

## Summary reports from Technology breakout groups

Four parallel discussion sessions each of ~1 hour were held on the morning of 12 May, to consider forward-planning issues relating to marine environmental technology and its applications. The groups were:

- Platforms and sensors (*Chair: John Huthnance, NOC*)
- Telemetry and tracking (*Ailsa Hall, SMRU*)
- Future modelling and data gathering needs (*Adrian New, NOC*)
- Molecular biology and technology (*Jack Gilbert, PML*).

Sessions were introduced by 2-3 short presentations (abstracts in ASM handbook, to be online at [www.Oceans2025.org.uk](http://www.Oceans2025.org.uk)). Summary notes for each group are below, with headings that match the key issues suggested for discussion. Group rapporteurs/report authors are given at the end of each section.

### 1. Platforms and Sensors

Short presentations were given on “Autosub6000 trials and science results, and an introduction to Autosub long range” (Steve McPhail, NOC); “From MYRTLE I to MYRTLE X” (Stephen Mack, NOC); and “Dense *in situ* biogeochemical sensing: innovation, progress and the future” (Matt Mowlem, NOC).

#### 1.1 Gaps and needs

- Space-time coverage may need to include the bed (possibly rough), water column, and the sea surface, all with long-term autonomy.
- There are present limits to user-led vision, e.g. GOOS (Global Ocean Observing System) is somewhat physics-dominated, other areas still under development, other variables could be better exploited. EU MSFD (Marine Strategy Framework Directive) is a driver.
- We need more (denser in time and space) biochemical measurements, and better measurements (e.g. chlorophyll is not properly represented by fluorescence) involving more sensor development, as in Matt Mowlem presentation – still a goal of cheap and practical measurements for many variables.
- There is difficulty in bringing many samples to the surface – water-sampling is a gap.

#### 1.2 Are Oceans 2025 researchers using the best tools available?

- Use NERC (and other) research ships as demonstrators for the value of Voluntary Observing Ships, and fully employ their measurement capabilities on all cruises.
- ESFRI (European Strategy Forum on Research Infrastructures); see under “Priorities”

#### 1.3 How will technology advances on 5-10 yr timescale change marine science?

- It was suggested to add other variables to Argo profiling floats (e.g. pCO<sub>2</sub>, although not with present sensors; others too) which is of proven benefit for sub-surface temperature and salinity fields for models.
- Extend use of Ships of Opportunity / Voluntary Observing Ships (CarbonOBS, CPR, FerryBox are good existing examples); smaller autonomous sensors help.
- Integrate the elements of state assessment for forecasting (sensor networks, models, Earth Observation, data protocols) to form an optimal monitoring system. Study cost-effectiveness of platform choices. (JMH note: use model experiments to optimise the array).

#### 1.4 Priorities/new ideas for NERC Technology theme?

- A call for “magic energy” suggests research into enduring or *in situ* energy sources.
- Biogeochemical sampling as emphasised above.
- European Infrastructures may give scope to add funding; e.g. fleet of AUVs, deep platforms. (Phil Weaver is on the panel). Cases need a well-developed business plan. NB Argo was developed by a well-organised community and even though floats are affordable individually by single countries the concept is essentially international for global coverage.
- Means to obtain vertical profiles from (moving) ships? [“coke can” oceanography – drop from ship with telemetry back – unclear feasibility].

The above suggestions (under all the headings) need a plan and champion groups with user-involvement; e.g. as being developed (?) for ICOS (Integrated Carbon Observing System; coordinated European CO<sub>2</sub> measurements and data analyses).

### 1.5 Constraints on commercial exploitation

- Limited marine market – who will buy? – budgets are limited. Improve prospects by working with industry from an early stage in development, demonstrating links to meeting legislative requirements, and by seeking other markets (e.g. fluorimetry for chlorophyll applied to whisky and tyre manufacture). EU MSFD may widen the market (c.f. water and WFD). Link “marine” and “maritime”.
- Developers of new marine technologies are time-constrained; their priorities are likely to be other than commercialisation.
- Developments take time, and both parties (researchers and industry) need patience.

