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The Antarctic Biological Prospecting Database

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1. Background

An earlier version of the present document was submitted to the XXXI ATCM as Working Paper 11 by the Government of Belgium. Since that time, a number of new records have been added to the Antarctic Bioprospecting Database. Thus the present document is an updated version of the original ATCM paper.

Biological prospecting continues to be a topic of interest and concern to the Parties of the Antarctic Treaty System. The significance attached to this topic is demonstrated by the decision taken by the XXX ATCM to establish an informal open-ended Intersessional Contact Group (ICG) to further examine the issue of biological prospecting in the Antarctic Treaty Area. It is generally acknowledged that bioprospecting is a complex issue, encompassing scientific and commercial interests, environmental concerns, ethics and equity, and considerations relating to international law and policy, including the adequacy of the Antarctic Treaty System to fully address bioprospecting. The ability of the ATCM to deal with the topic of bioprospecting is to a great degree dependent upon a solid informational basis about the level of commercial activity, both actual and potential, relating to Antarctic genetic resources.

The informational basis is currently being improved through the development of a central online database on biological prospecting in Antarctica. This database, though still work in progress, makes available to the user community a wealth of information about the level and outcomes of bioprospecting in Antarctica. A joint initiative of the Government of Belgium (Federal Ministry of Environment) and the United Nations Environment Programme (UNEP), the database has been developed by the United Nations University Institute of Advanced Studies (UNU-IAS). The web-based database will allow access to up-to-date information on bioprospecting. The aim of the database is to address existing information needs in a more comprehensive manner and allow for a more thorough consideration of the issues by the ATCM.

Information presently in the database demonstrates that there is considerable commercial interest in Antarctic genetic resources, and that products sourced from Antarctic genetic resources are already being marketed by a number of companies. These products include nutraceuticals from krill oil, anti-freeze proteins, anti-cancer drugs, enzymes and compounds for cosmetic products. Much of the commercial activity has focused on the marine environment, in particular krill. The rest is based on a variety of Antarctic source organisms which include micro-organisms, invertebrates (such sponges, tunicates, corals, sea stars and worms), vertebrates (such as fish) and plants (such as algae and Antarctic hairgrass). A considerable number of companies and research organizations from several countries are involved in the commercialization of Antarctic genetic resources. In addition, new scientific research currently being carried out, for example on venoms and other defence chemicals of marine invertebrates may result in interesting commercial applications in the future.

2. Introduction to the database

An updated version of the Antarctic Biological Prospecting Database is currently available on-line at http://www.bioprospector.org/bioprospector/antarctica/search.jsp. The database provides a searchable interface allowing the user to obtain information about research and commercial products arising from biological samples that were sourced from the Antarctic region. The information currently in the database (187 records) has been obtained from a variety of existing sources on bioprospecting, including publicly available information on the internet, records of appropriate patent offices, market trends, demand for biological compounds and genetic resources, and trends in research and development. The information has been collected and collated by UNU-IAS staff and through collaborative research.

The database contains two types of records: (i) those that have resulted in commercialization, either in the form of a patent (or patents) that have been filed, or in the form of an actual product that has been developed and is being marketed; and (ii) those that relate to scientific research that may have future potential for commercial development, but have not yet resulted in patents or other form of commercialization. While the database can be considered relatively complete in regards to the first type of record (those that have resulted in commercialization), there is a large amount of scientific research being carried out in Antarctica with unforeseen future applications, and it will be difficult, if not impossible, to include all such research in the

database. Therefore, the scientific research records currently in the database should not be considered complete, but rather a sampling of past and ongoing research. It should also be noted that only research where the scientists themselves identified potential future commercial applications has been included in the database.

At the present time, the database includes searchable information in the following categories:

- **Description**, including the title of the record and a short explanatory description;
- **Research sector**, for example, "pharmaceuticals", "food and beverage industry", "industrial applications", "aquaculture"…;
- **Organisations**, with details of the companies and research organisations involved in the work;
- **Countries**, i.e. countries either sponsoring research, or hosting the organisation undertaking research;
- **Commercialisation information**, including benefit-sharing terms, patents or other forms of Intellectual Property, commercialised product(s), market information, and actual or potential value;
- **Source organism**, including taxonomy, common name(s), area and method of collection, and geographic coordinates; and
- **References**, including publications, web sites and other sources of further information.

More information on the database and its search functions can be found in annex 2 of this document.

Sections 3 and 4 of this document provide a summary of the current content of the database. They review bioprospecting both in the terrestrial and marine environments. Section 3 provides an overview of the level of biological prospecting in Antarctica, while section 4 recounts specific examples of biological prospecting in the marine and terrestrial environments. Section 5 describes other resources made available to users in conjunction with the database. Finally, section 6 presents further observations that can be drawn from an analysis of the current content of the database, while section 7 contains conclusions.

3. An overview of the level of biological prospecting in Antarctica

The analysis in this section considers only those records in the database that have resulted in commercialization, either in the form of a patent or a product on the market.

3.1. Proportion of bioprospecting occurring in each biome

Although it should be stressed that the Antarctic Biological Prospecting Database is still work in progress, some patterns can be seen emerging from its current content. The database records relating to commercialization have been assigned into one of three biomes: terrestrial, marine or inland water (encompassing both lakes and streams). As can be seen in figure 1 below, a small majority (50%) of those records originate from the marine environment of the Southern Ocean. The terrestrial environment provided the source organisms for 43% of the records. Only 3% came from inland water environments, and consist mainly of organisms collected from hypersaline Antarctic lakes. The unknown records (4%) were generally bacteria whose location of collection was not stated.

