‘Antarctic biology in the 21st century — Advances in, and beyond the international polar year 2007–2008’

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Abstract

The International Polar Year 2007–2008 (IPY) has provided an opportunity for biology to show itself as an important part of Antarctic science in a manner in which it was not seen during earlier Polar Years. Of the 15 endorsed biological projects in Antarctica, 7 included more than 20 scientists and could be deemed truly international. Four were conducted in the marine environment, and one each in the fields of biological invasions, microbial ecology, and terrestrial ecology, and one was SCAR’s over-arching ‘Evolution and Biodiversity in the Antarctic’. The marine projects have left a robust legacy of data for future research into the consequences of environmental change, and into future decisions about marine protected areas. Studies on introductions of exotic organisms reveal an ever-present threat to the warmer parts of the high-latitude Southern Ocean, or parts which might become warmer with climate change. Studies on microbial ecology reveal great complexity of ecosystems with high numbers of unknown species. Terrestrial research has shown how vulnerable the Antarctic is to accidental introductions, and how productive the soils can be under changed climate conditions. Antarctic biology has come-of-age during IPY 2007–2008 and the campaign has set the scene for future research.

Keywords: IPY legacies; EBA; Marine biology; Invasion ecology; Microbial ecology; Terrestrial ecology

1. Introduction

As the sun sets on the International Polar Year (IPY) it is timely to reflect upon the contributions made by SCAR during this major international effort to focus scientific and social research on the Earth’s two Polar Regions. At its inception in the early years of the 21st century the objectives of IPY were: “(a) to make major advances in polar knowledge and understanding (b) to leave a legacy of new or enhanced observational systems, facilities and infrastructure (c) to inspire a new generation of polar scientists and engineers and (d) to elicit keen interest and participation from polar residents, schoolchildren, the general public and decision-makers worldwide.” (Rapley and Bell, 2004). SCAR’s focus is on the Antarctic where there are no polar residents but where worldwide interest remains at the highest level. As we know, the formal period for IPY was extended to 2009 on the basis that two field seasons at each pole should be incorporated; the informal period is likely to extend over decades.

SCAR’s Scientific Standing Group in the Life Sciences held a symposium in the northern Japanese city of Sapporo in July 2009 with the same title as this paper, in order to review the status of Antarctic biology in IPY. This paper provides an overview to the larger biological
studies conducted during IPY and is not intended to be comprehensive. Details of the many discoveries and advances will be found in the papers of this symposium, on the websites of the various projects, and increasingly in the international research literature.

2. Biology in IPY

SCAR’s biological contribution to IPY was coordinated by its ‘Evolution and Biodiversity in the Antarctic’ (EBA) Scientific Standing Group, and incorporated scientists and students from more than 25 countries. As EBA’s co-chairs point out, IPY is the first of three previous Polar Years to incorporate a biological approach to Antarctic science and this has led to the development of significant cross-disciplinary research (Convey and di Prisco, 2009). This is welcome as it is in step with the direction international research is taking all over the world and if the momentum set in train during IPY can be maintained into the future it augurs well for a deeper understanding of the processes whereby organisms can adapt to, and survive in cold conditions.

In order to analyse SCAR’s contribution to IPY EBA reported that the IPY Joint Committee had endorsed 15 projects in Antarctic biology. In seven of them more than 20 participants had been identified (Table 1). The 7 major projects — in terms of number of researchers — covered marine biodiversity in the Census of Antarctic Marine Life (CAML), SCAR’s Marine Biodiversity Information Network (SCAR-MarBIN), Antarctic Deep Sea Research (ANDEEP); Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED), Microbial and Ecological Responses to Global Change in Polar Regions (MERGE); Terrestrial Ecosystems in Arctic and Antarctic: Effects of UV Light, Liquefying Ice and Ascending Temperatures (TARANTELLA), and Aliens in Antarctica (ALIENS). The programs that declared they had fewer than 20 participants included effects of glacial melting on marine systems (ClicOPEN), further microbial biology (PAME), indigenous fish (ICEFISH), health of bird populations (BIRDHEALTH), vegetation changes (BTF) and automatic monitoring of penguin populations (AMPPoP). Collectively over 600 scientists and students participated in EBA IPY studies from over 25 countries, of which 47% were female. It is anticipated that when museum staff and other students are included the number of participants may approach 1000. Given that IPY is the first Polar Year that actively encouraged biological research these statistics give comfort that the biological sciences have achieved a high level of acceptance.

