Abiotic factors in the southern ocean

Update April 24, 2018 By A.P. Mentzer Polar regions include areas of the globe surrounding the North and South Poles that lie in the Arctic Circle in the north and in the Antarctic circle in the south. Conditions at the poles are difficult, but the polar regions are far from dead. Interaction between living and dead things is a framework for ecosystems in this biomic. The ecology of polar regions is classified as tundra. Low temperatures, low rainfall, sealess plains and a lack of biodiversity define this biom. The growing season is extremely short, and populations can vary greatly depending on resource availability at any given time. The Arctic tundra consists of the North Pole, located in the ice-covered part of the Arctic Ocean, and the northernmost coasts of North America, Europe and Asia. The Tundra region of the South Pole includes the continent of Antarctica and the surrounding Antarctic islands. Antarctic tundra has less diversity than a number of terrestrial species in the Arctic. Only a few species of mech, algae, lichens and flowering plants live here. A rare number of terrestrial species includes mites, ticks and the species of wingless fly. Most animals in or near the Antarctic region live in or near the ocean. Marine animals include: whales seal penguins squid fish small krill Abiotic factors affecting life in polar regions include temperature, sunlight and precipitation. The upper layer of the earth remains frozen all year round, which prevents the development of plants with deep roots, such as trees. Poles receive dim sunlight when they are tilted away from the sun. Reduced daylight by half a year limits the types of plants that can grow in this environment. When tilted towards the sun, increased hours of daylight drive rapid growth as plants and animals use up for extra hours of daylight. Despite the presence of so much snow and ice in the polar regions, these areas do not receive much rainfall and are like cold deserts. Ocean currents are an important abiotic factor in arctic and Antarctic biomes, as much of the biodiversity around the poles is based on marine life. Ocean currents carry nutrients and small organisms that supply the organisms of these ecosystems with food. In cold ocean water, ice, which forms on the surface, causes an increase in salinity in the surrounding water, which increases its density. Dense, salty water sinks, allowing less salt water to circulate. The flow of water circulates through nutrients and carbon dioxide. Water with high nutrient density at the bottom of the ocean is brought to the surface by upwelling currents to provide resources for the animals inhabiting the surface. About the author a.p. Mentzer graduated from Rutgers University with anthropology and biological sciences. She worked as a researcher and analyst in the biotechnology industry and editor for an educational publishing company before starting her career as an independent writer and editor. Alissa likes to write about life and medical topics, as well as scientific activities for children Abiotic factors: Marine habitat is along the polar region and to develop, depends on many different factors. Temperatures must be 50 degrees below zero under peak conditions. Antarctica will go six months with sunlight and six months without. This habitat will receive less than half an inch of rainfall, which is needed to keep sea ice at 1.6 km thick. Biotic factors: Antarctica has a very diverse marine habitat, as some animals will live above sea ice as well as under and into the ocean. The smallest of these species is phytoplankton and zooplankton, which swarmed with algae under sea ice. Antarctic krill colonies form and become food for squid, whales and fish. When we move up the food chain, we meet carnivores such as elephant seals, leopard seals and other breeds. Penguins and small-toothed whales also fit into this category, creating a large miraculous ecosystem. MossesMosses were one of the first plants to live on land. They live near wet places, which explains why some live in Antarctica. Like other plants, moss make their own food in the process of photosynthesis. LichensLichens are known for surviving at very low temperatures. Therefore, you can find many of them in Antarctica. Lichens do not live in places that have a lot of sun. They live in places near the water for survival. King penguins Many penguins live in Antarctica, including king penguins. They are adapted to very low temperatures. King penguins feed on fish and squid. They are the second largest penguins after the emperor. They have a population of 2 million pairs. Leopard Seal Leopard seals are adapted to very low temperatures. Among all seals, leopard seals are the fiercer. They are gray with spots around the body. They weigh up to 380 kg. They often feed on penguins and fish. IceAntarctica is covered with ice due to the very cold weather. The Antarctic ice sheet covers 98% of Antarctica. Although Antarctica has very cold weather, some plants and animals have adapted to it. Water (sea)Most animals in Antarctica live in the ocean and on land. The temperature of the ocean surface is close to its freezing point. In winter, the area will be covered with ice or snow. The Southern Ocean accounts for 9.6% of the world's oceans and plays a key role in various global cycles and budgets. It is a major contributor to global ocean primary production and biodiversity, exports nutrients to the world's ocean basins and contributes to a global current system that transports