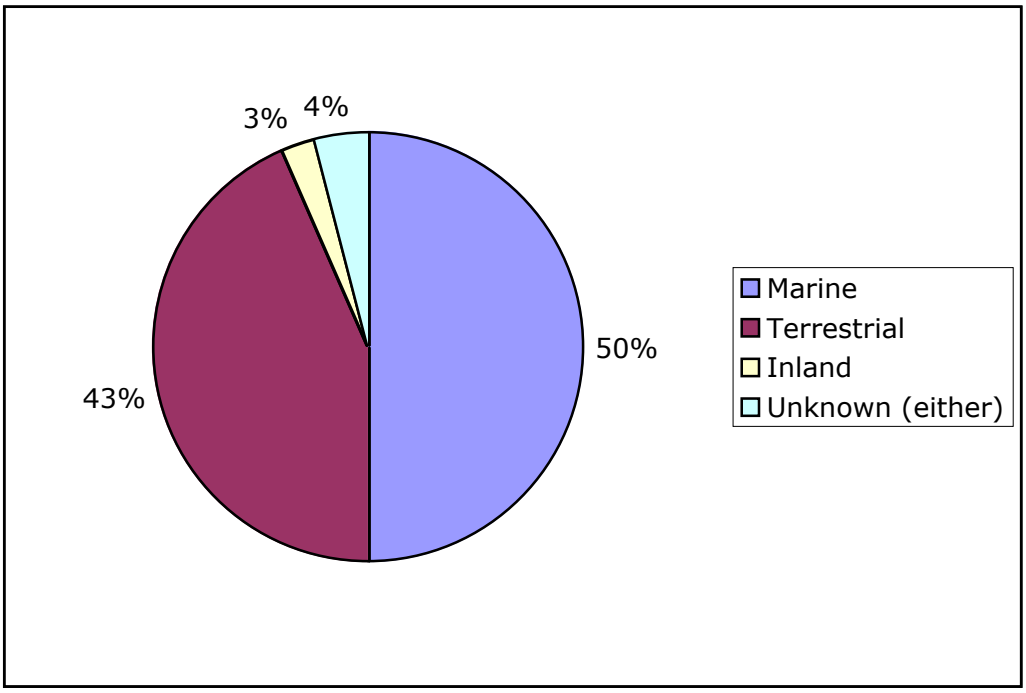

Figure 1: Breakdown of records for each biome. 50% of the records in the Antarctic Biological Prospecting Database relate to organisms collected from the marine environment, while 43% relate to terrestrial ecosystems and only 3% to inland water ecosystems. In addition, 4% of the records are of unknown origin. These records are generally bacteria, which could occur either in marine or terrestrial environments, and which might have been sourced from culture collections.

3.2. Types of source organisms and their uses

There are differences in the marine and terrestrial source organisms for bioprospecting in Antarctica. As can be seen in figure 2, the majority of commercialized terrestrial records in the database are based on yeasts and molds (in particular the yeast *Candida antarctica*), as well as bacteria and other micro-organisms. Other organisms, such as Antarctic hairgrass, fungi and lichen have also been used as source organisms for various commercial applications. The very few inland water records consist of bacteria, cyanobacteria and fresh-water algae.

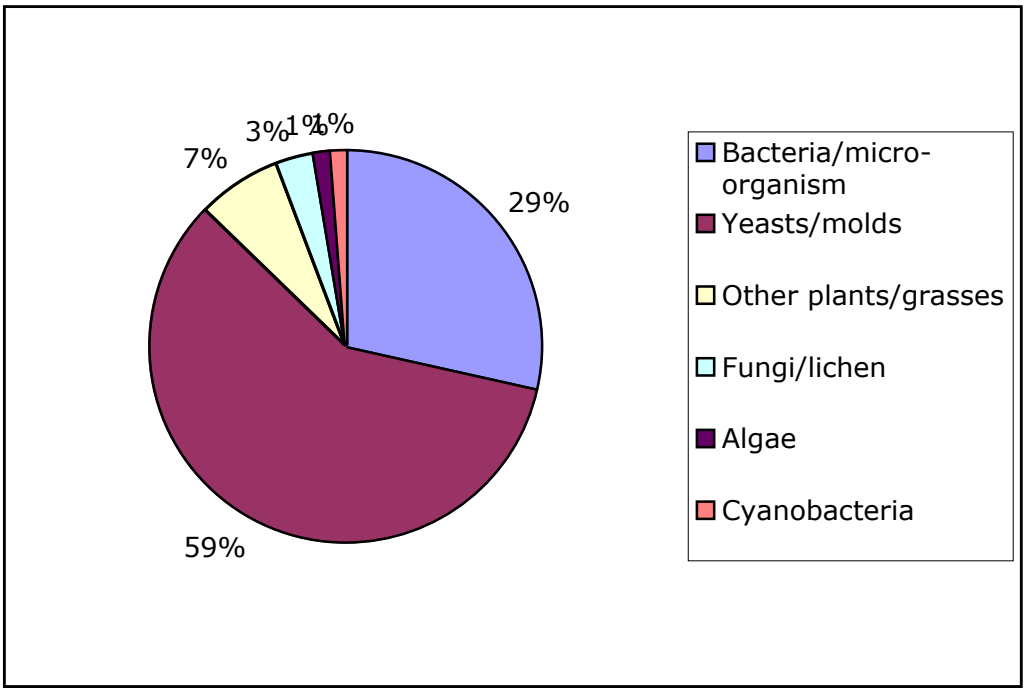

Figure 2: Source organisms for terrestrial (including inland water) bioprospecting in Antarctica. Yeasts and molds make up 59% of the terrestrial records, with bacteria and other micro-organisms also being popular source organisms at 29%. The rest of the records consist of other plants and grasses (7%), fungi and lichen (3%), freshwater algae (1%) and cyanobacteria collected from a stream (1%).

In contrast to the terrestrial records, the majority of the commercialized marine records in the database are based on various products derived from krill. As indicated in figure 3, the rest consist mainly of invertebrates (sponges and tunicates), bacteria, fish and algae.

