



Viewpoint

Developing human capital for successful implementation of international marine scientific research projects



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ABSTRACT

The oceans play a crucial role in the global environment and the sustainability of human populations, because of their involvement in climate regulation and provision of living and non-living resources to humans. Maintenance of healthy oceans in an era of increasing human pressure requires a high-level understanding of the processes occurring in the marine environment and the impacts of anthropogenic activities. Effective protection and sustainable resource management must be based, in part, on knowledge derived from successful research. Current marine research activities are being limited by a need for high-quality researchers capable of addressing critical issues in broad multidisciplinary research activities. This is particularly true for developing countries which will require the building of capacity for marine scientific research. This paper reviews the current activities aimed at increasing marine research capacity in developing and emerging countries and analyses the challenges faced, including: appropriate alignment of the research goals and societal and policy-relevant needs; training in multidisciplinary research; increasing capacity for overall synthesis of scientific data; building the capacity of technical staff; keeping highly qualified personnel in marine scientific research roles; cross-cultural issues in training; minimising duplication in training activities; improving linkages among human capital, project resources and infrastructure. Potential solutions to these challenges are provided, along with some priorities for action aimed at improving the overall research effort.

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1. Introduction

The oceans are a critical component of the Earth's environment, covering more than 70% of the surface to an average depth of about 4000 m, and containing more than 97% of the water on our planet's

surface. The wide surface coverage and great depth of the oceans lead to a wide variety of conditions in temperature, density and light, and demarcations between different zones are often difficult to delineate. The continuous exposure of the oceans to sunlight causes them to be the main energy store in the Earth's climate system and a major regulator of climate. In addition, the interaction between the oceans and the atmosphere plays a major role in controlling the composition of the atmosphere. This includes the

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production and transport of water vapour, as well as major processes in the global biogeochemical cycles.

In addition to these important physical roles, the oceans play a vital role in biological productivity and diversity, and in geochemical cycling. Millions of species inhabit the oceans, ranging in size from blue whales (*Baleonopterus musculus*) to krill (*Euphausia superba*), from giant kelp (*Macrocystis pyrifera*) to microphytoplankton (e.g., *Thalassionema* sp.). The total oceanic biomass is difficult to estimate, but figures of up to 10^9 tonnes of carbon (C) have been suggested (Groombridge and Jenkins, 2000). Humans harvest about 160–179 million tonnes of biomass annually from the oceans (FAO, 2013). The oceans receive the waters flowing from most of the world's major rivers (about 37×10^{15} kg/yr) containing varying loads of suspended and dissolved materials (Baumgartner and Reichel, 1975), while submarine groundwater discharges and volcanic hydrothermal systems add another 10^{15} kg/yr (Chester, 1990; Slomp and van Cappellan, 2004). The oceans thus represent the largest possible mixing vessel on Earth, facilitating a massive movement of materials and energy around the globe.

Despite these vital contributions to global environmental systems and human existence, our scientific knowledge of the oceans is far from complete (UNEP, 2007; Banse, 2013). Over the last 60 years, researchers have significantly expanded our knowledge base, but many unknowns still remain, especially for areas distant from the coast. In addition, much of the research carried out has focused on single disciplinary studies of the ocean (i.e., biology, chemistry, geology, and physics, etc.) and does not provide the information necessary to achieve a sufficient understanding of oceanic processes and the interactions between biological activity and the physical, chemical and geological processes that significantly affect ocean biology. Several international marine scientific research projects have been developed over the past three decades to examine ocean processes in an interdisciplinary manner, including the Joint Global Ocean Flux Studies (JGOFS), Global Ocean Ecosystem Dynamics (GLOBEC), Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB), the Surface Ocean-Lower Atmosphere Study (SOLAS), the International Study of the Marine Biogeochemical Cycles of Trace Elements and their Isotopes (GEOTRACES) and the Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) projects; these international initiatives have well-defined objectives to study one or several specific key global ocean scientific issues. For example, the IMBER project of the International Geosphere-Biosphere Programme (IGBP) and the Scientific Committee on Oceanic Research (SCOR) has a mission “to provide a comprehensive understanding of, and accurate predictive capacity for, ocean responses to accelerating global change and the consequent effects on the Earth System and human society” (cf. www.imber.info).

