*IMBeR Southern Ocean Regional Programme*

# Integrating Climate and Ecosystems Dynamics in the Southern Ocean

**The Challenge:** To improve understanding of ecosystem dynamics, climate interactions and impacts in the circumpolar Southern Ocean, generate scenarios and projections of the impacts of future change and inform decision making for conservation and fisheries management.

Over the last decade ICED has made significant progress in developing understanding of the structure, functioning and variability of regional ecosystems and drivers of change in the Southern Ocean, modelling the life histories of key species and food webs, and undertaking assessments of past, present and future change. This has been achieved through a range of ICED-led activities and science projects, involving contributions from individuals and national and international programmes. These have enabled ICED to raise awareness of the importance of Southern Ocean ecosystems in the global ocean, ensuring that it leads and fosters globally important analyses of changing marine ecosystems that also reflect international conservation and management priorities. ICED has identified three priority *Research Challenges (RC)* for Southern Ocean ecosystem science for the next decade that directly relate to the *IMBeR Grand Challenges*: i. State and variability of ecosystems, ii. Projections of future states and iii. Sustainable Southern Ocean governance. These areas of research are at the forefront of Southern Ocean science and require focussed and innovative activity in order to achieve the ICED Challenge. ICED and its partners seek to develop coordinated international circumpolar activities to deliver the required research.

### RC1 Understanding and quantifying the state, variability and change of Southern Ocean ecosystems

There are major regional variations in environmental conditions, biogeochemical cycles, food webs and ecosystem structure and functioning in the Southern Ocean, although detailed knowledge is only available for a few areas and underlying processes and causal mechanisms are poorly understood. These are crucial to understanding variability and change in these ecosystems, their role in ecosystem functioning, and to developing ecosystem models and projections of their future states. To address these issues ICED will develop strategic whole ecosystem analyses and assessments (MEASO) across multiple spatial, temporal and organisational scales in the full three-dimensional ocean. It will also identify the key natural environmental and anthropogenic drivers of change, their mechanistic impacts and their combined and synergistic effects on individual species and ecological communities. Sea ice is considered a major driver of Southern Ocean ecosystems, however many aspects of its interactions with biology are poorly understood. ICED will therefore develop a major research focus on sea ice ecosystems. With a new generation of icebreaking capable research vessels, ICED is developing plans for a major internationally coordinated field study of sea ice ecosystems and seasonal transitions, linking ocean and ice food webs and biogeochemical processes, underpinned by enhanced remote and autonomous biological observation systems.

**Assessing the status of Southern Ocean ecosystems:** the first *Marine Ecosystem Assessment* for *the Southern Ocean (MEASO)*

*MEASO* is generating a comprehensive assessment of the biogeochemistry, species distribution and abundances across trophic levels (from microbes to whales), food webs and ecosystems processes in regional ecosystems of the circumpolar Southern Ocean. It is examining how these species and ecosystems are being affected by change and considering how they may respond in the future. In addition, it is assessing the role of Southern Ocean ecosystems in maintaining globally important ecosystem functions and their connections and role in the Earth system. *MEASO* will provide a benchmark for assessing change and the basis for developing robust projections of the impacts of future change and identify future research priorities.

## RC2 – Improving scenarios and projections of future Southern Ocean ecosystems at multiple scales

Southern Ocean ecosystems are changing and further major impacts are expected in the coming decades as a result of continued climate and ecological change. There has been good progress in the development of ecological models for species and food webs, and of scenarios and projections based on these models. However, there has been little integrated modelling to provide the basis for developing projections across multiple spatial, temporal and organizational scales. ICED will continue to develop end-to-end ecosystem modelling approaches that integrate physical, biogeochemical and biological processes across multiple species and scales. A suite of alternative models of physical dynamics (ocean circulation and climate), biogeochemical cycles, and biological dynamics (life histories, population dynamics, food web structure) at different spatial, temporal and trophic resolutions is required. ICED will also develop future scenarios of physical, chemical, biological and human system change and future projections of changes in key species, food webs, whole ecosystems and ecosystem processes (including biogeochemical cycling) under the impact of multiple drivers. It will develop models that incorporate direct and indirect impacts of human activities, with particular focus on local and regional models and projections on decadal time scales to inform assessments and decision making for conservation and management.

**The changing balance of Southern Ocean ecosystems - climate change and the recovery of the great whales** Ocean warming and reductions in sea ice and pH are expected to have major impacts in Southern Ocean ecosystems in the coming decades. At the same time, populations of a number of whale species are expected to continue to increase following extensive exploitation of marine mammals during the 19th and 20th centuries. Improved models, scenarios and projections that consider the impact of their recovery and consequences for ecosystems alongside a range of multiple physical, chemical and ecological drivers are therefore required.

## RC3 Improving and achieving sustainable Southern Ocean governance

ICED will develop analyses to determine how understanding of the structure, functioning and response of Southern Ocean ecosystems to change, together with relevant projections can support adaptation, mitigation and sustainable management strategies. This will be achieved by building on collaborations with key international bodies (particularly the *Commission for Conservation of Antarctic Marine Living Resources*, CCAMLR) to provide the required Southern Ocean ecosystem science, scenarios and projections for policymakers and society. It will draw on the local and regional assessments, modelling and projections developed in RC1 and RC2 to provide a quantitative basis for decision-making. It will focus particularly on the development of management strategy evaluation approaches to provide policy makers with the basis for assessing alternative management strategies. ICED will also develop multidisciplinary natural, social, economic and political collaborative science activities to understand the potential global economic and societal drivers of future change in Southern Ocean ecosystems.

ICED is the Southern Ocean Regional programme of IMBeR, sponsored by: IMBeR, SCOR, futureearth, SCAR, CCAMLR, British Antarctic Survey

For more details see http://www.iced.ac.uk IMBeR is an international network that facilitates interdisciplinary marine research in order to achieve sustainable ocean governance for the benefit of society. Sign up to IMBeR via http://www.imber.info to benefit from networking, mentoring and collaborative opportunities with world-class natural and social scientists, practitioners and researchers. IMBeR is sponsored by:

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