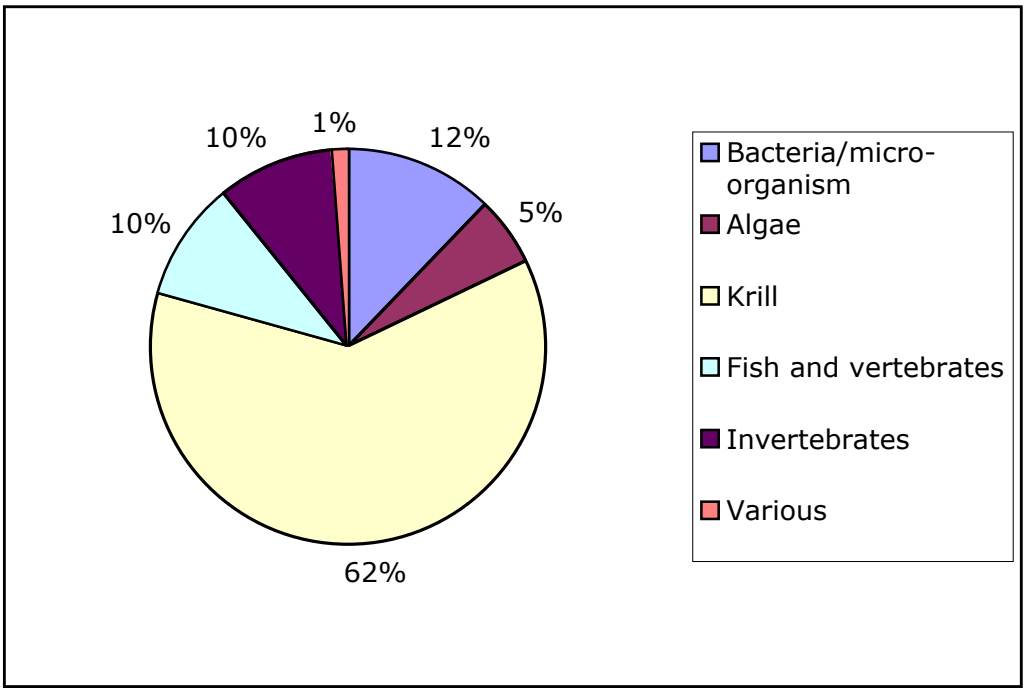

Figure 3: Source organisms for marine bioprospecting in Antarctica. Krill make up 62% of the commercialized marine records, while bacteria come in second at 12%. Invertebrates (sponges and tunicates) make up 10% as do fish and vertebrates. Of those records, the majority relate to fish, with one record relating

to the King Penguin (use of bacterial flora in penguin stomach contents for preservation of food). The rest of the records include marine algae (5%) and various unspecified marine organisms (1%).

As can be seen in figure 4 below, the biggest users of Antarctic genetic resources are the pharmaceutical/medical technology industries and the food and beverage and chemical processing industries. The molecular biology and biotechnology industries, other industrial applications, and the cosmetics and personal care industries are also major users of genetic resources from Antarctica.

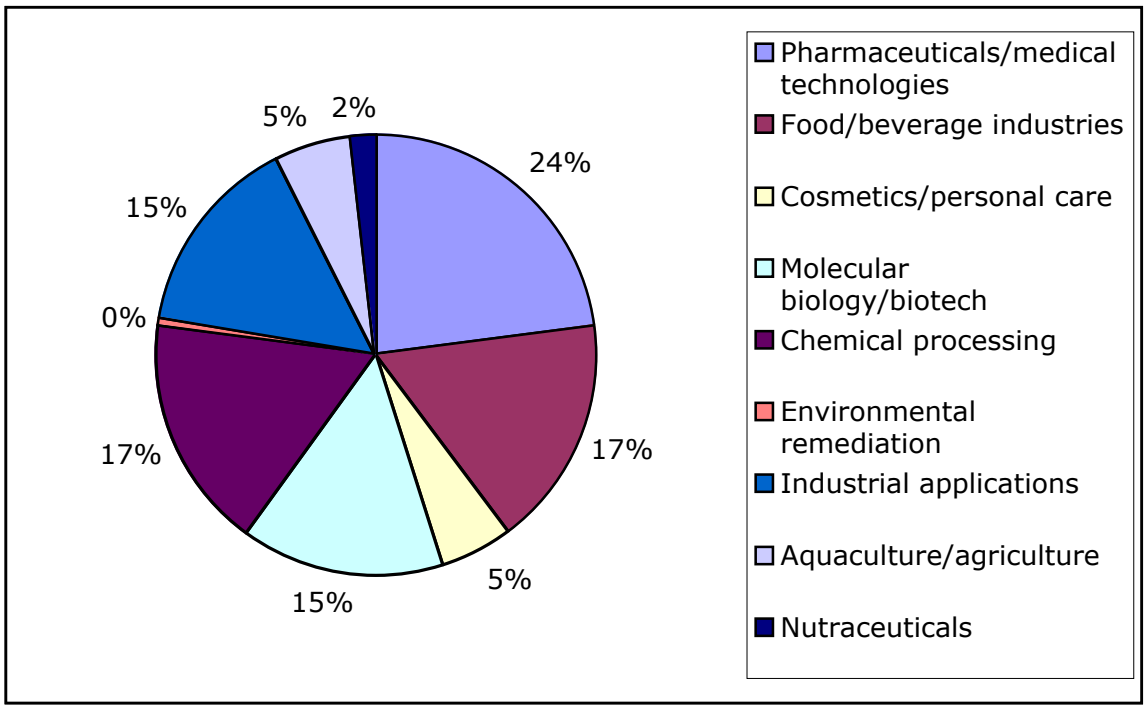

Figure 4: Types of uses of Antarctic genetic resources. The biggest user of genetic resources in Antarctica is the pharmaceutical/medical technology industries (24%), followed by chemical processing (17%) and the food and beverage industry (17%). Molecular biology and biotechnology (15%), industrial applications (15%), cosmetics and personal care (5%), aquaculture and agriculture (5%), nutraceuticals (2%) and environmental remediation (less than 1%) are other users of Antarctic genetic resources.

As was the case with source organisms, the uses of Antarctic marine genetic resources are somewhat different from their terrestrial counterparts. As can be seen in figure 5, marine genetic resources from Antarctica are more commonly used in the pharmaceutical, food and beverage and cosmetics and personal care industries. Marine organisms, namely krill, are the only patented Antarctic source organism for the nutraceuticals industry. The greater level of pharmaceutical use of compounds of marine origin can be generally accounted to the anti-cancer properties found in the Antarctic marine sponge *Kirkpatrickia varialosa* and tunicate *Synoicum adareanum*, as well the proposed use of krill-derived compounds for the treatment of various ailments. Krill, marine algae and other marine organisms are responsible for the dominance of marine-sourced compounds in the cosmetics/personal care industries, while krill has been commonly used for various industrial applications. Terrestrial genetic resources are more commonly used for the chemical processing and molecular biology and biotechnology industries. These industries use terrestrial micro-organisms, including bacteria and the yeast *Candida antarctica*, as sources of enzymes and DNA extraction reagents, which help in the process of purifying DNA from cells for use in molecular biology. Although marine microalgae and bacteria have also been used for these purposes, they seem at the present time to be under-utilized as source organisms for bioprospecting.

