's ability to sustain itself, a full understanding of the environmental context in which this sector must operate is essential.

Understanding future states of the *Earth*, *particularly the Carbon Cycle* *(but not excluding other element cycles)*

The vital role of the marine environment in maintaining biogeochemical cycling of gases and nutrients is now widely acknowledged and understanding future states is being investigated via research projects. Further work is needed to better understand the role of the marine environment as a source or sink of carbon dioxide and other greenhouse gases, much of the current research is either incomplete or not carried out at a scale which allows a policy response. Related questions such as whether the changing quantity of dissolved carbon in natural waters will impact ecosystem health and function are ongoing and require longer term observations in order to answer them.

Detecting changes in marine environmental chemistry over scales which may be relevant to policy or management responses (such as at a sub-sea carbon capture site) is very challenging and although existing measures obtained at broader scales (such as the AMT cruise) provide background data, continuing efforts to expand the intensity and scope of measurements are needed in the longer term.

Fisheries, Agriculture, Food Security and Water Supply

The effects of environmental change on agriculture, food security and water supply as they relate to the marine environment mainly concern the impacts on sustainably

harvested wild fish and mariculture. In the latter case, it is particularly the potential impacts of disease (new pathogens) and food supply that are of concern. Climate change may also alter the profitability associated with some species, and result in substitution of different species which are cultivable within the same systems.

In the case of harvested wild fish, the situation would not be as serious if all wild fish stocks were harvested sustainably – but much has yet to be done to bring unsustainable and illegal practices under control in European waters.

Human Health, Wealth and Wellbeing

Human well-being is influenced by the wide impacts of ecosystem goods and services provided by marine and coastal ecosystems. These range from the climate regulating function at the global scale, to the rise in sea level and extreme events such as flooding and tidal surges along the coast, to water borne diseases.

Continuing surveillance of the occurrence of toxic materials, both within the water column and consumable sea produce, is necessary to provide warning to potential users or consumers. Although currently out of scope for the UK-EOF, combining this information with surveillance of the health of coastal communities or users of the marine environment could help to improve our understanding of the links between human health and causative agents.

In addition, as sea temperatures rise, shellfish contamination and bathing water quality may be increasingly affected.

New issues are also emerging – for example, harmful algal blooms are implicated in coastal incidence of asthma, and a range of new pharmaceutical substances with endocrine disrupting characteristics are emerging as new environmental contaminants of concern in estuaries and coastal environments.

Understanding, avoiding and mitigating the effects of extreme events and disasters

In order to minimise the risk and potential impacts from extreme events such as coastal flooding or storm surges, our ability to predict extreme events is fundamental. This requires both monitoring capability at different scales (global to local) and appropriate predictive capability using up-to-date information. Although most of these requirements are in place through the Met office and Environment Agency – both of whom are involved in the relevant research, there is a constant drive to improve efficacy of the monitoring technology and for improvements in accuracy and cost effectiveness. Although a nuclear incident from UK (or non – UK facilities) continues to be a concern there is no UK statutory programme currently in place to cover these eventualities. Capability for monitoring toxic algal blooms using remote sensing technology is developing to provide routine management advice with respect to shellfish and recreational bathing.

Understanding and reducing the impacts of environmental change on marine and terrestrial biological diversity, ecosystems & services

The impacts of environmental change on marine biodiversity, ecosystems and ecosystem services are very poorly understood, with only rudimentary predictions of what the changes may be in future. The biogeographic range of many species is already changing, each at its own characteristic rate, and as a consequence new biological interactions are taking place. The outcome of these interactions and the consequences for ecosystem function is difficult to predict with any confidence.

The clearest evidence for poleward range expansion comes from the planktonic species collected within the CPR survey since this has data spanning 70 years. This means that a clear trend can be seen beyond the large natural inter-annual variations. The MarClim project has also shown clear shifts in the distribution of intertidal invertebrates from relating measurements of the same species (collected during a number of different research contracts) over the past twenty years.

The relationship between biodiversity and the ability of an ecosystem to deliver essential services is a complex one. Research effort is shifting to understanding the limits of ecosystem capability to withstand change, whilst continuing to deliver essential ecosystem services. Underpinning, longer term observations are needed to support this research and to provide information on the rates of change to validate and calibrate the models which support management action.

Understanding climate variability and climate change within earth system science

The current approach to detecting climate change and variability in the marine environment relies on regular (daily / monthly / quarterly) measurements of a range of physical parameters mainly (temperature, salinity, pH etc). These are not only needed to be collected in UK coastal waters but international collaborations, are needed to understand the worlds oceans and the polar regions. The information needs to be available to validate and calibrate climate prediction models.

Scientific and Technological Advancement/Innovation

A critical aspect of obtaining appropriate information not only for detecting physical changes in our earth system, but for monitoring key parameters efficiently and effectively is continuing technological advancement and innovation. The development and expansion of remote sensing methods and use of proxies or surrogate measures requires appropriate research effort to establish relationships between key parameters. Models can be used to ‘interpolate intelligently’ between measurements, especially if data assimilation experiments have been used to optimise the observational array for this purpose. Once in place this knowledge can result in more cost effective and geographically comprehensive programmes with fewer parameters monitored. The possibility of developing direct links between managers and real-time remote sensing information via web platforms also reduces the time scales needed for decision making, and could be a model to follow for a range of observation activities.

Other Requirements and General Comments

- The focus should be on future needs –supported by horizon scanning.
- There is inertia in the system of observations currently being made.
- The needs should be informed by clear objectives i.e. what is needed to meet legal obligations, what is needed for research purposes and what is needed for decision making purposes in relation to marine environmental management and on what time scale.
- There is a need for knowledge exchange and an assessment of the adequacy of current ecological monitoring networks - the system needs to be under constant review.
- A lack of seabed mapping is a requirement which does not fall directly under one of the headline issues. High resolution mapping of the UK Shelf seas provides fundamental information for marine resource use and is therefore important for marine spatial planning.
- There is a need for refining data and data handling facilities to allow information to be shared more rapidly and easily – particularly with respect to observations which have management implications.
- There is need to communicate with wider stakeholder groups. Humans are part of marine ecosystems and the reason for much of our legislation is to maintain or improve human health. Currently the effects in humans is out of scope for the UK-EOF, however it is apparent that there is a need for communication with DoH and HPA. Relevant Environmental Information gathered could be used in health impact assessments, which in turn could be incorporated into marine management.

Marine Observation Requirements Tables

Information captured in the table will help to articulate what the UK's requirements are for observing the natural environment, what the questions are that we need to answer and how close we are to being able to provide that evidence via a balanced suite of environmental observations.

For each environmental domain information has been collected on the specific issues or sub issues that are of importance for the headline issues identified in the UK-EOF Statement of Need.

Consultation with the community has led to the population and validation of the following table. The tables are currently 'work in progress' and will continue to be revised as requirements and priorities change. The requirements captured have not been prioritised in any way.