heat and CO_2 from to the deep ocean and O_2 in the opposite direction (Sarmiento et al,2004; Turner et al., 2009). Cala Cala the last 30 years, regional changes in various areas (e.g. water temperature, currents, stratification, changes in ocean frontal positions, increased western winds, changes in sea ice coverage and dramatic impact on wildlife, changes in the abundance of Antarctic krill Euphausia superba) have taken place in the Southern Ocean (Constable et al., 2014; Ropert-Coudert et al., 2014; 111. Gutt et al., 2015). The stability of the Earth System (including natural background dynamics) is under threat and the pace of change is accelerating (with the fundamental elements of climate change and biosphere integrity that could bring the Earth system to a new state), suggesting that current changes are only minor compared to expected future trends (Rockstrom et al., 2009; Steffen and others, 2015). These trends include, but are not limited to, increased ocean warming, widespread decline in sea ice, an increase in aragorite insufficiencies (acidification) and the interaction of these (and other) environmental factors that affect southern Ocean ecosystems (Gutt et al., 2015). Although, our understanding of the biological processes of the Southern Ocean (e.g. distribution, feeding ecology, reproduction; Figure 1) has improved significantly in recent years, the ability of organisms (at population, community and/or species level) to adapt to change and the dynamics of biological cycles remain poorly understood. However, this knowledge is necessary to predict biological responses to predicted physical changes (IPCC, 2013). Figure 1. Examples of marine biodiversity in the Southern Ocean. Penguins gentoo Pygoscelis papua (J.C. Xavier, MARE-UC/BAS), albatross Thalassarche melanophrys (J.C. Xavier, MARE-UC/BAS), icefish Chaenocephalus aceratus (Doug Allan, BAS), Antarctic krill Euphausia superba (Russ Hopcroft, AAD), amphipod Epimeria rubrieques (Torben Riehl, ZM-UH) and isopod Litarcturus cf. antarcticus (Torben Riehl, ZM-UH). The first Scientific Committee on The Horizon Scan Process (Sutherland et al., 2011), which selected these priority issues, was described by Kennicutt et al. (2015). The authors identified several questions that were widely included in six research topics that could lead scientists to the full potential of antarctic and southern ocean science (Kennicutt et al., 2014). Here we focus on three current clusters (Southern Ocean life and ecology, marine biosphere and physical environment, and biotic responses to change) that have been identified as priority issues when scanning the horizon and which relate specifically to Research on the Southern Ocean. Our goal is: (i) areas of high importance which, although not preserved at the end of the scan [(Kennicutt et al,2014, 2015) exchange the full 80 key questions, enter the selection process for exercises in southern Ocean biology and ecology and (b) identify challenges and requirements for technological development, research strategies (e.g. monitoring and coordination), as well as links with stakeholders (e.g. policy makers, NGOs, industry) and the general public, specific to biological research in Antarctica and the Southern Ocean. Research relevant to the life and ecology of the Southern Ocean In addition to the detailed compilation of research questions in data sheet 1 in the additional material, we present a number of issues related to the questions that have been voted on on life in the Southern Ocean and ecological sessions. Identification of the main marine ecosystem processes in the Southern Ocean Continuous warming of parts of the Southern Ocean requires an assessment not only of rising temperatures, but also of its impact on other physical and biological parameters. This is particularly important for species endemic to the Southern Ocean (characterized by narrow environmental niches) that may exhibit poor adaptability/acclimatization/plasticity to rapid environmental changes. The key issue is to determine which species will be threatened by the changes due to their inherent physiological limitations. Increasing ocean acidification (i.e. reducing the pH of seawater) is expected to significantly change the ecosystems of the Southern Ocean (Orr et al., 2005), but recent evidence suggests that some Antarctic species may be able to cope with reduced pH (Suckling et al., 2014). Taxonomy remains a key approach to discovering changes in the composition of fauna related to global change processes (Costello et al., 2013). identification of links between land and sea systems, in particular in inter-tidal and coastal areas, where land disglaciation can have a significant impact on local marine ecosystems (Schloss et al., 2012; Gutt et al., 2015; Hernando et al., 2015), requires further research due to the anticipated increase in ice melting levels, potential runoff of fresh water from the ground and potential sea level rise (Golledge et al., 2015). In addition, while there is evidence of the impact of the glacier on benthic communities on a local scale (Pasotti et al., 2015), it is necessary to understand factors that may explain the high spatial irregularity of benthos inhabiting the Antarctic shelf on a local and regional scale. Understanding the synergistic impact of many environmental stressors, including ocean acidification, sedimentation and hypoxia, on benthic habitats will prove particularly difficult; however, this is essential for the changes across the ecosystem. Examination of the structure