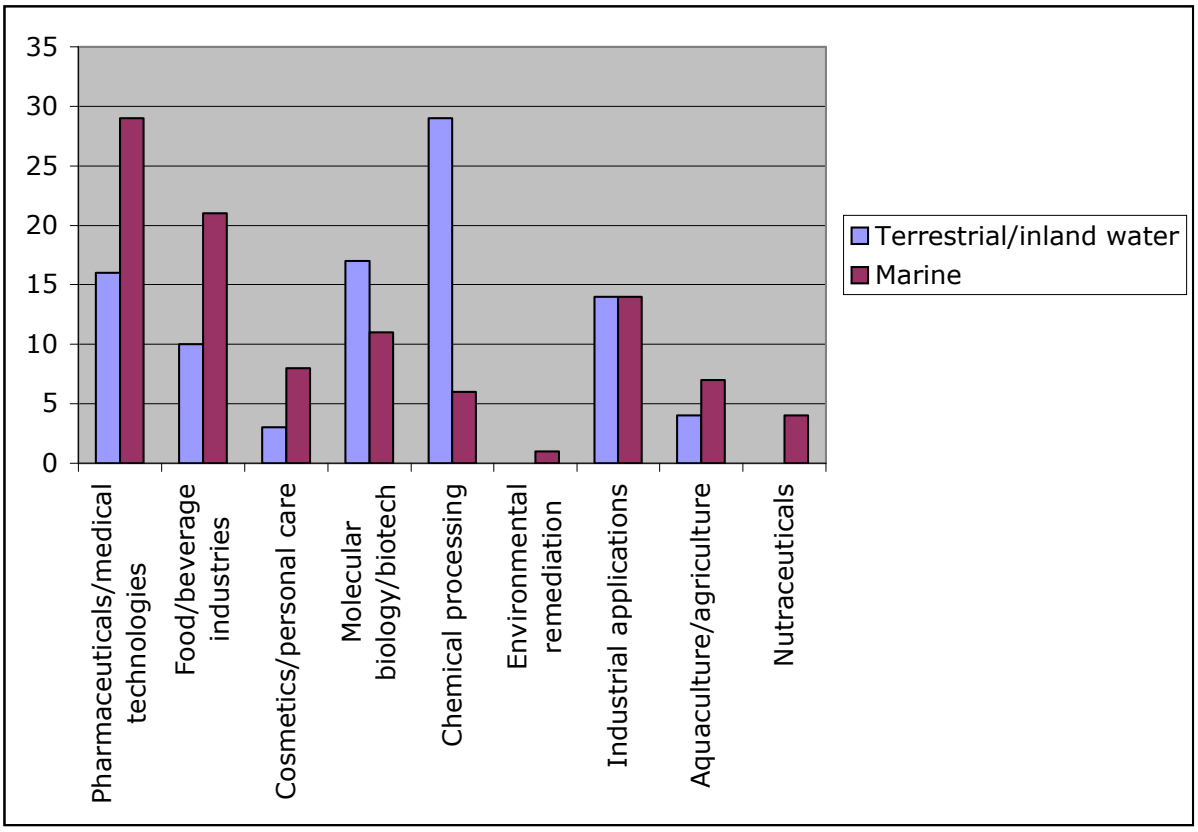

Figure 5: Comparison of uses of marine and terrestrial/inland water genetic resources. Marine genetic resources are more commonly used in the pharmaceutical/medical technology, food and beverage, cosmetics/personal care industries, as well as for general industrial applications. Terrestrial genetic resources are more commonly used for molecular biology/biotech and chemical processing industries.

3.3 Countries and organizations undertaking research and bioprospecting relating to Antarctic genetic resources

Research organizations and companies from a number of countries have undertaken research with actual or potential commercial applications in the Antarctic environment. These countries include (in alphabetical order) Australia, Argentina, Belgium, Canada, China, Chile, Czech Republic, Denmark, France, Germany, India, Italy, Israel, Japan, Korea, Mexico, The Netherlands, New Zealand, Norway, Poland, Russia, Slovenia, Sweden, Switzerland, Spain, United Kingdom, USA. The greatest number of records in the Antarctic Bioprospecting Database originate from Japan, closely followed by the USA. The great majority of the Japanese records are based on source organisms from the marine environment, mainly Antarctic krill. Similarly, the majority of the American records are of marine origin and include krill, bacteria, fish and invertebrates.

Companies and organizations involved in commercially-oriented research and/or development of Antarctic genetic resources, as well as scientific research with potential commercial applications, include A/F Protein Inc, Agriculture Victoria Serv Pty, Aker Biomarine, Alfred Wegener Institute for Polar and Marine Research, Almightly KK, Angulas Anguinaga, Antarctic Pharma AB, Aqua Bounty Technologies, Arcimboldo AB, Arunachal University, Australian Antarctic Division, Benares Hindu University, Biozyme Systems Inc., Board of Regents of the University of Texas System, Canceropole Grand Ouest, Centre National de la Recherche Scientifique, Clarins, Complesso Universitario, Council of Scientific and Industrial Research, Daicel Chem, Daiwa Kasei, DSM NV, Enzymotec, Florida Institute of Technology, Georgetown University Medical Center, Good Humor-Breyers Ice Cream, Green Blueprint International, Henkel, IFREMER, Institute of Advanced Industrial Science & Technology, Institute of Chemical Technology, Instituto Antártico Argentino, Ista Pharmaceuticals Inc., Istituto per la Chimica di Molecole di Interesse Biologico (ICMIB) del CNR, Instituto de Productos Naturales y Agrobiologi´a del CSIC, J. Craig Venter Institute, Kang Jae Shin, Kao Corp, Kansai University, Katayama Tarou, Korea Food Research Institute, Korea Ocean Research and Development Institute, Landcare Research, Lipotec S.A., Ljakh Pavlovna,