Table 1 Fundamental Issues (one table for every environmental domain**) MARINE**						
Specific/Sub issue	**What are the key questions that require answering in order to address the specific/ sub issue?**	**Measurement Type** (variables that would need to be measured to provide evidence to address the specific issues)	**Frequency of collection** e.g. A continuous measurement for 1 week in Spring, repeated every 2 years. Or A spot measurement, once a week, every week throughout the year. Or Irregular measurements as required i.e. extreme event monitoring.	**What geographic coverage do we need?** A) UK B) England C) N. Ireland D) Scotland E) Wales F) Localised UK G) Europe (non UK) H) Global I) Other (please specify) J) Ocean/Sea (please specify	**What is the primary use for the data?** A) Basic Science B) characterising environmental issues/solutions (influencing policy) C) Direct env. Management D) Modelling & Prediction E) Complying with Legislation F) Development & Growth	**Are the current actions / measurements sufficient to provide the evidence needed to address the issue?** If known, please list the current programmes/sensors which are capable of providing the evidence (e.g. for Sea Surface Temperature AATSR, SLSTR. AVHRR, AMSR and Modis satellites are capable of measuring SST).
Population Growth (Pressure on the environment in the light of population growth and associated pollution.)						
Ballast Water	Is the discharge of used and/or ballast water an issue in UK waters?	-Volume of water discharged per annum -Location of discharge -Monitoring for	-Continuous information from ships -Ad hoc for spp -Spot sampling of	A, G, H (to track non-native movement)	C	No current programme – some monitoring of headline non native spp (introduced by ballast water) monitored in WFD/Common Standards Monitoring programme

		presence of Non-native spp -Pre-treatment of ballast water	ballast water for plankton/cysts - WFD programme (freq. unknown)			
Marine Litter	- How can we meet the requirements of the MSFD (GES descriptor 10 – properties and quantities do not cause harm) for Litter? - What are the impacts of litter? - Which properties and at what quantities of litter, is harm caused? - What is the cause of the litter (MSFD requires measures to improve the traceability of pollution)	- Volume of Litter - Type of Litter - Impacts GES Descriptor 10 - observation programmes to be in place by 2014 (July).	Various – opportunistic (e.g.. Fishing for litter; regular (monthly) beach surveys (e.g. MCS)	A and OFFSHORE!	C E: GES under MSFD	MCS Beachwatch Litter Survey Seabird gut contents? Marine plastics – CPR/EcoOvo - VoP Fishing for litter CEFAS Data capture project: DEFRA programme development (litter) Some SAHFOS data on plastic debris MSFD (GES is still being determined, details of observation programmes/requirements will follow in 2014)
Pollution	What is the impact of discharges, emissions and losses of hazardous substances and radionuclides? What are the impacts of management activities?	Inputs of hazardous substances and radionuclides from rivers, groundwater WFD/MSFD requires many parameters: freshwater flows, discharges, industrial abstractions, morphological	Various Site specific Daily ⇔ yearly Need site-specific source data daily for when something goes wrong Non-specific: e.g.	UK – coastal and offshore	B ; C	Cefas, MS-S (formerly FRS), CCW & NIEA (Disposal) site condition monitoring; Cefas contaminants in mammals, shellfish; radioactivity in marine waters EA monitors 485 bathing waters, river inputs + direct discharges, DO in estuaries, dangerous substances & radioactivity inshore; likewise SEPA (UWW is Forth + Tay DO, nutrients, Chl, plankton) including contaminants in shellfish;

		pressures, nutrient enrichment, phytoplankton species, chlorophyll, macroalgae, angiosperms, benthos, fishing temperature, salinity, nutrients, light, DO, organic enrichment pollutants OSPAR 1. Comprehensive Study on Riverine Inputs and Direct Discharges (RID) 2. Comprehensive Atmospheric Monitoring Programme (CAMP) 3. Co-ordinated Environmental Monitoring Programme (CEMP) UKMMAS 1. Clean Seas Environmental Monitoring Programme MSFD Descriptors 8 & 9	T(z) @ 50 km, 10d, 0.2°C Seasonal or monthly			WFD monitoring (expand scope and scale for MSFD) Within the UK we are aiming to have Clean, Healthy, Biologically Diverse and Productive Seas – thus we have targets. For WFD – good or high status. OSPAR – concentrations at background, and cessation in discharges, emissions and losses. MSFD Descriptor 9 "Contaminants in fish and other sea food for human consumption do not exceed levels established by Community legislation or other relevant standards." Descriptor 8: "Concentrations of contaminants are at levels not giving rise to pollution effects."
Eutrophication	-What is the impact of Eutrophication? -How can we	Nutrients, DO, chlorophyll, plankton Inputs from rivers, groundwater	@ 10-100 km Seasonal or monthly Various – for	UK – coastal and offshore	B; C; E (to meet international agreements	Cefas (North Sea transect + Ferrybox) EA for WFD SEPA nitrates, Forth + Tay UWW (DO, nutrients, Chl, plankton);

	reduce/mitigate the impacts?	OSPAR Eutophication Strategy – Comprehensive Procedures	nutrients, winter months; Chl – summer months		and directives)	L4, E1 nutrients, Chl Coastal (Irish Sea) Observatory SAHFOS – CPR (x 20+) EMECO CEFAS smart buoys, satellites MARIS etc
Noise	What levels of Noise adversely affect the marine environment?	MSFD Des 11 Cetacean population distribution	Spot measurements		E	~ no monitoring, some data at UKHO CEFAS effects of dredging noise No criteria fro ecosystem effects
Heat	What are the impacts of changing the thermal regime (on biota/marine system)?	Temperature Species/ecology	License dependent Discharges continuously-daily	Local	E	Changes to thermal regime (e.g. from outfalls) is mentioned as a pressure in the MSFD.
Land reclamation						
Light						
Defence	- a) What is the impact of dumping munitions? - b) What is the impact of testing weapons at sea? (this is relevant to noise) - c) submarine detection - d) sea conditions for operations	Marine meteorology, for c, d temperature, waves, currents for a, b, c, d	R/S SST @ 10km, 6h, 0.1-0.3°C *Insitu*SST @500km, 1 week, 0.2-0.5°C T @ 50km, 5 modes (z), 10d, 0.2°C wind @ 50km, 1d, 1-2 m/s	Global Where and when needed	D	Met Office MAWS, Mike (NOCS), VOS (Voluntary Observing Ships) Argo POGO Wavenet Smartbuoys
Education	How can we recruit students to science? - Interesting sample data products on Web					Coastal (Irish Sea) Observatory