of the food network and the functioning of the Southern Ocean Certain basic biological information on primary, primary, necton, and top predators from different regions of the Southern Ocean is still missing (Figures 2A,B; Griffiths et al., 2014). Comparative knowledge was gathered as part of the Census of Marine Life and its flagship project, the 5-Year Antarctic Census of Marine Life (CAML), which investigated, among other things, the diversity, distribution, functions and abundance of marine organisms in the Southern Ocean (Gutt et al., 2010; Kaiser et al., 2013), culminating in the Southern Ocean Biogeographical Atlas (Brandt et al., 2014b; De Broyer et al., 2014). However, there are still knowledge gaps in the biology, distribution and diversity of most marine groups. As of today, very little information is available from the microbial area (including viruses), in particular on their distribution in Southern Ocean ecosystems and their role in refuelling and recycling organic matter in compartments of different systems. Similarly, we know little about the life cycle of many species of plankton and nectone (a large number of which remain unidentified), especially under sea ice, at the touch of ice water and in open ocean regions, or about the recruitment success of any population dynamics of taxa of ecological importance (e.g. cephaloga or marine fish). In this context, from the point of view of the food chain, meso- and upper predators (e.g. albatrosses, seals, penguins) are now considered early organic species of indicators of change in the Southern Ocean and are used as ecological indicators of the state of lower trophic levels (Hindell et al., 2003; Xavier and Cherel, 2009). Figure 2. (A) Relative distribution of benthic sampling intensity (A), pelagic sampling intensity (B) and seabed area with depth (C). The red line indicates a depth of 1000 m (shelf break), and the blue line indicates 3000 m deep plains of the abyss; after (Griffiths et al., 2014) (B) Relative distribution of geographic sampling intensity (yellow dots; ~1.07 million separate records) in the Southern Ocean (after Griffiths et al., 2014). In the case of marine bentos ecosystems, it is important to document and understand the functional diversity of benthos and to identify the ecological drivers of different communities. What environmental factors are responsible for the development of filter-dominated communities? Why are the stains of such assemblies in a gradient from aggregations limited to a few meters to eco-regions stretching for tens of kilometers? In addition, there is a need to explore the dynamics of benthic systems, including seasonal variability, in order to map biodiversity and biomass hot spots, and to clarify the rates of return between trophic levels and nutrient cycles at community level, including consumption, carbon sequestration and Some of these challenges relate to (Brandt et al., 2007, 2012), in which our understanding of the dynamics of deep-sea organisms in physically changing oceans and in diverse climates is key to assessing the role of these organisms. Deep-sea, where ecological communities are diverse but mostly unknown, is one of the limits to explore in the coming decades as the foundations for ecosystem functioning (Brandt and Ebbe, 2011) and changes in species and food-structure-websites are almost unknown (Brandt and Others, 2014a,b). The relatively stable deep-sea ecosystems of the Southern Ocean have great potential for evolutionary research, for example in identifying key factors that lead to speciation events in this vast environment. In addition, it is important to understand the contribution to the sequestration/recycling of coal and nutrients of different plankton and benthic communities in the deep sea, on slopes and on biomass-rich shelves. Only when these knowledge gaps are filled can Antarctic marine systems be described qualitatively and quantitatively and considered in a broader context that will allow prediction in a changing environment. Future challenges and requirements for methodological and technological development Future requirements for life in the southern oceans and ecology research Antarctic life sciences are limited by the scarcity of self-ecological basic data for key marine organisms (Kennicutt et al., 2014), in particular micro-organisms despite their fundamental importance in the functioning of the ecosystem (Danovaro et al., 2014). There is much more data on the distribution of species compared to their functioning and their productivity. In addition to traditional – but often methodologically difficult – inventories, future generations of scientists will need to support international coordination in order to conduct long-term programmes to monitor and obtain biological information on poorly known species and their interactions, either directly or through species of ecological indicators. These long-term, multinational monitoring programmes will also improve the quality and choice of data for the next generation of climate models and food networks. For example, an accurate selection of basic ocean ecosystem variables (Constable et al., 2014) is required to reliably predict antarctic regional or global marine ecosystems (Murphy and Hofmann, 2013; Xavier et al., 2015). Antarctic ecosystem services are increasingly important and there is an urgent need to clarify their role and the impact of change. How does the functioning of the ecosystem inform ecosystem services? How does it contribute to the global budget, and more