Loders-Croklaan BV, Lu Gao, Magellan BioScience, Martek Biosciences Corporation, Molecular Plant Breeding CRC, Morski Inst Rybackis, Nagata Sangyo, Natural ASA, Neptune Technologies & Bioress, New England Biolabs, New Mexico Tech Research Foundation, Nichiwa Sangyo, Nihon Nosan Kogyo, Nippon Paper Industries, Nippon Suisan Kaisha Ltd, Novartis Institutes for Biomedical Research, Novo Nordisk, Nomura Nobuhiko, Novozymes A/S, Oxford University, Phairson Medical Inc., PharmaMar, Pharmanutrients, Procter & Gamble, ProQinase GmbH, Puratos Naamloze Vennootschap, Regents of the University of California, Rigel Pharmaceuticals Inc, RIKEN Bioresource Center, Shin Dong Bang Corporation, Station Biologique, Roscoff, Symrise, Technical University of Lodz, Third Institute of Oceanography SOA, Tokuyama Corp, Tokyo University of Science, Transucrania, Unilever, Universidad de Barcelona, Universidad de Chile, Universidad de Buenos Aires, Universidad de Cádiz, Universidad de Concepcion, Universidad de la Frontera, Universidad de Santiago de Compostela, Università di Florence, Università di Messina, Universitá di Napoli, Università di Trento, Università di Pisa, Universite de Liege, Universite Lyon, University of Adelaide, University of Alabama, University of Chile, University of Florida, University of Ljubljana, University of London, University of Melbourne, University of New South Wales, University of Shanghai, University of South Florida, University of Tasmania, Universität Zürich-Irchel, US Department of Energy Joint Genome Institute, Verenium, Vitrogen SA, Yellow Sea Fisheries Research Institute and ZyGEM. This list is not exhaustive.

4. Some examples of biological prospecting in Antarctica

4.1 Marine biological prospecting

The Antarctic krill, *Euphausia superba*, has been the source organism of the largest number of patents and commercial applications of all marine species. The patented applications of krill range from commercial purposes including laundry detergents and other cleaning agents, food processing, food products, chemical processing, molecular biology, enzymes, aquaculture, pharmaceuticals, nutraceuticals, dietary supplements and skin care products. Many of these patents have been filed by companies in Japan, Spain, Chile, United Kingdom, Sweden, Canada, USA, Poland and Korea. Krill-derived enzymes and extracts have been proposed for the treatment or prevention of acne, infections, inflammations, diabetes, immune reactions and certain cancers, as well as for the removal of dental plaque. Another common use of krill is as food for aquaculture, pets and even humans, for example as flavouring in soya sauce. Because krill are rich in Omega-3 fatty acids, krill oils have shown to be beneficial as dietary supplements for humans. Companies such as Canada's Neptune Technologies & Bioresources, Source Naturals (USA) and Norway's Aker BioMarine market a range of vitamins and nutraceuticals derived from krill and krill by-products. Examples of nutritional supplements include NKO Neptune Krill Oil (US$ 21.50 for 30 softgels) and Superba™ krill oil (launched in March 2008). A 2008 European patent granted to Neptune Technologies & Bioresources for krill oil has raised objections from the other two major krill oil producers, Aker BioMarine and Enzymotec, an Israeli company, which have filed their own competing patents. The use of krill oil in food and nutritional products will likely increase in the future, given a recent ruling by a U.S. panel that Neptune Krill Oil is safe as an ingredient in food, paving the way for its wider commercialisation in the USA. Neptune signed research deals in 2007 with Swiss food group Nestle and with the Yoplait dairy unit of U.S. food maker General Mills Inc. over use of krill in foods. Some questions have been raised about potential environmental impact on krill stocks in the future, particularly in the context of potentially expanding krill catches combined with the predicted long term decline in Antarctic krill due to the effects of climate change[1].

Scientific research relating to the chemical ecology of marine invertebrates has shown that many of these organisms have defensive metabolites, which may be of potential future interest for the pharmaceutical industry. Sponges are one of the major targets of chemical investigations in Antarctica and elsewhere because of their high biomass and the presence of novel compounds, some of which appear to have cytotoxic properties. Similar properties, including interesting metabolites, have been found in Antarctic soft corals, molluscs and other invertebrate groups. A new study by the Australian Antarctic Division titled "Venom on Ice" examines the structure and function of venoms in Antarctic marine organisms, such as cephalopods (octopuses and cuttlefish) using cutting edge analytical techniques.

[1] Atkinson, A., V. Siegel, E. Pakhomov, and P. Rothery, 2004: Long-term decline in krill stock and increase in salps within the Southern Ocean. *Nature*, 432, 100-103.

The commercial developments of marine invertebrates that have taken place thus far relate to sponges and tunicates. The Antarctic sponge *Kirkpatricka varialosa* is the source of a potential cancer drug, Variolin, which has been patented and is now being tested in-vivo by the Spanish pharmaceutical company PharmaMar. Complete synthetic derivatives of Variolin have also been developed and patented. In addition, Variolin is one of the two compounds used to produce Meriolins, a new class of potentially promising anti-cancer drugs. Meriolins are a chemical structural hybrid between Meridianins and Variolins, and seem to display better properties in human tumor cell cultures than their parent molecules.

The University of South Florida has shown that extracts from the tunicate *Synoicum adareanum* show selective toxicity against several different cancer cell lines, and may be useful in the treatment of cancers, particularly malignant melanomas, colon cancer, and renal cancer cell lines. The potential drug, Palmerolide A, is in preliminary experiments with laboratory mice at the United States National Cancer Institute. These experiments have shown that Palmerolide A maintains its test tube melanoma-killing properties in living tissue. Full testing on a mouse melanoma model should begin soon, but development of a human treatment using the compound will take years. A new patent application filed in 2008 by the University of Texas provides for the synthetic manufacture and derivatives of Palmerolides, providing for a way to manufacture this cancer-fighting compound without the utilization of the original source organism. If successful, these new cancer medications might generate similar annual sales to other successful cancer drugs such as Avastin ($2.7 billion per year) or Herceptin ($1.3 billion per year). However, it must be kept in mind that most of the experimental medicines do not lead to commercial drugs.

Marine bacteria collected from seawater, sea ice and abyssal ooze have also lent themselves to commercial applications. For example, the bacterium *Pseudoalteromonas haloplanktis* collected from Antarctic seawater has yielded enzymes that are able to function at extremely low temperatures, and can be useful as novel tools for biotechnology. Exopolysaccharides (EPSs) are abundant in the Antarctic marine environment, for example, in sea ice and ocean particles, where they may assist microbial communities to endure extremes of temperature, salinity, and nutrient availability. Several EPS produced by microbes from these extreme environments are showing biotechnological promise. The psychrophilic bacteria HK-47, collected from the oceans surrounding Antarctica, has yielded a new, heat sensitive form of the enzyme alkaline phosphatase. This phosphatase is useful as a research tool, particularly for radioactive end-labeling of nucleic acids. There is demand globally for these types of enzymes, and the international enzyme market is valued at a minimum of $50 billion a year, with growth occurring at between 3% and 5% in each of the past several years. In general, the microbial biodiversity of Antarctic ecosystems is relatively unexplored and these ecosystems can thus be considered reservoirs of microbial biodiversity that are largely unexploited.