Leisure and recreation; Tourism	-What is the impact of leisure, recreation and tourism on the marine environment? -How can we promote tourism, but minimize impacts on the marine environment? - What measurements enhance tourism?	Marine meteorology, temperature, waves Assessment of impact of tourism Water quality		UK & North Atlantic	D	Met Office MAWS, Mike (NOCS), VOS, Argo, R/S (SST, winds) EH wreck monitoring (45 of 60 protected sites) & Historic Scotland EA monitors 485 bathing waters, & NIEA, SEPA bathing waters monitoring NO measurement of impact? Wavenet
Telecoms, pipelines, power lines	- How do telecoms, pipelines and powerlines affect the seabed, sediment movement, currents and biota? - What measurements are needed for design and installation	Bathymetry, marine meteorology, waves, currents; Bed structure, sediment	wind @ 50km, 1d, 1-2 m/s	UK & North Atlantic (local monitoring for currents and bed)	D	WebMET (22 oil/gas rigs) MCA/UKHO bathymetry WaveNET / Coastal Wave Network BGS seismic lines, samples
Energy	What are the impacts of Offshore renewable and nuclear new build (see economic growth /sustainability)	Ecosystem health		UK	C; E; F	
Land run-off	-How does land run off impact the marine environment? - Does run off increase turbidity? And nutrients?	Turbidity (see biological diversity & ecosystem services) nutrients	monthly	F, Local monitoring	B, C	EA / SEPA / WFD monitoring

Economic Growth & Sustainability (Reconciliation of economic growth with sustainable use of natural resources)						
Water	- What impact will increasing economic growth have on the changing water cycle?	River discharge				Oceans2025, NERC intent
	- How will water abstraction e.g. • Cooling water • Desalination (in the UK) affect the marine environment?	Temperature	Continuous	Local at outflows (or near)	B, C, E	
Environmental Services	How can we assess the value of environmental services?					Oceans2025
Fisheries	How do you or are we delivering ecosystem based fisheries management? Forecast conditions for fishing operation	Marine meteorology, temperature, salinity, waves, currents, bed-type, plankton, DOM, benthic biomass Fish biomass, fish recruitment, ecosystem structure, trophic dynamics	R/S SST & colour @ 10km, weekly, 0.5°C *Insitu*SST @500km, 1 week, 0.2-0.5°C T(z) @ 50 km, 10d, 0.2°C wind @ 50km, 1d, 1-2 m/s plankton, biomass, fish @ ??	UK & North Atlantic	D	Sustainable Marine Bioresources research Met Office MAWS, WebMET (22 oil/gas rigs) NIEA fish monitoring; AFBI, MS-S & Cefas commercial fish + shellfish landings, discards MS-S North Sea + W Scotland pelagic fish, deep-water fish, Rockall haddock, Cefas Bury Inlet cockles, monitoring crustacean pot fisheries; MCA ShipAIS / MFA satellite vessel monitoring Met Office drifting buoys; Ferrybox, VOS Argo, POGO
Transport/Ship	- What are the impacts of	Bathymetry, marine	R/S SST @ 10km,	UK & North	D	MCA/UKHO bathymetry

ping	Marine transport & shipping? - What is the impact of associated dredging? - Forecast conditions for operations - What can be done to mitigate the impacts?	meteorology, sea level, temperature, waves, currents; turbidity Bed structure, sediment Gases e.g. NOx + CO2 Shipping routes	6h, 0.1-0.3°C wind @ 50km, 1d, 1-2 m/s	Atlantic		ABP port cargo throughput MCA ShipAIS NTSLF WaveNET / Coastal Wave Network Met Office MAWS, WebMET (22 oil/gas rigs) VOS MS-S, NIEA monitor dredging locations BGS seismic lines, samples
Sea Bed Disturbance (from Human Activity)	- What are the impacts of Mining, dredging & sand and gravel extraction? - What impact do oil and gas installations have on the seabed? - What is the bed quality near rigs?	Bathymetry, marine meteorology, sea level, temperature, waves, currents; Geohazards; Bed structure, sediment Ecology (impacts on)	wind @ 50km, 1d, 1-2 m/s T(z) locally, 10d, 0.2°C	UK & North Atlantic Where needed Bed, sediment impacts locally	D B, D	MCA/UKHO bathymetry WaveNET / Coastal Wave Network MS-S, NIEA monitor dredging locations NTSLF Met Office MAWS, WebMET (22 oil/gas rigs) UKOOA / AFEN monitoring VOS FEPA (NI) visits BGS seismic lines, samples CEFAS (RATS) MALSF
Renewable energy	1. feasibility by area 2. impact on seabed 3. impact on biota including avoidance	Bathymetry, marine meteorology, sea level and land uplift, temperature, waves, currents; Bed structure, sediment Turbidity Hydrology	wind @ 10km, 1d, 1 m/s sea level: x 30-50+GPS + alt. *or* x 100s+GPS @ monthly mean, 1 cm T(z) locally, 10d, 0.2°C	UK & N. Atlantic (@ 50km,1-2m/s) – ops Local for design Sea level: global Where needed	Wind: B, D, F Sea level: B, F T(z): B, D	UKERC, Marine Bioenergy (NERC intent) – research MCA/UKHO bathymetry Oceans2025 NTSLF, POL & IESSG GPS + gravity WaveNET / Coastal Wave Network Met Office MAWS, WebMET (22 oil/gas rigs) VOS BGS seismic lines, samples Lack knowledge of structures' impacts
Seasonal	Is there appropriate	Ocean temperature,	R/S SST @ 10km,	UK & North	D	Argo, remote-sensed sea surface temperature

weather prediction	seasonal weather prediction in support of tourism, other human activities/ecosystem services, energy requirement predictions & human health?	salinity, circulation Waves (height?) ice	6h, 0.1-0.3°C *Insitu*SST @500km, 1 week, 0.2-0.5°C ice extent, conc. @ ~30km, 1d, 10-30 km / 2-5%	Atlantic Polar need to localise wave forecast	D	Met Office MAWS, Mike (NOCS), WebMET (22 oil/gas rigs) VOS
Spatial Planning	- Where are the best locations for MPA's - What are the Cumulative impact of pressures on ecosystems?	Bathymetry, waves, currents, temperature, salinity, nutrients, DO, chlorophyll, plankton, DOM, biomass, SPM, habitats + species; Bed structure, sediment properties High-res mapping of UK shelf seas	Nutrients, sediment, DOM @ 10-100 km (statistics of) other variables at spatial resolution needed for various planning requirements		B, C, D, E, F	MCA/UKHO bathymetry AFBI coastal (10 moorings: T, S, Fl; some turbidity, DO); Cefas coastal T; SAMS subtidal T (x2); MS-S coastal T, S, nutrients, Chl, plankton, SEPA nitrates, Forth + Tay UWW (DO, nutrients, Chl, plankton); Cefas Smart buoys (6??: T, S, Fl, SPM, light, Fl, DO, nutrients); IoM T, S, DO, nutrients, Chl, plankton L1, E4 T, S, nutrients, Chl MFA vessels monitoring, MCA ShipAIS Ferrybox WaveNET / Coastal Wave Network Met Office drifting buoys Coastal (Irish Sea) Observatory BGS seismic lines, samples
GDP	What is the contribution of marine industries to GDP?					See D.T. Pugh report
Nuclear Power	What will be the effect of installing new Nuclear power stations?	Assessment based	Site specific by EDF	local	B, C, D, E	