specifically to the Southern Ocean? Marine protected areas that have been implemented with varying degrees of success throughout the oceans, can play a key role in protecting the environment of the Southern Ocean. Our ability to implement and determining the efficiency and effectiveness of MPAs in the conservation of ocean resources is crucial to ensure their sustainable exploitation and, again, requires long-term monitoring. To this end, it is also crucial to better understand the structural and functional differences between the regions of the Southern Ocean. International organisations such as SCAR and the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) gather expert scientific groups for whom monitoring is a key issue for scientific research, species conservation, the conservation of areas and the sustainable development of ecosystems for life in the Southern Ocean. The recently established International Southern Ocean Observing System (SOOS; www.soos.aq/) initiative, under the Global Ocean Observing Systems (www.ioc-goos.org/) and Deep Ocean Observing Systems (www.ioc-goos.org/deepocean), aims to coordinate and expand efforts to collect scientific data in the Southern Ocean and to develop a coherent and effective observation system that provides the data needed to meet key scientific and social challenges. International SCAR initiatives such as the AnT-ERA Biology Programmes (www.scar.org/srp/ant-era) and AntEco (www.scar.org/srp/anteco) can facilitate better coordination of environmental research. In line with the requirements and/or pressures of stakeholders to ensure a comprehensive knowledge of the ecosystems of the Southern Ocean, it is necessary to apply the frequently cited need for standardisation. This refers to sampling methods as well as analyses and strategies, even in simple parameters such as absence/presence and abundance. The CCAMLR Ecosystem Monitoring Programme (CEMP) has put considerable effort into this problem and has been collecting data on various species around the Southern Ocean since 1987 (Agnew, 1997). These efforts must be continued and extended, while encouraging research groups to use the CEMP as a standard data collection procedure. However, standardisation and coordination must not block the development of new technologies and ideas, but rather complement them. In addition, efforts should be made to achieve integration outcomes that are representative of entire communities or trophic elements of the ecosystem. Similarly, the challenges of state-of-the-art Antarctic marine science require the development of a logistics and technology network combining neural networks, coordination of data collection and a wide range of devices (Meredith et al., 2013). Future research vessels may have state-of-the-art instrumentation and laboratories on board, along with next-generation technologies (e.g. marine remote-controlled vehicles and autonomous underwater vehicles, gliders and rovers), as well as advanced technology (i.e. any platform that has one or more seabed, remains there until it is recovered). In addition, autonomous profiling floats will continue to be extremely useful for collecting valuable information and delivering long-term trends in the future (Gille, 2002; Sallée et al., 2010; 1010– 19:10; Tagliabue et al., 2014; 1111– 1211– 12 Heuzé et al., 2015). The use of such data, with data possible from satellites (due to improved accuracy and uncertainty) will also help our information on ocean processes (Sarmiento et al., 1998; Arrigo et al., 1999; Arrigo, 2005; Hauck et al., 2015), ecology and food network dynamics (Gillett and Thompson, 2003; Weimerskirch et al., 2012; Siegel et al., 2014; Laufkötter et al., 2015; Xavier et al., 2015). These technologies are efficient and environmentally friendly and will significantly improve the spatial and temporary coverage of biological and physical sampling of the southern ocean. In addition, they will help to improve ecological observation and assess significant ocean variables (EOV), which are the subject of major international Antarctic programmes such as SOOS (Meredith et al., 2013, 2015). Taxonomic descriptions of new species, providing the basic knowledge on which all other studies are based, must be provided, for example, by supporting taxonomists and developing programmes such as the taxonomic description language (Dallwitz et al., 1993), in combination with molecular methods. At the same time, technological progress and constant miniaturisation have made it possible to record or transmit animal data (Cooke et al., 2004; Ropert-Coudert and Wilson, 2005) to become increasingly useful in monitoring a wider range of parameters for smaller species without worrying about negative effects. The projected miniaturisation, at the same time as the market for biology technology is expanding, will lead to the development of increasingly expensive devices. This will open up large-scale monitoring capabilities at the peripolar level in the coming decades. The development of new sensors and on-board data processing systems bodes well for future research to identify in situ and store, in improved memories, environmental information at small scales to provide a true dynamic vision of the state of the Southern Ocean. Linking foray behaviour, trophic interactions and population dynamics of leading predators will also significantly contribute to the development of more efficient food models and networks that are crucial for assessing life in the changing Southern Ocean. Universal food-web models (e.g. combining trophic interactions, biodiversity, biotic and abiotic parameters, in an evolutionary context), following previous studies in this direction (Steinacher et al., 2010; Bopp et al., 2013), can be developed to explain the evolutionary origin of high biodiversity in the Ocean and future response to ongoing changes in the environment. Finally, continuous improvements in the implementation of cost-effective high-throughput molecular sequencing will also have an impact on various disciplines, including biogeochemistgy, following previous work (Bohmann et al., 2014; Zhan and MacIsaac, 2015). The southern ocean marine food webs forecasting systems modeling tools have been developed and available to enable prediction, although there is a need for improvement (Xavier and others, 2015). From the perspective of forecasting marine food networks, in order to improve biological forecasting around the world (i.e. predicting the response of biological organisms on a local to global scale) (Barnosky et al., 2012), we need to be able to assess the ecological subversive points of southern Ocean ecosystems (Gutt et al., 2013). Furthermore, assessing the impact of these turning points on the functioning of the Southern Ocean is an important issue for the next 20 years. To this end, in addition to traditional monitoring, we need to carry out experimental manipulations over long periods (e.g. several decades) on species of ecological indicators (defined here as any biological species that defines an environmental characteristic or characteristic) or groups of species. The challenge remains to incorporate life history parameters (e.g. growth, mortality) into static species distribution models (Gutt et al., 2012) that correlate biogeography with the latest and future dynamic environmental components. In addition, it is difficult to include all ecology-related species or the entire community in many – rather than individual – stressors in ecological risk models (Gutt et al., 2015). Particular attention should be paid to invasive marine species or native species that extend their biogeographical range and may cause a change in diversity that will disrupt the existing dynamic balance between trophic guilds. One of the issues of interest to Antarctic marine resource managers and policy makers is our ability to distinguish between ecosystem change and climate change and the effects of fisheries exploitation (Figure 3). With regard to the management of the living resources of the Southern Ocean, in the near future of environmental change, the CCAMLR has approved the development of a feedback management strategy. The system will use information on the state of the ecosystem to change harvest levels and spatial management of Antarctic krill fishing. This approach provides an opportunity to make initial attempts to forecast and adequately respond to the potential effects of climate change (CCAMLR, 2014) through signals from ecosystem elements such as meso- and the best predators. Similar initiatives should be carried out for other commercially used species, such as gearfish and frozen fish, while knowledge of the ecology of the species that are to be in the future. Antarctic predators have already been shown to be used as oceanographic samplers. For example, mirounga leonina's southern elephant seals habitat covers vast areas of the Southern Ocean and is therefore useful for investigating physical and biological changes occurring in the vast, remote, Southern Ocean throughout the year (Roquet et al., 2013). Further development of the use of the best predators as oceanographic samplers, bearing in mind ethical concerns, would not only address key issues in the ecology of the species, but would also be an important step towards fuller sampling and monitoring of the Southern Ocean. Figure 3. A conceptual diagram illustrating knowledge gaps in Southern Ocean life and environmental research, examples of major technological development needs and how they need to be linked to monitoring and modeling efforts to predict future changes in the Southern Ocean. The results of these areas/research gaps can be politically applicable, such as conservation efforts, along with a strong element of communication (education and outreach). The Arctic and Antarctica differ in age, stability and heterogeneity, human presence and ecosystem services (Meltofte et al., 2013; Walton, 2013), but different marine species occur at both poles (De Broyer et al., 2014). How polar ecosystems respond and respond to change is crucial to our understanding of processes around the world, so comparative research can be obtained from comparative studies (Smetacek and Nicol, 2005; Convey et al., 2012; Bennett and others, 2015). Comparing these polar regions at the levels of functioning of species and ecosystems will be very important in the coming years, in climate change scenarios, through cooperation between the international scientific community (e.g. under SCAR and expert groups of the International Arctic Committee). Supporting the ethical perspective While conducting Antarctic Science, the ecosystems of the Southern Ocean are remote, sometimes isolated and consequently may be more easily affected by change. Signals of natural dispersion, colonisation and diversification for Antarctica and the Southern Ocean are now at risk of being overwhelmed by the effects of a changing climate and rapidly increasing human movement both to the region and between its distinct regions (Chown et al., 2015). These features mean that scientists