Fish (Cold Ocean Teleost Fish) from the Southern Ocean have been a source of patented anti-freeze proteins. The fish anti-freeze proteins are used for the control of cold-induced damage in medical, food, and cosmetic products, and are marketed by the American/Canadian company A/F Protein Inc. as “antifreeze protein type I”, “antifreeze protein type III”, and “antifreeze glycoprotein”. Some proposed and actual applications include improving the survival of biological materials, for example in transplant surgery, improving aquaculture production in cooler climates, and lengthening the shelf life of frozen foods.

The cosmetics and personal care industries have used Antarctic marine algae and other organisms in their products. The French cosmetics giant Clarins uses the algae *Durvillea antarctica* in its Extra Firming Day Cream, which it markets for the treatment of mature skin. Algae from the Antarctic are claimed to provide resistance to pollution, central heating and other hazards. Launched in 1996, this product quickly became a top seller with a 1.7 fl.oz. (50ml) jar costing US$ 75. In addition, Mycosporine amino acids found in a myriad of Antarctic marine organisms are thought to have potential as sunscreen agents.

Some marine algae are also thought to have properties of pharmaceutical interest. For example, plastoquinones isolated from the brown alga *Desmarestia menziesii* have cytotoxic activity against leukemia cells, toxicity to fish, and are thought to inhibit mitosis of fertilized sea urchin eggs. No commercial developments have resulted from these findings as of yet.

4.2 Terrestrial and inland water biological prospecting

Micro-organisms, in particular extremophiles, have been some of the most common Antarctic source organisms for bioprospecting, particularly in the terrestrial and inland water environments. One interesting example of such applications is the use of anti-freeze proteins from a variety of bacteria, including *Marinomonas protea*, *Pseudomonas sp*. and *Moraxella sp*. in the frozen food industry, especially the ice

cream industry. Marinomonin, an anti-freeze protein of a bacteria sourced from a hypersaline Antarctic lake could be added to ice cream to keep it creamy through the process of thawing and refreezing. The patent for this invention belongs to one of the biggest ice cream companies, Unilever (the owner of both Ben & Jerry's ice cream and Breyer's ice cream). With its 16% share of the $59 billion global ice cream market, this invention, if successful, could be bring considerable profit to Unilever.

Another interesting use of an enzyme derived from a micro-organism (*Bacillus sp*.) found in a volcanic vent in Antarctica is as a reagent that enables DNA extraction from diverse sample types. This reagent is said to increase the speed and accuracy of the DNA extraction process. The reagents are marketed by the New Zealand company ZyGEM for the human and animal DNA testing industries. ForensicGEM™ is used to extract human DNA from crime scene samples, while prepGEM™ is used in animal DNA testing. ZyGEM also maintains a large proprietary Antarctic culture collection.

Equally interesting is recent research that demonstrates that bacteria (*Nocardiaceae, Rhodococcus or Gordonia sp*) isolated from Antarctic soils can degrade hydrocarbons such as petroleum distillates that may be found in the Antarctic region as a result of accidental oil spills. This work, by Landcare Research of New Zealand, shows that hydrocarbon-degrading microbes, if naturally occurring, could be used for environmental clean-up operations, for example in oil-contaminated soils of the Ross Dependency.

A common source organism for bioprospecting is the Antarctic yeast *Candida antarctica*, which has contributed to numerous patents, as well as commercial products. *Candida antarctica* lipases (enzymes that break down fat) are being used to catalyse chemical reactions ranging from organic chemistry to the paper industry. A *Candida antarctica* lipase is marketed by Novo Nordisk of Denmark as Novozyme 435™ and commonly used in a variety of commercial applications.

Another yeast, the Antarctic black yeast (*Nadsoniella nigra*) is the source of a melanin-containing product called Astromelanin, which has been the subject of a number of Russian patents. Astromelanin is marketed as an anti-cancer agent, as well as an agent for the treatment of a variety of conditions including osteochondrosis, arthritis/osteoarthritis, radiculitis, various pain syndromes, cardiac and gastroenterological pathologies, gynecological affections, stress, immune problems, and psycho-emotional disorders.

The cosmetics and personal care industries have used Antarctic algae and other organisms in their products. The green algae *Prasiola crispa* has been patented by the German company Henkel for use as a cosmetic skin care and treatment composition, including for sun protection and as an after-sun cream. *P. crispa* colonizes aquatic and terrestrial biotopes enriched in minerals by birds and seals, and its spreading has been observed in areas of increased human activity, thus making it readily available for collection.

Relatively new and novel applications of Antarctic genetic resources include research by the Australian Molecular Plant Breeding Cooperative Research Centre (MPBCRC), backed by a group of farmers, to develop frost-resistant, genetically modified wheat using a gene from Antarctic hairgrass (*Deschampsia Antarctica*). The frost tolerant gene creates a protein that inhibits ice crystal growth on the plant. This research is still at the proof-of-concept stage, and a long way from commercial development.

The above provide some selected examples of Antarctic biological prospecting. These and other examples can be found in the Antarctic Biological Prospecting Database at http://www.bioprospector.org/bioprospector/antarctica/search.jsp.

5. Tools and resources relating to biological prospecting

The Antarctic Biological Prospecting Database also contains a section relating to resources. This section provides access to tools and resources relating to bioprospecting in Antarctica, including work of the ATCM, scientific and policy publications, research programmes, biotechnology companies and legislation. It is hoped that these resources will assist the Parties to the Antarctic Treaty System in considering issues of relevance to bioprospecting. The compilation is a work in progress and suggestions for inclusion are welcomed.

The following sections are currently included:

- **Relevant international conventions and processes**. This section provides links to, for example, the Antarctic Treaty Secretariat, Scientific Committee on Antarctic Research, UN conventions such as the

Convention on Biological Diversity and the UN Convention on the Law of the Sea, as well as processes, such as the World Trade Organization and the World Intellectual Property Organization.

- **Ongoing relevant research projects**. This section provides links to ongoing research projects of interest to biological and microbial diversity and genetic resources in Antarctica. The information has been sourced from the ATS Annual Reports.

- **Research programmes, societies and other relevant websites**. This section provides links to a large number of programmes and initiatives that undertake Antarctic or polar research, or disseminate information of relevance to Antarctica.