Carbon Cycle (Future States of the Earth and particularly the Carbon Cycle)						
Feedback Processes	How can we increase our knowledge of feedback processes?				A	NCEO Carbon EO data and models CARBON-OPS
(Global) biogeochemical cycling (+ feedbacks)	- How can we improve our understanding and reduce current uncertainties?[1]	pCO_2, pH, nutrients, DO, Chl, DOM(z), plankton(z), total SPM(z); POM SST, mixed layer depth, MOC, feedback other gas, N deposition, methane hydrates Seabed and benthic	surface pCO2 @ ??25-100 km, daily, 0.2-0.3 µatm?? (GOOS) generally @ 10 – 100 km	UK & North Atlantic	A, B, D	CARBON-OPS (unfunded); Pride of Bilbao (finished), MVs Santa Maria (finishing in 2009) + Prince of Seas, Canoba (??) Oceans2025 (Carbon measurements on short-term funding – ended/ending 2010): AMT, PAP site, Ellett line GCOS hydrography ? CP2 data sources, Ferrybox, VOS Cefas Smart buoys (6??: T, S, Fl, SPM, light, Fl, DO, nutrients); IoM T, S, DO, nutrients, Chl, plankton L4, E1 nutrients, Chl SAHFOS – CPR (x 20+) Lack of pH+CO2 baseline in shelf seas – NERC/Defra/DECC OA programme? Link with atmospheric CO2 Benthic – NIEA
Carbon Capture and Storage	What are the Implications of carbon capture and storage? Will CCS have wider scale implications on feedback processes? (See Feedback processes and	CO2 (pH) Monitoring leakage + effects	Continuous spot measurement		B, C	Carbon capture & storage (BGS & NERC intent) Vent studies The Former DTI (then BERR, now BIS) carried out research on CCS.

[1] This may require process studies in a range of locations and seasons rather than monitoring. However some of the measurements may be required longer-term for other purposes – see other entries in the table.

	biogeochemical cycling for wider implications)					
Carbon Dioxide	How can we improve our knowledge of the uptake, transport and storage of CO2? (See CCS above)				A, B, D	
Atmospheric CO_2	How is atmospheric CO2 changing? - At what rate is atmospheric CO2 changing? - What are the long-term consequences (for humans/fauna/biota etc[2])	Monitor atmospheric CO2	Continuous	H but a few suffices	A, B, D	Hawaii (& maybe a few other places)?
CO_2 Fluxes	- What are the reasons for changing air-sea flux? - Ditto for Land/ocean flux	As biogeochemical cycling			A, B	EU ICOS
Ocean	What are the long-term effects of ocean fertilization	As biogeochemical			A, B, D	

[2] Understanding the potential consequences may require process studies/research. Periodic observations to assess whether these predictions are correct may be necessary.

Fertilization	/ geo-engineering[3]?	cycling				
Ocean Acidification	What are the long-term effects of ocean acidification on the physical and environmental aspects of the marine environment[3]?					NERC/Defra/DECC Ocean Acidification Research Programme. EU projects (many of which are coming to an end in 2009).
Agriculture, Food Security & Water Supply (The effects of environmental change on agriculture, food security and water supply)						
Mariculture	What is the impact of Mariculture on the health of the ocean and natural systems/feedbacks? What is the impact of the changing environment on mariculture (i.e food security)? Specific questions include: - What is the impact of increased sealice on both mariculture and the surrounding ecosystem? - Is there a sufficient (sustainable) supply of available feed? - What is the optimum carrying capacity? - What is the risk of disease	Temperature Nutrients Plankton species Pathogens ***Carrying capacity is a process research issue, therefore would***	Continuous	Mainly C+D (N.I. & Scotland) Some E + B (Wales & England). F, Locally at scale of mariculture & a few "downstream" (by a few km)	C,D,E	Sustainable Marine Bioresources AFBI Sea Loughs CEFAS (Weymouth) Complex and diverse…

[3] Initial short term process studies may indicate some of the effects, however long term observations would be required to fully understand the long term future impacts.

	transmission between mariculture organisms and also to the surrounding natural system? - What is the impact of climate change on profitable species	***this need sustained observations?***				
Changing water cycle		Marine climate – temperature, salinity, clouds/evaporation	routine meteorology	Hemispheric Argo,	A, B, D	Oceans2025, NERC intent (maybe no more monitoring) ARGO Atmospheric reanalyses + forecast + Scenarios
Fisheries	What is the impact of natural environmental change on sustainably harvested wild fish?	Spawning stock biomass. Fishing Mortality. Maximum Sustainable Yield Sediment, habitat damage. Invertebrate health By-catch (cetaceans) Removal of non-target species/discards Change in food web	R/S SST and colour for chlorophyll @ 10km, 6h, 0.1-0.3°C *Insitu*SST @500km, 1 week, 0.2-0.5°C T(z) @ 50 km, 10d, 0.2°C **Annual or less** **Weekly**	UK & North Atlantic A	D C, E	Sustainable Marine Bioresources research Met Office MAWS, WebMET (22 oil/gas rigs), Ferrybox, VOS NIEA fish monitoring; AFBI, MS-S & Cefas commercial fish + shellfish landings, discards MS-S North Sea + W Scotland pelagic fish, deep-water fish, Rockall haddock, Cefas Bury Inlet cockles, monitoring crustacean pot fisheries;
	What are the impacts of over fishing? What does this mean for the state of our fisheries?	Fish stock assessment Sea-bed surveys	annual	UK waters	B, C, D, E	AFBI, MS-S and Cefas commercial fish + shellfish landings, discards MS-S North Sea and west Scotland … IFYS / bottom

	How can we manage the distribution of fishing effort (food security depends on fish stocks outside UK/EU waters)?	Vessel monitoring	All fishing vessels at sea	UK waters	C, E	VMS (not generally available)
Human Health (Consequences of environmental change for human health, wealth and well being)						
Pollutants/ Pathogens	- What is the general distribution of pollutants/pathogens in water/sediments? - What concentrations are detrimental and what is the effect on fish and shellfish? ***Would process studies including lab experiments would be more effective?***	Sediment properties, nutrients, DO, plankton, bacteria (viruses?), Faeces, pollutants Inputs from rivers, groundwater Metals GES descriptor 8 and 9: concentrations of contaminants in water, sediments, fish and other sea food + cetaceans, seabirds, seals,…(for well being an indicator for top predators)	@ 10 – 100 km Food: every time sampled Stranding: as above Dependent on purpose, known to be done: - annually - monthly Major events more frequent	A-G I: Southern Ocean, Antarctic, British overseas territories	E, C, A, B, D (priority order)	Oceans2025, Cefas, EA, MS-S, NIEA, SEPA, AFBI Sediment Contaminants NIEA & Cefas Clean Seas, CSEMP, + Cefas contaminants in mammals, Cefas & NIEA Disposal site monitoring EA monitors 485 bathing waters, river inputs + direct discharges, shell fish waters, dangerous substances & radioactivity inshore; likewise NIEA, SEPA (UWW is Forth + Tay DO, nutrients, plankton) WFD monitoring Coastal (Irish Sea) Observatory Shellfish monitoring ans assessment (FSA/CEFAS). Imposex (SHD) CEFAS, NIEA, SEPA, MS-S OSPAR CEMP UKMMAS CSEG
	How are pollutants / pathogens transported and under what processes does transformation occur? *[This and next are very closely related]*	Shelf-sea currents Local currents Riverine inputs + modelling Tracers (bacteriophages), etc	As above but also continuous current meters	As above	C, D, A, B	Oceans2025 (Tiree Passage); NERC Environmental nanoscience; NERC Env. Radioactivity intent current mooring sites, HF radar Met Office drifting buoys Coastal (Irish Sea) Observatory
	- How are humans exposed	Nutrients, plankton,	Connected to level	As above	C, E	ERA-EnvHealth