2.1. Marine studies

Four of the main IPY projects were in marine biology, reversing a trend in SCAR that started with the creation of CCAMLR’s Scientific Committee over 20 years ago.

<table>
<thead>
<tr>
<th>Name of project</th>
<th>Abbreviation</th>
<th>Project #</th>
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<tbody>
<tr>
<td>Impact of climate induced glacial melting on marine and terrestrial coastal communities on a gradient along the western Antarctic peninsula</td>
<td>ClicOPEN</td>
<td>#34</td>
</tr>
<tr>
<td>Census of Antarctic marine life</td>
<td>CAML</td>
<td>#53*</td>
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<tr>
<td>Microbial and ecological responses to global change in polar regions</td>
<td>MERGE</td>
<td>#55*</td>
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<tr>
<td>Terrestrial ecosystems in Arctic and Antarctic: effects of UV light, liquefying ice, and ascending temperatures</td>
<td>TERANTELLA</td>
<td>#59*</td>
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<td>Antarctic benthic deep-sea biodiversity: colonisation history and recent community patterns—system coupling</td>
<td>ANDEEP-SYSTCO</td>
<td>#66*</td>
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<tr>
<td>Polar aquatic microbial ecology</td>
<td>PAME</td>
<td>#71</td>
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<tr>
<td>SCAR-marine biodiversity information network</td>
<td>SCAR-MarBIN</td>
<td>#83*</td>
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<tr>
<td>Integrating climate and ecosystem dynamics in the southern ocean</td>
<td>ICED</td>
<td>#92*</td>
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<tr>
<td>International collaborative expedition to collect and study fish indigenous to sub-Antarctic habitats</td>
<td>ICEFISH</td>
<td>#93</td>
</tr>
<tr>
<td>Integrated circumpolar studies of Antarctic marine ecosystems to the conservation of living resources</td>
<td>AMES</td>
<td>#131</td>
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<tr>
<td>Aliens in Antarctica</td>
<td>ALIENS</td>
<td>#170*</td>
</tr>
<tr>
<td>Health of Arctic and Antarctic bird populations</td>
<td>BIRDHEALTH</td>
<td>#172</td>
</tr>
<tr>
<td>Evolution and biodiversity in the Antarctic</td>
<td>EBA</td>
<td>#173*</td>
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<tr>
<td>Vegetation changes in the polar regions</td>
<td>BTF</td>
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</tr>
<tr>
<td>Automatic monitoring of Penguin populations</td>
<td>AMPPoP</td>
<td>#251</td>
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Projects marked with asterisks includes more than 20 collaborators.
The CAML sampled about 350 sites in the high-latitude Southern Ocean for pelagic, demersal and benthic fauna with many kinds of sampling gear. Continuous plankton recording equipment sampled over 24,000 nM of ocean. More than 15,000 sample lots were returned from voyages for laboratory analysis. Many thousands of samples were specially prepared for genetic barcode analysis. Data flowing into SCAR-MarBIN now number over 14,000 taxa with 8600 species authenticated by taxonomic experts [www.scarmarbin.be]. Currently there are over 1 million geo-referenced data points culled from over 135 databases, including many stretching back over 5 decades. This database, housed in the Royal Belgian Institute of Natural Sciences, is a major legacy from IPY providing future researchers with a new platform of knowledge for the development of marine biodiversity studies. It is probably the single largest IPY Antarctic biological legacy.

As Alison et al. (2009) point out, the emerging picture is one of rich and complex marine faunas around Antarctica which indicate that, as far as the marine environment is concerned, the southern polar region is far from species poor; on the contrary, there is evidence that high-latitude waters have acted as a source of speciation and the Antarctic Circumpolar Current has acted as an expressway for distribution of species into more northerly waters (e.g. as shown by Strugnell et al., 2008 for deep-sea octopus species). Evidence is emerging to show that truly circum-Antarctic species are uncommon but that there are many examples of cryptic species. The almost-routine application of genetic barcoding techniques to large number of Antarctic samples will yield a heavy harvest of new information about species relationships in the years ahead. Examination of the databases from the Arctic and Antarctic revealed that over 250 species appear to occur in both the Arctic and Southern oceans. This is to be expected for birds and whales that annually migrate across the globe but to find the phenomenon in sedentary, benthic organisms is surprising. Genetic analyses are currently underway to determine if the phenomenon is, in fact, real and early observations suggest that it is not. If confirmed these observations throw up a problem of wider significance — that of the reliability and inconsistency of taxonomic determination based on morphological characteristics. Despite these very real new understandings in our knowledge of marine fauna the rich MarBIN database reveals how little we know and how under-sampled are the deeper waters around Antarctica and how relatively oversampled are some parts of the shallow, near-shore waters.