- **Selected companies with interest in Antarctic micro-organisms**. This section provides links to the websites of companies with interests in Antarctic genetic resources.

- **Documents of the ATCM relevant to bioprospecting.** This section provides links to all ATCM documents that have dealt with this topic.

- **Legislation relevant to access and benefit-sharing (ABS).** This section includes ABS legislation from a number of ATS countries. This section will be made more comprehensive in the near future.

- **Access and benefit-sharing (ABS).** This section includes ABS guidance and standards, sample ABS agreements and case studies.

- **Intellectual property.** This section includes information about the valuation and exploitation of intellectual property and the use of patents for research purposes.

- **Biotechnology economics, valuation and statistics.** This section provides links to reports relating to the status and potential of the biotechnology market.

- **Selected publications.** This section includes a summary of the status of marine bioprospecting in Antarctica, libraries and archives relevant to polar research, and listings of both policy and scientific publications.

6. Observations

The research that has been undertaken in the context of the Antarctic Bioprospecting Database, though still preliminary, concludes that there is significant scientific and commercial interest in Antarctic genetic resources and their biotechnology potential. This interest is not new, but has been present for decades, with the earliest patents dating from the 1970s. Of the over hundred records currently in the database, some have already resulted in products that are being marketed. The products currently on the market include nutraceuticals, anti-freeze proteins, anti-cancer drugs, enzymes and cosmetic creams. They are based on a variety of Antarctic source organisms which originate from the marine, terrestrial and inland water environments, and include micro-organisms, invertebrates (such as krill and sponges), vertebrates (such as fish) and plants (such as algae and Antarctic hairgrass). A considerable number of companies and research organizations from several countries are involved in the commercialization of Antarctic genetic resources.

Many of the filed patents and already-developed products are of actual or potential benefit to society. Examples include Variolin, a potential anti-cancer compound originally isolated from an Antarctic marine sponge, as well as the Antarctic bacteria Nocardiaceae, which has the ability to degrade hydrocarbons in soils, making it of potential use in bioremediation. One of the challenges facing the ATCM is thus how (or whether) to regulate biological prospecting, including potential environmental impacts and benefit-sharing issues, without discouraging the use of research findings for beneficial commercial purposes.

The interest in Antarctic genetic resources will not disappear, but rather is likely to increase in the future, mirroring similar developments in the Arctic[2]. The biotechnology potential of extreme and isolated environments has not yet been fully exploited. For example, much more research remains to be undertaken on marine micro-organisms, which have thus far received less attention than their terrestrial counterparts. It is likely that the cold oceans and light-deprived deep seas surrounding the Antarctic continent hold organisms with unique physiological and biochemical adaptations of interest to biotechnology. Similarly, the remote Antarctic continent is still likely to hold new species of interest to commercially-oriented science.

New technologies and techniques, such as the use of 'metagenomics' to sequence the DNA in entire environmental samples, rather than the traditional method of sequencing the genomes of single, cultured species, will expand the possibilities of Antarctic research. Metagenomics
will give access to the genetic information of all organisms in a sample, without the need for isolation and cultivation of the individual components. This approach will provide scientists with a more rapid and expanded view of microbial diversity and function in Antarctica. Metagenomics is central to the newly proposed Australian Southern Ocean Genome-Based Microbial Observatory (ASOMO), which plans to compare whole water samples of archaea and bacteria collected in the same locations in different seasons, to understand the genomic and functional differences that occur in the populations. This will provide information on the diversity, energy generating processes and adaptive capabilities of the microbes, and enable predictions to be made about the impact of continued global warming. It can also contribute to industrial applications, for example bioremediation.

The growing interest in Antarctic genetic resources is supported by the continuing growth of the biotechnology industry at large, including the pharmaceutical, enzyme, cosmetics, chemistry and agricultural sectors. According to the Ernst and Young Global Biotechnology Report of 2007, at 31-years old biotechnology has reached a point where it has "come of age" and now it's on to the maturing years. There is evidence of strengthening pipelines, revenue growth, and progress towards profitability.

As an example of such progress, the world market for pharmaceuticals, which was valued at $643 billion in 2006, is expected to more than double in value to $1.3 trillion by 2020, according to a new report on the future of the pharmaceutical industry released recently by PriceWaterhouseCoopers. In this market, the development of a new and successful medical drug can be highly profitable. The four largest U.S. "Fortune 100" pharmaceutical companies (Pfizer Inc., Johnson & Johnson, Merck & Co. Inc., and Abbott Laboratories) generated combined revenues in excess of $129 billion in 2003. At the same time, the costs of bringing new drugs to the market are staggering. The pharmaceutical industry reports that it can take as long as 15-20 years and cost as much as $800 million to develop and market a new drug. The Pharmaceutical Research and Manufacturers of America further notes that for every 5,000 novel compounds found to have biomedical potential, an average of only five make it into human clinical trials, and only one will receive final approval for commercial patient use.[3] Any success and profit therefore comes at the cost of a considerable investment in research and development.

Similarly, the cosmetics industry (valued at $231 billion in 2005) is predicted to experience market growth with expanding populations and increasing demand for anti-aging products. Antarctic organisms, including algae and krill, are already used in such products. New and developing sectors, such as alternative fuels and bioremediation, are certain to create additional market opportunities, and may result in increased biological prospecting in remote and extreme environments.

This current (and likely future) commercial interest in Antarctic genetic resources has raised questions regarding the environmental impacts of bioprospecting. Generally, such impacts are thought to be relatively minimal at the early biodiscovery stages of collection, where the size of samples collected is small. If a given species has shown biotechnology potential, repeated collection may require larger quantities, raising the likelihood of environmental impact. However, the synthetic manufacture in a laboratory of the chemical of interest generally eliminates the need for repeated collection, as is now the case with potential cancer drugs Variolin and Palmerolide. In addition, if the compound was found in a cultivated strain, it will not be necessary to go back to the sampling site, as the multiplication of the strain in laboratory conditions will generate sufficient biomass. Moreover, if the original strain is not easy to grow and the genes of interest are

[2] Leary, D. (in press) Bioprospecting in the Arctic. A UNU-IAS Report.
[3] http://www.marinebiotech.org/devpartners.html

identified, it is possible to clone them in a new bacterial host with better growth capacities (ex. a laboratory strain of E. coli).