	to the pollutants and pathogens and what is the risk? *[This and previous are very closely related]* Read across required observations	pollutants, pathogens - biological effects measurements - cumulative risk - Contaminants in food+water	of risk/exposure			EA monitors 485 bathing waters, river inputs + direct discharges, shell fish waters, dangerous substances & radioactivity inshore; likewise SEPA (UWW is Forth + Tay DO, nutrients, plankton) WFD monitoring
Algal toxins, HABs	Are algal toxins present and therefore do they provide an exposure risk to humans?	Temperature, salinity, currents, waves, sediment properties, solar radiation, DO, plankton, Chl (remotely sensed??), nutrients Toxins (DSP, PSP, ASP) + others Parameters here = for modelling and sufficient observations to constrain model For actual monitoring: - species if toxic or not - shellfish (matrix in which find algal blooms) - Aerosols (toxins)	T(z) locally, 10d, 0.2°C ? sediments, DO, plankton, nutrients, Chl, toxins at vulnerable season @ 10 - 100 km Seasonality is very important	UK, Local to vulnerable areas	A, D E,C	SAMS, Ferrybox, VOS, L4, HAB-buoy, HAB risk AFBI coastal (10 moorings: T, S, Fl; some turbidity, DO); AFBI, MS-S & Cefas, IoM, SAMS toxic phytoplankton monitoring; MS-S coastal T, S, nutrients, Chl, plankton; SEPA nitrates, Forth + Tay UWW (DO, nutrients, Chl, plankton); Cefas coastal T, Smart buoys (6??: T, S, Fl, light, Fl, DO, nutrients); IoM T, S, DO, nutrients, Chl, plankton Current mooring sites, HF radar Coastal (Irish Sea) Observatory EU programmes GeoHAB CEFAS currently do this. FEPA, shellfish
Metals (contamination)	What is the risk of Metals in biota / contaminants in seafood?	See “pollutants” above & “Pollution” under Population Growth				AFBI, MS-S, SEPA & Cefas monitoring: shellfish biotoxin + microbiological contaminants Cefas monitor radioactivity in a range of foods MS-S in Clyde

Wealth & Wellbeing	What is the impact of change on environmental factors that affect human health? - distinguishing natural and anthropogenic changes - resilience to pressures/tipping points Is the change in Climate influencing the emergence of new diseases, parasites etc? Genomics: Adaptation, capability - Are the ranges/hosts of diseases and parasites changing with changing climate? - Can future changes be predicted?	Monitor for pathogens See “climate” for “input” state of climate variables	Continuous (current flow, etc)	A, G, H	A, B, D	

Extreme Events (Extreme Events and Disasters)						
Forecasting	There is a need for forecasting (weather, storm surges, tsunamis, ice) so that extreme events can be predicted.	Marine meteorology sea level temperature waves currents ice Seismic events	wind @ 50km, 1d, 1-2 m/s ??rain?? Sea level anomaly @100 km, 1h, 10cm R/S SST @ 10km, 6h, 0.1-0.3°C *Insitu*SST @500km, 1 week, 0.2-0.5°C ice extent / conc. @ 30km, 1d, 10-30km / 2-5% ice velocity @ 200 km, daily, 1 cm/s Continuous	UK & North Atlantic UK coastal UK & North Atlantic Polar	D B, D D B, C, D	Met Office MAWS, Mike (NOCS), WebMET (22 oil/gas rigs); VOS FREE; Storms NCAS, NERC intent; R/S for developing weather; IOC et al. tsunamis; Oceans2025, NCOF/NTSLF tide gauges/STWS/weather forecast; WaveNET / Coastal Wave Network / Channel Coastal Observatory
	Prediction of hurricanes/ winter storms	Link to forecasting above		Global		
Risk management		Beach profiles Realignment sites Sea level waves	sea level: x 30-50+GPS + alt. *or* x 100s+GPS @ monthly mean, 1 cm Sea level anomaly @100 km, 3h, 10cm	Global UK coastal	B, C B	Defra/EA FCERM; some EA regions monitor; Centre for Environmental RM WaveNET / Coastal Wave Network
Oil and	Are we adequately prepared	Shelf-sea currents	Irregular as needed	UK	C, D, E	R/S tracking

chemical spills	and have the relevant knowledge for efficient Incident response?	Hazardous substances	& measurements to constrain operational NCOF models			HF radar CEFAS: oil and chemical spills. Merchant shipping – ships of opportunity
Search and rescue		Marine meteorology Temperature Waves currents	wind @ 50km, 1d, 1-2 m/s R/S SST @ 10km, 6h, 0.1-0.3°C Irregular as needed & measurements to constrain operational NCOF models	UK & North Atlantic	D	Met Office MAWS, WebMET (22 oil/gas rigs) VOS WaveNET / Coastal Wave Network Coastal (Irish Sea) Observatory HF radar
Geohazards to structures		Bed structure, sediment properties	Local as required	Localised UK (c.f. planning should be UK comprehensive)	B, C, D, E	BGS seismic lines, samples
Toxic blooms		Satellite colour event-driven sampling for toxins Pigments	- daily - as required event-driven sampling for toxins	A+G	A, C, D, E	Links to human health programme (Cefas)
Overturning circulation (AMOC) shut down		As RAPID-WATCH	continuous	I) North Atlantic	A, B, D	✓ if NERC RAPID-WATCH maintained (>10 years) - Marine Scotland, CEFAS

Nuclear Accident: Radioactive leakage (plans for coastal power stations go to "Planning"?).	Incident response	c.f. oil and chemical spills: currents, radiation count, sampling	Irregular as needed & measurements to constrain operational NCOF models	Localised UK	C, D, E	No current observation which would be able to monitor this. (CEFAS may be doing something. NERC themes Human Health and Pollution – but not to deal with event)
Baseline data	Do we have the long term data to provide baselines, for comparison after an event?	See Climate Change for data needed to provide this				
Biological Diversity, Ecosystems & Services[i] (Impacts of environmental change on biological diversity, ecosystems and ecosystem services)						
Biodiversity	Do we have adequate methods to describe / measure biodiversity, its distribution[4], function?	Plankton types Benthic/ sediment Impacts of fishing Various 'indicators' Habitat maps Species and habitat composition, abundance, area, range, condition (many variables)	Density and frequency of sampling may be a research issue	A, G	A, B, D	Oceans2025 (L4, E1 plankton types; AMT; SAHFOS – CPR x 20+) SAMS deep-sea benthic diversity (not ongoing?) Dove sites M1, P, Z SEPA Forth + Tay UWW (plankton); Integration +testing needed CEFAS – impacts of fishing