Ocean researchers are increasingly being asked to provide an improved understanding of processes essential for better management and more sustainable use of the oceans (Millennium Assessment, 2005; UN World Ocean Assessment, 2009). Issues of particular interest and complexity include transformation of organic matter in marine food webs, transfers of matter across ocean interfaces, changing supplies of nutrients and the impacts of marine harvesting. Understanding and predicting how marine biogeochemical cycles and ecosystems will respond to a variety of global changes (e.g., ocean warming, oxygen depletion and acidification) is critical for examination of the feedbacks between the ocean and other Earth surface components. In addition, the multiple feedback mechanisms between humans and ocean systems need to be better understood to clarify what human institutions can do, either to mitigate anthropogenic perturbations of the ocean system or to adapt to such changes.

Marine scientific research is constrained by insufficient and aging infrastructure for sea-going observations and limited funding sources, particularly in developing countries (NRC, 2008); there

are also related problems in the education of marine researchers with regard to adopting multi-disciplinary/inter-disciplinary approaches. To fully address the range of complex ocean issues requires researchers with a strong multi-disciplinary/inter-disciplinary background (e.g., physics, chemistry, ecology and geology, plus statistics, computational and spatial science, and social science) and preferably with a wide range of laboratory and field skills, including experience on ocean-going vessels. There is also a complementary need for skilled and experienced technical staff to support these global marine research activities. The number of researchers/technicians with such backgrounds is limited, especially in developing countries. There is, therefore, clearly a need for research capacity building to support this field (Zhang et al., 2013).

As a minimum, all countries with an ocean coastline must develop and maintain a pool of marine scientists large enough to protect and manage their marine resources, from the coastline to the outer limit of the National Exclusive Economic Zone (EEZ). In order to keep this pool of scientists, several different social mechanisms are needed to attract and retain talented individuals and recruit young researchers. This is particularly important in developing and emerging countries, where resources for research may be limited. To overcome the lack of resources, developing countries may share facilities through bilateral and/or regional cooperation and developed countries can and do provide assistance to developing nations.

Current international marine research initiatives require integrated multi-disciplinary approaches with strong support for equipment and observations funded at the country level. Involvement in open ocean research across the globe is relatively uneven in terms of country and institution participation, with a distinct lack of researchers based in developing or emerging countries. The reasons for this include, but are not limited to, the following factors:

- The capacity of a national marine scientific research community may be limited; for example, the community may lack expertise in certain disciplines, owing to the nature of the existing education systems in the country;
- Sea-going equipment and facilities for research and observations are limited, especially for open ocean studies, which means that most developing countries focus their research on the coastal environment, and hence find it difficult to participate in international research initiatives with an open ocean focus and also to develop the expertise to characterise and manage their wider EEZ environments;
- The limited financial resources to support sea-going observations mean that developing countries tend to depend on bilateral collaboration, rather than international research projects that require more infrastructure. Also, the scarcity of national funding for ocean research may lead to an emphasis on short-term investment in equipment purchases as opposed to a long-term strategy for research and maintenance of facilities; and,
- In some countries, government support for research is somewhat erratic, and developing country scientists are not able to make longer-term commitments to international collaborations and other cooperative opportunities that could assist in the development of scientific capacity.

Among others, a key factor affecting investment in scientific research is the national appreciation of the importance of the marine sector to the country's economy and resources. Some countries (e.g., Chile, India, South Africa, and Malaysia) are highly aware of the relative importance of the marine sector and invest heavily in research and marine resource development and management.

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