*John Huthnance (NOC)*

## 2. Telemetry and Tracking

Presentations to introduce this topic were given on “Long-term GPS tracking of pelagic fish” (David Sims, MBA) and “Technological advance in marine mammal science” (Bernie McConnell, SMRU).

### 2.1 Gaps and needs?

To some extent this depends on the research drivers. For example, this could be investigating the impact of marine renewable energy on marine organisms; using animal-borne sensors to measure oceanographic parameters or research purely driven by curiosity or by the need for education and outreach. One current major driver is the Marine Strategy Framework Directive with its requirements for spatial planning, determining good environmental status and the designation of conservation areas.

There is a clear need to link the science outputs to the policy needs. How this is achieved is likely to be species specific. For marine mammals the Special Committee on Seals provides advice to UK and Scottish government on the management of seal populations. This allows stakeholders and policy makers to talk directly to scientists about their needs and questions on an annual basis. Other organisations that similarly deal with issues relating to cetaceans are the Joint Nature Conservation Committee and the International Whaling Commission.

Within the fish and perhaps other communities policy makers appear to rely on well established links with selected organisations (such as Cefas links to Defra). There is a need to improve the dialogue with other labs such as MBA and perhaps PML. Some information on pelagic fish does feed into the Tuna Commission, but stock assessments for these larger species are limited.

There is a continuous need to reduce tag size and thus the potential welfare impacts of telemetry tags on the individual animals being tracked. Further research into fish tagging mortality is needed. Devices should have minimal impact on the study subjects, since the overall conclusions of the research could be affected. Designers should engage with hydrodynamicists to produce the most streamlined instruments. Information on individual condition (including death) and performance may also be inferred from the behavioural data being collected and relayed. Modelling the joint processes of tag failure or animal mortality permits true mortality to be estimated.

There is also a need to engage more with the public. The movement and tracking data collected from these larger marine species are of great interest to the public (e.g. the Great Turtle Race and the Tagging of Pacific Pelagics). We as a community do need to do more but we are often limited by time and resources. Press releases relating to the publication of scientific papers are often the main method for disseminating results. It was noted that much more could be achieved through closer associations with the marine aquaria industry within the UK.

As more detailed data (such as 3D dive data using accelerometers integrated into GSM or Argos tags) becomes available, there is a need to become more inventive about how these data are relayed ashore. Such very large datasets can saturate even GSM bandwidth. One solution is to restrict the collection of such detailed information to periods when animals are in an interesting area. In addition the raw data can be processed and compressed on board to reduce transmission overheads.

For other species, such as pelagic fish, the tags that currently provide this kind of detailed dive data are ‘loggers’ that must be retrieved, which for the majority of species is not possible. This means their utility (particularly for policy related questions that require data to be collected in specific areas) is limited.

## **2.2 Are Oceans 2025 researchers using the best tools available?**

Yes. This is exemplified by the uptake of new technologies as they become available (e.g. moving from Argos to GSM and using the Fastloc GPS location system). We all want to know where the animals are, how they use the areas, why they are there and how they will react to changes in their environment and will use the best available technology to do this.

## **2.3 How will technology advances on 5-10 yr timescale change marine science?**

Examples here include improvements in battery technology, increasing the lifespan and decreasing the size of the instruments; bandwidth availability to allow increasing volumes of data to be relayed and improvements in antenna design.

## **2.4 Priorities / new ideas for the NERC technology theme?**

The interaction between scientists and engineers is critical in the development of new technologies and initiatives crossing between NERC and EPSRC scientists have arisen. However, in some situations the NERC scientists need engineers to do a “job of work” rather than to publish independent high impact papers. This may not be attractive to EPSRC. Indeed many of the developments needed are not technology limited, but are money limited. A priority for the theme would therefore be to encourage inter-disciplinarity and facilitate the inclusion of engineers and computer scientists at the level required by the specific project.

A related issue is also the wider problem of identifying small manufacturers willing to provide small scale products at a cost-effective price. Often larger companies require minimum orders.

The group would also like to encourage the inclusion of an animal-borne sensor and animal telemetry initiatives in the new technology theme to encourage interchange of ideas and information perhaps initially through a workshop to be followed by funding for animal-specific projects.

## **2.5 Constraints on commercial exploitation?**

The main constraint here is the size of the market. We should encourage engineers to exploit their developments where there is a clear need. The proof of concept idea should encourage engagement with commercial companies at an early stage.