[4] Distribution of functional group rather than species range, which is covered under "Marine Species"

	Is the changing environment impacting biodiversity? Can we predict and mitigate effects of biodiversity change? (Do we always want to mitigate effects of biodiversity change? Is a decline in biodiversity always bad?)	As above		H for prediction	A, D	Oceans2025 MBA MarClim (ended) project and MECN Basic lack of knowledge about biodiversity status Natura 2000 – monitoring of MPAs e.g. SAC, SPA, etc JNCC, NE, SNH, CCW
	What is the role of biodiversity in ecosystems[5]?					
Habitat	As Habitat underpins marine ecosystem goods and services there is a need for better understanding and therefore more defined: - description - mapping - Monitoring change.	Mapping of types, e.g. sediment type, bed properties, wave and current strength, temperature cycle, salinity "cycle" or range, sea-level range as below		I – NE Atlantic A-G	C, E, B	BAS in Antarctic, Oceans2025, SAHFOS, Defra MF and ME Basic research (BEF) needed MESH (for mapping)

[5] This question may require research to understand the role, but observations to determine whether the role is changing with a changing environment.

	Are our marine habitats healthy (including the benthos)	Bathymetry marine meteorology, sea level and land uplift temperature salinity, waves, currents, sediment properties, nutrients DO, chlorophyll, plankton, biomass, solar radiation	Bathymetry @ 1 km wind @ 50km, 1d, 1-2 m/s sea level: x 30-50+GPS + alt. *or* x 100s+GPS @ monthly mean, 1 cm T(z) locally, 10d, 0.2°C nutrients 10-100km	UK & particular localities Sea level: global	B, C, D, E	MCA/UKHO bathymetry, EA lidar AFBI, Natural England, NIEA & SNH (SSSIs, many SACs, SPAs) NTSLF, POL & IESSG GPS + gravity AFBI coastal (10 moorings: T, S, Fl; some turbidity, DO), Sea Loughs (ecosystem), AFBI, MS-S & Cefas Nephrops burrows Bottom trawl surveys Cefas/CCW Burry Inlet cockles CEFAS CSEMP programme Cefas coastal T, Smart buoys (6??: T, S, Fl, SPM, light, Fl, DO, nutrients); SAMS subtidal T (x2); IoM T, S, DO, nutrients, Chl, plankton; L4, E1 T, S, nutrients, Chl, benthos ; MS-S coastal T, S, nutrients, Chl, plankton, SEPA nitrates; MS-S monitor disturbance; benthic surveys around fish farms (CA Regs for SEPA); WaveNET / Coastal Wave Network; CCW monitor Cemlyn SAC condition, intertidal rock, benthic subtidal sediment, Pen Llyn ar Sarnau SAC horse mussel reef , benthic rock at 4 SACs, Cardigan Bay SAC bottlenose dolphins; Skomer MNR Dove M1, P Irish Sea Observatory - occasional NIEA sublittoral survey, macroalgae, benthic monitoring Shetland – Sullom Voe BGS sea-bed samples SAMS deep-sea benthic diversity Lack of Sea-bed mapping

Non-indigenous species	-What is the impact of non indigenous species on native species? -Which areas are most impacted?	Detection / ID (DNA/barcoding?) Species monitoring	Mainly ad hoc WFD/ SAC	A-G, H. Range change	E, C, B, D	No targeted monitoring Economic impacts needs quantifying
Valuing environmental services						Oceans2025 Basic research needed
Fish	Are fish (stocks and the fish themselves) healthy? Are there appropriate age and size distributions within the stocks?	Body length, condition, otolith Recruitment success, egg surveys	As per sampling programmes. For ICES assessments	UK A, G	B, C, D, E C, D	Sustainable Marine Bioresource (not observational)s; AFBI transects 54N, Herring + juvenile fish + nephrops + scallops surveys; MS-S scallops; MBA West Channel; Cefas, MS-S, NIEA Bottom Trawl / Young Fish surveys; MS-S North Sea + W Scotland pelagic fish, deep-water fish, Rockall haddock, FES Mackerel eggs triennial survey Beam Trawl surveys ICES Cefas Solent Bass + oyster, Thames Bass + Herring; fish disease monitoring, shellfish, discards
Turbidity	- Are turbidity levels acceptable? - Are the levels changing (thus affecting primary production?)	Total SPM Light attenuation (secchi disk, Satellite remote sensing – MODIS)	As, where and when habitat interest	A-G	B, C, D, E?	Ferrybox, VOS R/S colour, Smart buoys (6??; SPM) Coastal (Irish Sea) Observatory
Sedimentary Processes /Morphology	Process research experiments. Mapping on time-scale of changes	Bathymetry, total SPM, seabed forms	Years-decades	A/F	A, B, C, D	MCA/UKHO bathymetry, EA lidar Coastal (Irish Sea) Observatory R/S colour, Smart buoys (6??; SPM)
Plankton	Biomass Species composition	Nutrients, Chl (in situ and R/S) – not just Chl – pigment	To capture production Sections or @	A, G; H	B, D	SAHFOS (CPR on VOS x 20+); AMT; PAP site; Ferrybox MS-S T, S, nutrients sections (x3), Calanus;

		markers for species/type identification cf HABs Plankton	O(100 km) ~ continuous locally (kms) because patchy			SEPA Forth + Tay UWW (nutrients, Chl, plankton); Loch Creran UWB Menai Strait T, S, nutrients, Chl L4, E1 T, S, nutrients, Chl Dove Z Coastal (Irish Sea) Observatory R/S colour EA +SEPA for WFD Lack of data on coastal waters phytoplankton variability
Ecosystems	Do we have a Healthy and resilient marine ecosystem?	~ "Biodiversity"		UK	B, C	MS-S – Stonehaven + Loch Ewe; Buzzard + Beryl oilfied impact
	Can we improve our understanding of ecosystem functioning?	Information needed on functional role of species/communities[6]		local	A, B, D	Current knowledge very poor. Benthic studies at L4
Marine Species	What is the status of our Seabirds, seals, turtles, cetaceans?	Surveys of species of interest	Seasonal All areas of interest	UK	B, C, D Some are E	BTO & WWT wetland bird surveys incl. geese and swans, JNCC seabirds, Natural England (Wash), SAMS rocky shores; Shetland Seals: SAMS, SNH (several isles), SMRU, NIEA, CCW, National Trust at Farne Islands, Lincs. Wildlife Trust at Donna Nook Cetaceans: SMRU, strandings (IOZ) CCW monitor Carmarthen Bay scoter Cefas/CCW Burry Inlet cockles (food) VOS
	How will species ranges change in the future (with Climate change)?	Covered by WFD/SMFD surveys? Needs test of predictive models cf. existing data	Historical species distributions and relevant climate indicators	A, G, H	B, D	

[6] This may need process research experiments rather than prolonged observations.