Environment impact remains a concern if the target organism is rare, has a restricted distribution, and/or the collection is focused on a particular population[4]. Also, anthropogenic pressures (such as helicopter landings, impact of camping or skidoos, etc.) can have an impact on pristine environments. Adding to the uncertainty of potential impact is the fact that the population and life history characteristics of many Antarctic source organisms are not well known. Further, the scale of the bioprospecting activity in terms of amount of samples collected, the exact location of collection, and the time period of sampling activity is often not disclosed.

The environmental impacts of bioprospecting may also be of concern when they are cumulative with other pressures already suffered by the source organism. For example, the many patents and large amount of commercial interest in krill may be a source of concern in the context of the long-term decline in the abundance of Antarctic krill that may be associated with reduced sea ice cover caused by climate change[5]. Future expansion of the krill fishery, the development of new fishing techniques, and the lack of precise estimates of the total biomass of Antarctic krill could further add to the concern.

The significant commercial interest in Antarctic genetic resources, and the fact that products developed from these resources are already on the market, raises questions regarding the need to address or somehow regulate biological prospecting in Antarctica in the context of the Antarctic Treaty System. The considerable amount of marine biological prospecting, consisting to a large extent of krill, may also indicate the need for CCAMLR's involvement in any such measures.

7. Conclusions

It is not the purpose of this document to enter into a policy debate. Rather, this document has sought to improve the informational basis that will need to underpin a debate on potential policy responses to biological prospecting. The Database seeks to address existing information needs in a more comprehensive manner and allow for a more thorough consideration of the issues by the ATCM. It will provide a tool for scientists and for governments, which will facilitate information exchange amongst researchers. The Database has been gathered from public records, such as patent databases, scientific journals, the internet and published company literature. Wherever possible the relevant companies and researchers have been consulted to verify the accuracy of the record.

The Database was presented by Belgium to the last ATCM (see in document ATCM XXXI WP-11, *An update on biological prospecting in Antarctica, including the development of the Antarctic Biological Prospecting Database*). The report of the meeting noted that "many Parties highlighted the value of a review of the Antarctic biological prospecting database and the development of working definitions relating to biological prospecting in the Antarctic Treaty area". After consultations at the XXXI ATCM, SCAR agreed to provide a paper at ATCM XXXII in response to the following questions:-

> "1. review the most recent published research that may involve biological prospecting in the Antarctic Treaty region and provide an assessment of these efforts from discovery to development to commercialisation to product use, based on fundamental scientific principles.
>
> 2. provide a survey of ongoing biological prospecting research being undertaken within the SCAR community."

SCAR noted in this connection, that its review of recent research would involve a review of existing databases, including the Database. At XXX SCAR (2008), delegates agreed to provide a paper on bioprospecting for the XXXII ATCM. The deadline for working papers to be submitted to the Antarctic Treaty Secretariat is 20 February 2009. A questionnaire was sent to SCAR National Committee Representatives requesting a reply by 22 November 2008.

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[4] Hunt, B. and A. C. J. Vincent (2006) Scale and Sustainability of Marine Bioprospecting for Pharmaceuticals. Ambio, vol 35, issue 2, pp. 57–64

[5] Atkinson, A., V. Siegel, E. Pakhomov, and P. Rothery, 2004: Long-term decline in krill stock and increase in salps within the Southern Ocean. *Nature*, 432, 100-103.

The Database has been further developed since then. The Database now contains 187 records and provides a wide variety of additional information about the policies of ATCPs and the activities of those involved in biological prospecting in the Antarctic Treaty area.

The Database still has important limitations. It is not comprehensive. For example activities not officially reported or patented are not included, and it is evident from the interviews carried out to develop the Database that there are many activities that fall into this category. Another weakness of the Database is the detail it contains about the level of involvement of companies in Antarctic research. For example, there is very little information about:

- The origin of the Antarctic samples used;
- The arrangements used to access the resource;
- The arrangements used to confirm or assert a right to use Antarctic resources;
- The nature of pipelines and applications in development of products relying on Antarctic biodiversity; and
- The impact the rise in commercially orientated research and the expansion of patents has had on the free exchange of scientific information.

Finally, the Database needs to be hosted and managed by the Antarctic Treaty Secretariat if it is to properly fulfill its aims.

8. Recommendations

1. Recall ATCM Resolution 7 (2005) on Biological Prospecting in Antarctica which recommended to Parties that:

   1) their governments draw to the attention of their national Antarctic programmes and other research institutes engaged in Antarctic biological prospecting activities the provisions of Article III(1) of the Antarctic Treaty;

   2) their governments continue to keep under review the question of biological prospecting in the Antarctic Treaty Area, and exchange on an annual basis information and views relating to that question as appropriate.

2. Parties to share their experience in implementing Resolution 7 (2005).

3. ATCM to request the Antarctic Treaty Secretariat to adapt the Electronic Information Exchange System (EIES) in order to integrate information on bioprospecting activities.

4. ATCM to request Parties to submit information on bioprospecting activities through the EIES.

5. ATCM to request SCAR to integrate information on bioprospecting activities into their annual reports.

Annex

Searching of the database

The records in the prototype database are accessible through the **search database** facility, which is pictured in figure 1 below. The user can undertake a quick keyword search, or he/she can use search filters, such as "area of research", "organization name", or "government". Alternatively, the user can **browse all records** registered with the database.

Figure 1. The database search interface, selecting "food and beverage industries" as the area of research interest.

As demonstrated in figure 2 below, an initial search will return a summary of relevant records, including: the title of the record; a short description; the country sponsoring the original collection mission; the organisation commercialising the product; taxonomy of the biological sample; and reference information.

Figure 2. Results using the search filter "food and beverage industries".

The user can then choose to view any of the records in further detail by choosing the **view record** option. This option brings up all currently available information relating to the record of choice, as demonstrated in figure 3.

Figure 3. Available information relating to a record on the use of anti-freeze proteins in frozen food products, such as ice cream.

The **browse** function will allow the viewer to view all the records in the database, as demonstrated in figure 4 below.

Figure 4. The database browse interface.

It should be noted that the prototype database is still work in progress, and that further records, as well as updates to existing records, are being continuously added. While information relating to published research, patents and already-commercialised products is relatively easy to find, other types of information (exact collection location, terms of commercialisation, profits and benefit-sharing) are not always readily available. Including this information in the future will require close collaboration with companies undertaking or supporting biological prospecting in Antarctica.