need to be particularly careful when conducting experiments, and in this context the international nature of Antarctic Science requires greater coordination between countries in defining ethical guidelines to meet the challenges of the coming decades. Pursuant to the Protocol on the Protection of the Environment to the Antarctic Treaty (Madrid Protocol) Antarctic programmes should continue to submit their scientific proposals to the impartial national environmental agencies, but procedures may vary from country to country. This diversity in evaluation processes means that the same study or experiment submitted to two different countries may not have the same level of limitations. In addition, ethics committees could be aware of specific scientific approaches (e.g. experiments on animals with higher circles associated with working in the Southern Ocean) and ensure that their legislation continues to allow data collection. The lack of data could indeed be very detrimental to the creation of effective protective measures. Establishment and further development of education and information activities More efforts Due to the great public interest in Antarctic animals (e.g. penguins, seals, whales) educational and information activities such as those conducted during antarctic treaty consultation meetings, by the Association of Polar Early Career Scientists and Polar Educators International, as well as through national programmes, have increased antarctic scientific profiles to a wider audience than the scientific and conservation communities currently achieved (Baeseman et al. , 2011; Walton et al., 2013; 111: 13. May and Others, 2014). Therefore, Antarctic marine environmentalists should be encouraged to engage in scientific communication for the general public, to solve social problems related to antarctic environmental issues (Pace et al., 2010; Xavier et al., 2016) and be actively involved in providing the best scientific information and advice to policy-making bodies. If Antarctica is to be protected, remote ecosystems such as the Deep Sea of the Southern Ocean, ice shelves and those under solid sea ice should be used more intensively than in the past and will have to be studied and monitored in society and in future research initiatives. ConclusionS The first SCAR Antarctic and Southern Ocean Science Horizon Scan study identified the most pressing scientific questions to be addressed over the next two decades. Based on the questions originally sent by the scientific community, we take into account the serious gaps in current ecological knowledge that are necessary to shed light on the future life and ecology of the southern ocean. We concluded that there is still a lack of basic biological information on the taxonomia (and physiology) of organisms, from viruses to predators (especially the former), as well as in areas such as the deep seabed or ice-ice environments. At the ecosystem level, the response and resilience to change are largely unknown, making accurate forecasting virtually impossible in the near future. However, a future in-depth understanding of these responses will be crucial in determining the importance of the different elements of Antarctic ecosystem services (e.g. Antarctica). and carbon sequestration) and future environmental changes in these services. Filling these gaps will require the continuation of long-term engagement and the development and use of innovative technologies to adequately study and monitor Southern Ocean ecosystems, detect early stage changes and assess multi-stress effects in marine ecosystems in order to improve modelling efforts focused on interactive outcomes. Importantly, disciplines such as taxonomy and long-term monitoring should receive strong logistical and financial support if we are to anticipate the likely consequences of climate change and other threats. Finally, informing stakeholders, policy makers and the general public about the results of this research will highlight the importance of this unique ecosystem, highlight its key role in the world and, most importantly, its increasing vulnerability to man-made change. The author of Contributions JX, AB and YR coordinated the manuscript, and all authors contributed (writing and reviewing) the manuscript. All authors were very active in Horizon Scan, coordinating sessions with Horizon Scan. Conflict of Interest Statement The authors declare that the research was conducted in the absence of any commercial or financial relationship that could be interpreted as a potential conflict of interest. Thank you to the organizers and all participants of the first SCAR Antarctic and Southern Ocean Science Horizon Scan and Tinker Foundation for their financial support, as well as the Antarctic New Zealand, the New Zealand Antarctic Research Institute, the Scientific Committee on Antarctica and the Antarctic Research Committee. Support was provided by the Antarctic Climate & Ecosystems Cooperative Research Centre (Australia), the Canadian Polar Commission, the Climate And Cryosphere Programme, Kelly Tarlton's Sea Life Aquarium, the Korean Institute for Polar Research, the Instituto Antarctico Chileno, the National Institute of Polar Research (Japan), the New Zealand Post, the Programma Nazionale di Ricerche in Antartide (Italy), Monash University, the Polar Research Institute of China and the University of Malaya (Malaysia). The support of the SCAR secretariat and the staff of Antarctica New Zealand is gratefully appreciated. 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