Marine Protects Areas	How effective are MPAs?	Monitoring and assessment	As Habitat (healthy?)	A, G	C	Met Office drifting buoys Natura 2000 condition amendments
Coastal squeeze	What is the extent of habitat loss and which type(s) are most effected/vulnerable? Is the rate of loss changing?	Habitat mapping as above, plus intertidal area	High and low water line @ 1-2 years	A (F)	B, C	
Microbes (fundamental for eco-function)	What is the role of microbes and is this function changing?					
Cause + effects measurements at key locations observations	Key Questions are needed to determine the observations required – as questions are not stated – experiments may be required **before** sustained observations.					
Climate Change (variability & Climate Change: Challenges in Earth System Science)						
Predictions	Can we make fine-resolution regional predictions for decision-making?	Bathymetry ***Otherwise this is model R&D (needing historical test data) and scenario definition***		Some global as context	B, C, D	MCA/UKHO bathymetry JCRP, Oceans2025
	Can we validate climate change predictions	Data to test hindcasts		A, D		

Detecting Climate Change	Can we detect Climate change "against" natural and anthropogenic variability: temperature (warming or cooling), salinity, waves, sea level (rise) and land uplift, circulation	Marine meteorology Ecology Nutrients sea level (GLOSS), Long-term data Temperature Argo or equivalent profiling, hydrographic sections (shelf seas) and at slopes/edge Salinity currents, waves ice	Wind @ 2°, 1-2 d, 0.5-1 m/s (& ≡^{nt} dir) Heat flux @ 2° x 5°, 1 mo, 10 W/m^2 net Precipitat'n @ 2°x5° daily, ??5?? (GOOS) cm/month sea level: x 30-50+GPS + alt. *or* x 100s+GPS @ monthly mean, 1 cm Sea level anomalies @ 100-200 km, 10-30 d, 2 cm SST monthly @ 10-100 km *Insitu* SST @ 500km, 1 mo, 0.2-0.5 °C T(z), 100km 1mo, 0.2°C Sections quarterly SSS @ 200km, 10d, 0.1 accuracy S(z) @ 200km+, 30 m in z, monthly, 0.01 accuracy ice volume, thick' @ 500km, 1mo, 30cm	UK and N Atlantic	B, D, A	GLOSS/PSMSL/tide gauges (NTSLF); altimetry; POL & IESSG GPS + gravity RAPID-watch (bottom pressure incl. WAVE; moorings, sections); SAMS Svalbard, Wyville-Thomson Ridge; R/S for SST, ice, winds, sea level, waves Argo COML / HMAP VOS temperature, salinity Drifters / Met Office drifting buoys GCOS hydrography Met Office MAWS, Mike (NOCS), WebMET (22 oil/gas rigs) CARBON-OPS Oceans2025 (Drake, AMT, CO, PAP, Ellett line, Tiree Passage, E1, L4, SAHFOS – CPR x 20+, ..), Dove M1, P, Z CP2 data sources, Cefas Denmark Strait overflow array MS-S JONSIS (N North Sea) line, Faroe-Shetland Channel sections (Nolso-Flugga + Fair Isle-Munken) and current moorings Ferrybox Shelf-sea current moorings, HF radar AFBI coastal (10 moorings: T, S, Fl), transects 54N + Irish-Celtic Bottom Trawl surveys Cefas coastal T, Smart buoys (6??: T, S, Fl, light, Fl, nutrients); SAMS subtidal T (x2); IoM T, S, nutrients, Chl MS-S coastal T, S, nutrients, Chl UWB Menai Strait T, S, nutrients, Chl WaveNET / Coastal Wave Network / Channel

		pCO_2 DIC, pH, TA Chlorophyll Oxygen	surface pCO2 @ ??25-100 km, daily, 0.2-0.3 µatm?? (GOOS) Full depth sections			Coastal Observatory R/S for SST, ice, winds, sea level, waves; Assimilative models
	Do we have sufficient baseline information to be able to detect relevant changes?	Whatever are "relevant" variables	30 year scale datasets (historic and future)	UK (A) Europe (G)	B	MECN
Climate Sensitivities	Do we understand climate system sensitivities and the controlling processes?	Needs measurements to test models[7]		H	A, B, D	RAPID, DIMES, JCRP, Oceans2025 MBA MarClim project and MECN
Forces and Feedbacks	***To answer questions fully process studies, model tests, experiments and observations will be needed***	Trace gases? Other than CO2	A few places seasonally	H (a few)	A, B, D	QUEST, IODP, SOLAS, Ocean Acidification (NERC AO), Methane network, Oceans2025
Polar Regions	Do we understand the role of polar regions on the marine climate around the UK and wider seas and oceans?	***This would involve process research, as "Climate Sensitivities" to gain an understanding and longer term observations to ascertain change***		A, H	A, B, D	BAS, Oceans2025, NERC considering Arctic R/S ice, SST SAMS, University Sector CEFAS and Marine Scotland (Aberdeen) NERC intent Ice sheets and sea level rise programme
Abrupt Change	Can we sufficiently Fore-warn others about abrupt change?	As "Predicitons" at top of "Climate Change" here	As "Predicitons" at top of "Climate Change" here	As "Predicitons" at top of "Climate Change" here		QUEST, Oceans2025

[7] The system is too complex for measurements of all direct sensitivities. Process research will also be required to answer this question.

Scientific & technological advancement/ innovation (Stimulation of Scientific & Technological Advance and Innovation)						
Models	Can we validate developing models for prediction of future marine state and best estimates of current state (in conjunction with data)? Is there adequate provision of appropriate data to validate models?	Bathymetry Often the answer to the questions here is “no”, but need to categorise by what is being predicted or estimated, i.e. refer back to relevant issue(s) above		UK(A) Global (H)		MCA/UKHO bathymetry, EA lidar Oceans2025 model development, Developing data assimilation Coastal (Irish Sea) Observatory
Remote Sensing	How can we use remote sensing, instruments, platforms to enhance monitoring/information/knowledge?	Plankton blooms from satellite for spatial distribution Ships of opportunity can provide in situ “truth”	Daily	A+G	A,B,C,D,E	Oceans2025, Autosub6000; NERC R/S intent; NCEO; sensor network pilot? NEODAAS et al. R/S for SST, ice, winds, sea level, waves, colour
Intelligent Sensors	(catastrophic) event sampling					Oceans2025. Smartbuoys (CEFAS)
Real time monitoring			Constantly	UK		CEFAS, EMECO (Wavenet), L4
Molecular Biology	Improvement of Molecular biology methods for characterising biological diversity – DNA barcoding, micro-arrays					
Sonar	Can we use Sonar for more applications?					
Merchant shipping	Could we use merchant shipping to make	More FerryBox variables	Constant – good spatial coverage in			New kits for ships of opportunity. New satllites/sensors

	observations and improve coverage?		some areas?			
Reanalysis	Can we improve Reanalyses availability (of the NOAA type?)	Need to keep updated and curated (data centre)		H	B, D	ERA-40 via BADC
Ecosystem Functioning	Can we improve technology/methods to monitor ecosystem functioning?					
Others						
Indicators	Can we develop Indicators, which are at a varied but generally early stage of development, further? (Targets against Good Environmental Status)	Needs research with existing data. May imply some enhancement but must be realistic. Maybe a call for scenarios but only outcome suggests (more) observations		A, G	B, C, E	
Accuracy	Can we improve sufficient accuracy? This is important and often lacking; unreliable data are a cost without benefit	This is generic question and need to be asked with reference to each issue; not a stand-alone issue				