2.2. Invasion studies

With the seemingly inexorable rise in visitations being made to Antarctica the ALIENS program is particularly timely. Over the past decade the Antarctic Treaty Consultative Meeting (ATCM) has been concerned about the consequences of accidental introductions of exotic species to the Antarctic continent, as we know have occurred in the sub-Antarctic islands (Frenot et al., 2005). The ALIENS program took a measured approach to examining the organisms which hitch-hiked to Antarctica aboard the clothing, backpacks and on the boots of human travellers. Perhaps surprisingly the data show that tourists carry fewer plant and animal propagules with them than tourist support staff and scientists from national Antarctic programs. Footwear and backpacks provide the richest source of unwanted aliens. Missing from the ALIENS program was an examination of microbes hitching rides to Antarctica, an understandable omission in view of the vastly increased work and institutional support that their inclusion would have necessitated. Further information about ALIENS can be found elsewhere in this volume.

2.3. Microbe studies

Major microbe studies in the Antarctic have focussed primarily on the curious moss pillars which have been found in lakes close to Syowa Station (69°00’S 39°35’E). Moss pillars cyanobacterial, algal and bryophyte mats measuring up to 600 mm in height and 400 mm in diameter at the base and consist of a community characterised by Leptobryum, a genus unknown in the Antarctic terrestrial bryoflora, and often associated with Bryum pseudotriquetrum (Imura et al., 1999). In the MERGE program concerted analysis of the composition of the pillars was undertaken revealing that about 20% of the micro-organisms are cyanobacteria and proteobacteria — the remainder are unidentified. These were identified from the outer bottom-most part of the pillars; much remains yet to be elucidated about these fascinating assemblages. As the world turns its focus ever more to new sources of organisms which might produce biologically active molecules, interest in the microbial communities of moss pillars with continue to grow.

2.4. Terrestrial studies

On dry land experimental research into the productivity of Arctic and Antarctic soils shows that, with a warming of 0.5—1.0°C, Antarctic soils can markedly increase respiration rates, suggesting that
the highest predictions of global warming come about significant changes to terrestrial environments can be anticipated. TARANTELLA conducted a series of field observations in many locations in both Polar Regions, using the well-tried methodology of open-top chambers as mini-greenhouses. The effects of UV-B was studied through the use of UV-B lamps to increase radiation, or foil patches to exclude it. The observation that the vegetational response to changed climate conditions is swift and obvious is consistent with popular opinion about the consequences of global warming. Scientists in TARANTELLA are now engaged in quantifying the effects of subtle change in climate and its results will take our understanding of the consequences of climate change to a new level.

2.5. Legacies

Many significant legacies have been left upon which new research can be built in the ensuing years and decades. The most significant legacies for the future are databases and IPY has created and is creating valuable new resources for the future. Major biodiversity databases in SCAR-MarBIN and process databases in ICED will prove invaluable for work on ecosystem function in the face of change. The initiative of a Southern Ocean Observing System (SOOS) came from an ad hoc meeting of marine biologists held during SCAR’s Open Science Conference in Hobart in 2006 and supported by the Alfred P Sloan Foundation in New York. Developed subsequently through a series of workshops SOOS may yet become the most enduring legacy of IPY with a global significance that far transcends its initial humble beginnings.

Molecular approaches to taxonomy have demonstrated that problems of assumed circum-polarity are able to be examined, and as has been demonstrated with the colonisation of the deep sea by octopus species these techniques can start to link past changes in the physical environment to speciation and dispersal. It can be predicted with some certainty that the value of the genetic databases collected during IPY will eventually be taken as the starting point for modern Antarctic biological research. The declaration by CCAMLR of two Vulnerable Marine Ecosystems in 2008, based upon marine biodiversity data, is a lasting societal legacy of IPY.