*Ailsa Hall & Bernie McConnell (SMRU); David Sims (MBA)*

# **3. Future Modelling and Data-Gathering Needs**

Introductory presentations were given on “Large-scale ocean modelling with adapting unstructured mesh methods” (Matt Piggott, Imperial) and “Creating a legacy- new insights from new hydrographic sections in the North Atlantic” (Brian King, NOC).

## **3.1 Gaps and needs**

- Better coordination is needed between the observational and modelling communities. In particular, increased use should be made of ocean circulation models with embedded models of biogeochemistry to enhance the interpretation of important biogeochemical quantities such as carbon. Time varying inverse models also need to be developed for biogeochemical variables such as carbon.
- The use of gliders in the UK should be better coordinated. There was discussion as to whether or not the technology is mature enough for a central facility to be operated by the NMEP.
- There is currently uncertainty as to how the GO-SHIP programme of long hydrographic lines should be maintained into the future.
- Moorings need to develop real time telemetry, and additional sensors (i.e. for nutrients) should be developed for the Argo profiling floats.
- A mass conserving ocean model is needed for global sea-level impact studies: this should include downscaling for regional studies and the gravitational interaction between the ocean and ice sheets.
- A new ecosystem modelling framework should be developed to bring together the community . This should include coupling to higher trophic levels (eg fish) and societal impacts.

## **3.2 Are Oceans 2025 researchers using the best tools available?**

- Oceans 2025 researchers currently use state-of-the-art modelling and observational systems. No better tools were identified that are not currently in use.

### 3.3 How will technology advances on 5-10 yr timescale change marine science?

- Long range missions with Autosub are expected to become available, and the development of new sensors for Argo profiling floats. These will reduce the need for ship-based observations to some extent but not remove it.
- There will be a continuing need for ship based observations to provide high quality datasets (e.g. Argo calibrations downgrade with time). There is also a continued need for a range of observational platforms including fixed observatories.
- New computing architectures are moving to become massively parallel eg up to  $10^6$  processors, with limited memory and limited bandwidth per processor. This requires a new computational approach to achieve scalability, eg new dynamical cores for the ocean. Such a project would fit with the mission of the Hartree Centre (the new high performance computing facility at Daresbury) for the development of the next generation of codes.
- New models will emerge which seamlessly span the deep ocean to the shelf and coastal regions. This requires multi-scale/ multi-grid modelling which will foster closer working throughout the ocean modelling community.
- Uncertainty as to the format of new generations of computer architecture in the future means that a flexible programming approach will be needed.

### 3.4 Priorities/ new ideas for the NERC technology theme?

- Several specific priorities are outlined in the “gaps and needs” section above.

### 3.5 What are the constraints on commercial exploitation?

- Model output and observational data are being provided free of charge and this should continue. For example, the EU MyOcean project provides model products, and the PAP (Porcupine Abyssal Plain) observatory observational data, on this basis, and model codes are open access.
- There is a need for better mapping of, and engagement with stakeholders and identification of new stakeholders for modelling and data products. This will help to generate new markets, and to bring new sensors and products to the users.
- There is a need to better educate stakeholders so they know what we can provide; and a corresponding need to be educated by the stakeholders to find out what they want – a two way education process. Perhaps each NERC centre should have a specialised post to manage such relationships and to provide training as needed.
- There should be an emphasis on coastal, estuarine and fjordic systems as most stakeholders apply their modelling to coastal issues. Links should be maintained with these stakeholders (without encroaching on their territory) in order to provide them with enhanced modelling capability when it becomes available.

*Adrian New (NOC), Mike Ashworth (STFC Daresbury Laboratory)*

## 4. Molecular Biology and Biotechnology

Introductory presentations were given on “Transcriptomic response of different *Emiliana huxleyi* isolates to elevated seawater pCO<sub>2</sub> conditions” (Frederic Verret, Essex/MBA) and “Genomics of host-pathogen interactions in marine algae” (Claire Gachon, Laura Grenville-Briggs & Frithjof Küpper, SAMS; Pieter van West, Aberdeen).