Modelling: Data Assimilation	Can we use experiments assimilating varied data in models to find the value of various measurements, density, frequency, extent, latency?	***The answer to this should be Yes. Experimental results would inform what sustained observations are required.***				
Integration	Model development. Not a call *per se* on sustained observations.					
Microbiology knowledge	See microbes					
Genetics	What is the relationship to species range / distribution	Map species composition	Map, occasional	H	A	
Ecosystem (interactions)	Can we define variability in the ecosystem?	Baseline issue				
	Can we identify spatially relevant relationships between activities and pressures and how they impact habitats and species?	***Is this more of a research issue than one requiring sustained observations?***				
Cumulative impacts	Lack of data and techniques to assess		Localised, time-series	Localised, UK	A, B, C, D, E	

Issues raised but thought to be outside of the UK-EOF scope/Marine Environmental Domain						
Carbon Trading	How will Carbon trading – export of carbon footprints e.g. to China impact emissions?					Not thought to be a marine issue. Atmosphere – Carbon Emissions Trading??
Imports	What is the impact of Global trade on the UK food supply/availability? **Economic monitoring**	Not marine – but could be related to shipping volume?				Socio-Economic observations are not currently in scope for the UK-EOF
Human Health and Wellbeing	What is the impact of change on environmental goods and services that affect marine communities and economic activities? (e.g. as a result of movement of food species, ocean acidification, sea level rise, extreme events, coastal flooding…)	NHS statistics, population movement, infrastructure development e.g. barrages, run-off/rainfall (pollution), value of human life. Unclear if *marine* measurements required	Coastal and island communities			Social economic information and human health are currently out of scope for the UK-EOF. The UK-EOF does cover the environmental aspects, which may affect human health e.g. impacts of rainfall/pollution on marine life, which may be eaten by humans.
Abatement technologies	May need research before technologies can be put in place?					

In general we may not expect to monitor currents and ocean interior variables (for example) with fine resolution in space and time, even if required. We will have to rely on sparse data constraining model estimates.

Wave conditions are known and forecast globally. However, locally and especially in shallow water and near coasts, waves need some transformation from the large scale to be established.

Observations				Optimised Requirements				Threshold Requirements			
Code	application	variable	type	Horizontal scale (km)	cycle	time	accuracy	Horizontal scale (km)	cycle	time	accuracy
A	Mesoscale variability	Sea-surface topography	input	25	7 days	2 days	2 cm	100	30 days	15 days	10 cm
B	Large scale variability	Sea-surface topography	input	100	10 days	2 dats	1 cm	300	10 days	10 days	2 cm
C	Mean sea-level variation	Sea-surface topography	input	200	decade	10 days	1 mm/yr	1000	decade	10 days	5 mm/yr
D	Absolute circulation, heat transport	Sea-surface topography	input	100	N/A	N/A	1 cm	500	N/A	N/A	5-10 cm
E	Geoid estimation	geoid	base	100	N/A	N/A	2 cm	500	N/A	N/A	1 cm
F	Wind forced circulation	Wind field	input	25	1 day	1 day	1-2 m/s, 20º	100	7 days	7 days	2 m/s, 30º
G	Ocean-atmosphere coupling	Sea-surf temperature	input	10	6 hrs	6 hrs	0.1º K relative	300	30 days	30 days	1º C
H	Ocean forcing	Short – wave irradiation	input	200	1 day	1 day	15 W/m^2	500	7 days	7 days	20-30 W/m^2
I	Circulation & water transport	salinity	input	200	10 days	10 days	0.1 psu	500	10 days	10 days	1 psu
J	Ice-ocean coupling	Sea ice cover	input	10	1 day	3hrs	2%	100	7 days	1 day	10%
K	Upwelling to recirculation	Ocean colour	input	25	1 day	1 day	2%	100	1 day	1 day	10%
L	Sea state prediction	Significant wave height	input	100	3 hrs	3 hrs	0.5 m	250	7 days	12 hrs	1 m
M	Sea state prediction	Period & direction	input	10	1 hr	2 hr	½ sec, 10º	30	6 hr	4 hr	1 s, 20º

Table: UK GOOS Strategy Plan table (from GOOS) regarding ***remote sensing requirements***. This table is separate because UK control of implementation is only via international consortia; on time-scales the data from remote sensing are essentially a "given".

Parameter	Horizontal Resolution (des, min)	Observation Cycle (des, min)	Availability (des, min)	Accuracy (des, min)
Sea Surface Temperature	0.1, 1 km	3, 6 hr	1, 3 hr	0.2º, 0.5ºC
Wind speed & direction	0.3, 100 km	1, 6 hr	1, 3 hr	1, 2 m/s 10º
Sea surface height	1, 15 km	1, 10 day	1, 3 hr	4, 6 cm
Surface wave height & direction	1, 10 km	3 hr, 1 day	1, 3 hr	0.2 m 5º, 10º
Salinity	1, 25 km	1, 7 days	1, 3 hr	0.1, 0.3 psu
Currents	0.3, 5 km	1 hr, 1 day	1, 3 hr	3, 10 cm/s
Stream-flow	1, 10 km	1 hr, 1 day	1, 3 hr	10%, 30%

Precipitation	1, 15 km	1, 8 hr	1, 3 hr	0.5, 2 mm/hr
Ice cover	50, 100 m	6 hr, 1 day	1, 3 hr	100, 200 m
Phytoplankton pigments	100, 500 m	1.5, 3 hr	1, 3 hr	20%, 30%
Total suspended matter	100, 500 m	1.5, 3 hr	1, 3 hr	30%, 40%
Coloured dissolved organic matter	100, 500 m	1.5, 3 hr	1, 3 hr	30%, 40%
Optical properties including PAR	100, 500 m	1.5, 3 hr	1, 3 hr	10%, 20%
Chlorophyll fluorescence	100, 500 m	1.5, 4 hr	1, 3 hr	30%, 40%
Aerosol properties including AOT	100, 500 m	1.5, 4 hr	1, 3 hr	10%, 20%
Nutrients	10, 100 km	1 day, 1 mo	1, 7 days	10%, 30%
O2 & pCO2	10, 100 km	1 day, 1 mo	1, 7 days	10%, 30%
Slicks, films, sea surface roughness	25, 50 m	3 hr, 2 day	1, 3 hr	50, 100 m
Bathymetry	30, 50 m	2, 24 day	4 hr, 1 day	0.1, 1 m depth
Shoreline position	1, 5 m	15 day, 3 mo	1, 7 days	1, 5 m
Habitat maps	5, 20 m	15 day, 3 mo	1, 7 days	

Table: UK GOOS Strategy Plan table (from GOOS) regarding ***coastal ocean sampling requirements***. This table is separate because many values for resolution are unfeasible and probably unnecessary given some ability for models to assimilate and then interpolate between observations.