2.6. The future

Where does Antarctic biology go from here? Given that the environment is most at risk in the face of climate change and the change in the natural environment of living organisms it is unsurprising that the Committee for Environmental Protection of the ATCM is establishing a research agenda requiring much input from the biological community. A five-year work plan was adopted at the ATCM in New Delhi in 2007, much in the same way that the Scientific Committee of CCAMLR sets out a future program of scientific research. As a community we will have to respond to our National Programs’ commitments to this requirement. SCAR has already taken the lead by producing a comprehensive report on climate change in the Antarctic and its environmental consequences which goes some way to integrating physical changes with biotic response (Turner et al., 2009).

We can predict that we will be increasingly drawn into the consequences and advantages of biological prospecting — a topic which has been around the agenda of the ATCM for several years without, yet, taking centre stage. The cumulative impact of humans on the Antarctic environment has been referred to SCAR by the ATCM a few times in recent years, and there have been a number of workshops and symposia. The topic is far from settled and will assuredly return. The future will see expansion of biological prospecting for biochemicals and useful gene sequences in Antarctic organisms, as well as for harvesting Antarctic organisms as aquaculture food. The matter of bio-prospecting has been considered by ATCM over the past decade with a number of useful papers and presentations made to parties. The Convention on Biological Diversity does not apply to waters around Antarctica as it is binding only on nation states. Nevertheless the United Nations University maintains a database on patents taken out on materials obtained from, or derived from Antarctic organisms (http://www.bioprospector.org/bioprospector/antarctica/home.action) with links to 185 patents, and at ATCM 17, held in Kiev in 2008, Belgium presented a valuable summary of the issues lying ahead (Working Paper 11). More recently in October 2009, Australia presented a paper to the Scientific Committee of CCAMLR (SC-CCAMLR-XXViii/BG/15) on “The use of patent databases to detect trends in the krill fishery” and suggests that the CCAMLR Secretariat take over the patent database on krill to maintain it as an index of future trends in the krill fishery. A total of 812 krill-related patents have been lodged from 1976-March 2009 and the annual trend shows no signs of flattening (and only 4 are included on the UN University database). Antarctic organisms are of value across a wide range of industries — krill are used for aquaculture food, nutrient supplements, low temperature enzymes, anti-freeze proteins and in cosmetics. A growing range
of other organisms are currently being investigated including particularly sponges and tunicates, and the number will grow. Although responsibility for issuance of permits for taking marine organisms rests with CCAMLR, SCAR must ensure it works closely with CCAMLR to ensure biological inventories are up to date and are more representative of the biota of the high-latitude Southern Ocean. It would run counter to the letter and spirit of scientific cooperation that sits at the heart of the Antarctic Treaty if bio-prospecting activities were to adversely affect the free flow of scientific data. That is a challenge for the ATCM.

In recent years the UN has passed a number of resolutions concerning the marine environment in general (e.g. 59/24 (2004), protecting deep-sea biodiversity on the high seas, and 61/105 (2006) concerning sustainable fisheries), and there can be no argument that the debate about marine environmental protection will grow in the years and decades ahead. As far as the high-latitude Southern Ocean is concerned SCAR should position itself strategically, in collaboration with CCAMLR, to contribute scientific data and analyses. Current discussions about bio-regionalisation of the Southern Ocean are in urgent need of biological input and we have little enough at present to provide. Much the same applies to the recently adopted (June 2007) Systematic Environmental Geographic Framework for Antarctica. This designates ‘environmental domains’ in Antarctica in terms of ice, bare rock, precipitation and other climatic variables, but lacks adequate biological data.

The future will demand ongoing long-term observational science for purposes of monitoring vulnerable habitats and species. The Antarctic biological community is currently working with, and assisting the development of sophisticated electronic data gathering devices that will expand our understanding of species biology as the environment subtly changes. Such studies will continue to underpin our knowledge of the consequences of environmental change. Remote sensing in biology lacks behind its application in physical science and it behoves us as research biologists to give careful consideration as to whether SCAR should embrace this field as one that will enable us to contribute our full potential to the future.

3. Conclusion

Biological research in the Antarctic is in good heart. The cooperative research undertaken during IPY, its emphasis on involvement of the next generation of Antarctic researchers, and its focus on cross-disciplinary studies have done much to describe the current status of the Antarctic environment and identified some of its pressure points. We biologists have played our part in the success of IPY and gained an intellectual acceptance that previous Polar Years denied. But there’s yet much more to be done, and it is to be hoped that we have enough momentum to give us a good start to the run-up to the next IPY!

References