### 4.1 Gaps and needs?

The biggest gaps are in the approaches to systems biology, understanding the big picture and pursuing the links between the different components.

Systems biology and traditional community ecology have a lot in common, and this needs to be understood so that ‘omics technologies [(meta-)genomics, (meta-)transcriptomics, (meta-)proteomics, (meta-)lipidomics, (meta-)metabolomics, etc] can be leveraged against the relevant questions.

We need more bioinformaticians – that is people who are extremely computer literate and also have an interest in biology. These people are absolutely necessary to fill the gap between ecological theory and the vast datasets we can now produce. Data handling is essentially the biggest gap at the current stage.

There needs to be more education regarding the power of these tools, and better exemplars of the technical capability.

BBSRC is better sourced to handle these technical issues, e.g. algorithm development, systems biology at the cellular level, etc. Needs to better cross over with NERC so that this can be scaled up to incorporate whole communities – the META-CONCEPT.

One way to bridge the gap is to define a better link between taxonomy and molecular biology. This is fundamental for the Eukaryote ecologists among us whom require taxonomy far more as a population-driven concept. For microbiologists it is less essential as the species concept is far more precarious in organisms which such high DNA/genomic information flux – however, educating people about the pan-genome concept could start to have significant relevance for microbial eukaryotic biology as there seem to be far more species of eukaryotes in the micro-sphere than in the macro-sphere, and they may behave far more like bacteria in terms of the pan-genome and virus-mediated DNA flux.

#### **4.2 Are Oceans 2025 researchers using the best tools available?**

On the whole yes, the range of activities are utilising the latest technology. Although we still struggle behind the US and China. Several key European initiatives in FP7 could see this change, but on the whole NERC will need to address this issue if they are to keep the UK science community globally relevant.

#### **4.3 How will technological advances on 5-10 yr timescale change marine science?**

The exa-scale concept of systems biology is becoming the norm. This will make the data we produce – so called meta-omics data, far more relevant. We can currently link population genetics to single cultures – this needs to be scaled up and related to the environment from which these organisms come from, the community from which they derive.

Sequencing, both protein, nucleic acids, metabolites and lipids, will play the most major role in driving forward marine science, but we need to ask how much sequencing is enough. When should we stop, because in theory while there is an end, the constant change and flux of any genetic component (for example) in an ecosystem is so rapid and great as to make any single time point study difficult to validate. Hence we need to ask ecologically relevant questions that take into consideration this flux. Biogeographic and temporal studies are essential to understand the flexibility of the ecosystems

#### **4.4 Priorities/new ideas for the NERC Technology theme?**

BIOINFORMATICS, BIOINFORMATICS, BIOINFORMATICS. The technology is now relatively cheap, but people who can make sense of vast unending datasets, or at least provide mechanisms through which these datasets can be examined by the biological experts in our community, are vastly expensive. They are also hard to come by.

NEOMICS (NERC omics strategy; [www.nerc.ac.uk/research/themes/biodiversity/events/omics-strategy.asp](http://www.nerc.ac.uk/research/themes/biodiversity/events/omics-strategy.asp)) was brought up by Jack Gilbert (as an expert working panel member for the initiative). This activity will hopefully produce a document to rationalise the UK needs and requirements, e.g. should we have a bioinformatician in every lab to help out with data on hand, or will a centralised resource be sufficient? Ideally we need both. Local support is vital for individual researchers and will enable the production of significantly better datasets.

#### **4.5 Constraints on commercial exploitation?**

Data mining issues – this is the bottleneck and again it is driven by a lack of bioinformatic experts to help us appropriately interrogate the datasets. Most discoveries are serendipitous – so in a way shot-gunning can be useful as tool to uncover novel biodiversity and hence novel enzymes, lipids, metabolites etc.

Ideally we also need to know what industry wants, they usually have big IP issues and hence a lot of this research will need to be performed with NDAs (non-disclosure agreements) in place. This exemplifies the need for an in-house bioinformatician in each facility.

The BBSRC-led IBTI activity (Integrated Biorefinery Technologies Initiative, with EPSRC and industry) is an ideal example of how linking industry with science can be productive. Hence NERC needs specific calls to exploit environmental omics data for the benefit of industrial development and UK plc.

*Jack Gilbert (PML)*