INTRODUCTION

A strategy for UK marine science for the next 20 years

This Theme Issue arises from a symposium on the future of UK marine science, sponsored by the Challenger Society for Marine Science and the UK National Committee for the Scientific Committee on Oceanic Research (SCOR) and held at the Royal Society premises in 2011. The speakers were chosen to represent young and mid-career British scientists and different facets of marine science and technology. This issue presents the written versions of their visions for the future of marine science, technology and science policy in the UK.

At the turn of the millennium, a similar exercise was conducted globally by the SCOR, the Intergovernmental Oceanographic Commission of UNESCO and the Scientific Committee on Problems of the Environment. They commissioned a group of marine scientists to project global trends from 2000 to 2020 in a volume called Oceans 2020: Science, Trends and the Challenge of Sustainability [1]. To achieve their task, the group reviewed major advances over the previous 20 years and used this information to project forward for 20 years. Clearly, unexpected discoveries, such as the existence of deep-sea thermal vents and the associated chemosynthetic organisms, cannot be anticipated, but trends can be projected forwards. The group concluded that all the major advances in marine science were made possible by developments in technology. Examples of these include satellite oceanography made possible by sensors on satellites, developments in faster and more powerful computers to handle global ocean datasets, profiling floats, micro- and nano-sensors, molecular technology, etc. These have revolutionized oceanography and shown that, collectively, technology leads the science. This does not mean that there is little scope for marine scientists in the future; on the contrary, it indicates that more thoughtful, creative scientists are needed to harness new technology and plan experiments and observations using the new capacity we have for large-scale observations and massive datasets. It is therefore fitting that scientists, technologists and marine policy specialists were invited to contribute to this issue.

Marine science has become global in the twenty-first century. We have the ability to observe the oceans globally through satellites, floats, acoustics and many other techniques. Thus, it is important that any national marine science policy takes cognizance of what other nations are doing and also contributes to the global effort in a manner that makes best use of geographical location and the available expertise and technology. The UK has played a leading role in many successful global marine programmes such as the World Ocean Circulation
Experiment, Joint Global Ocean Flux Study and the Global Ocean Ecosystem Dynamics Programme. Its future ocean research policy needs to capitalize on these successful programmes and contribute to their successors in the most cost-effective way. The present generation of global programmes to which the UK should contribute includes the Global Ocean Observing System, Surface Ocean Lower Atmosphere Study, International Study of Marine Biogeochemical Cycles of Trace Elements and their Isotopes, Global Ecology and Oceanography of Harmful Algal Blooms and Integrated Marine Biogeochemistry and Ecosystem Research. These are all sponsored by SCOR and other international bodies. Indeed, the paper by Bryden et al. [2] recommends a course of action that would contribute to most, if not all, of the above research programmes.

In the first paper, Bryden et al. [3] present a recommended strategy for understanding and predicting ocean circulation for the next 20 years. They recommend that the UK should focus on three types of research: sustained observations of the varying and evolving ocean circulation led by UK marine scientists, careful analysis and interpretation of observed climate changes to compare with model projections and focused field experiments to understand ocean processes that are not yet resolved in coupled climate models. These approaches would make a real difference to global marine and climate change science and would build upon British expertise, both technical and scientific. Sustained observations would use smart, cost-effective observation network designs and sensors that would help bridge the gap between prototype instruments and operational ones. UK scientists are in a strong position to lead the world in careful interpretation of climate change records to extract patterns and project into the future. Similarly, the UK is in a position to provide individual and team efforts to lead in combining observational and modelling studies to provide the needed improvements to coupled ocean–atmosphere climate models.

Garabato [4] advocates curiosity-driven and fundamental research in physical oceanography, particularly on the effects of turbulent flows in setting the strength and structure of the large-scale ocean circulation. For decades, physical oceanographers have sought to understand the basics of how the ocean circulation is driven, how it is damped and how ocean dynamics connects the very different scales of forcing and dissipation. In the last two decades, significant advances have taken place in all these three fronts, and most progress has been in understanding the driving mechanisms of ocean circulation and the dynamical response of the oceans, with issues surrounding energy dissipation receiving comparatively little attention.

O’Cofaigh [5] emphasizes the ice–ocean interface in studying the ocean’s effects on marine-terminating glaciers such as melting at glacier edges and stability/instability of glaciers associated with grounding line interactions with ocean currents and temperatures. While these are major research frontiers in glaciology and ones in which marine science has a pivotal role to play, advances will require an integrated collaborative approach between oceanographers, glaciologists, marine geologists and numerical modellers.

Robinson & Siddall [6] stress the need for good palaeo-data to understand the processes that caused abrupt climate changes in the past in order to have confidence in future climate projections. They argue for well-quantified proxies with age control and offer constructive suggestions for improved
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Palaeo-chronology to enable critical model comparisons for palaeo-events. It is suggested that core-top sediment concentrations should be compared with modern observations of *in situ* water properties. A key challenge is to combine data and modelling in a common framework to improve our knowledge of how the Earth system works.

Mitchell [7] provides an extensive review of marine geoscience in the UK and stresses the benefits of studies driven by intrinsic scientific interest, as opposed to those driven by commercial applications. There is a lot to be learnt about active processes such as turbidity currents and sedimentary processes, lava flow and seabed tectonic displacements.

Rees [8] provides a strong case for continued and sustained observations of changing ocean biogeochemistry, including the development and application of new sensors to sample critical properties. He discusses ocean acidification and global warming of the oceans as pressing issues, along with eutrophication and oxygen depletion in coastal waters. The longer a time series, the more valuable it becomes and several long period variations are being revealed as time series get longer, helping us to separate climate trends from natural cycles.

McQuatters-Gollop [9] considers the challenges for implementing the European Marine Strategy Framework Directive in a climate of macro-ecological change. Under the Directive, each Member State must set environmental targets to achieve Good Environmental Status by 2020. However, in order to do so, an understanding of large-scale ecological change in the marine ecosystem is first necessary. A long time series of near surface macro-ecological variability and change comes from the Continuous Plankton Recorder (CPR) survey that has been sampling in the North Atlantic since 1931. Indicators developed using CPR data have revealed information about shifts in primary production, alterations to plankton composition and biodiversity, biogeographical shifts, and links to fish populations and ocean acidification. These unmanageable climate changes need to be taken into consideration in implementing targets to achieve Good Environmental Status.

Shuckburgh [10] writes on the oceanographers’ contribution to climate modelling and prediction. The ocean plays an essential role in determining aspects of climate variability and climate change through its influence on coupled processes involving the atmosphere, cryosphere and biogeochemistry, including budgets of heat and carbon dioxide and sea-level rise. She emphasizes that any long-term modelling strategy needs to be underpinned and complemented by fundamental theoretical and observational research activities.

Potts et al. [11] discuss future European marine policy, which, in the past, has evolved in a fragmented and uncoordinated way with different sectoral agencies and arms of government often competing in aims and objectives. The call for integrated and ecosystem-based management has demanded a new approach, with ecosystem-based planning becoming the norm for coastal and maritime planning. The challenges presented by the new approach are discussed with ideas for implementation that incorporate public involvement aimed at building a sense of ocean citizenship in the public at large.

John G. Field

*Marine Research Institute, University of Cape Town, South Africa*

*E-mail address: jgfielduct@gmail.com*

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