An overview of bioprospecting

(Antarctica & the Southern Ocean)

Literature review: Martin Hayes GCAS 2003/4

Introduction

An escalating amount of scientific research on the flora and fauna of Antarctica is focused on the identification of commercially useful genetic and biochemical resources. The potential for commercial gain from such activity is likely to see it increase significantly, in the next few years. Much of this type of work falls under the umbrella term of bioprospecting

The need to consider bioprospecting has been raised at the Committee for Environmental Protection (CEP), in the Scientific Committee on Antarctic Research (SCAR), and at the Antarctic Treaty Consultative Meeting (ATCM). (Hemmings, A.D. 2003) Most recently, the matter was considered at the last meeting of the CEP and ATCM based on a Working Paper submitted by the United Kingdom (Jaastad, N. 2002).

The CEP concluded that biological prospecting needed to be discussed during the next CEP meeting. The ATCM agreed with the CEP that biological prospecting was a very important matter. The ATCM also agreed that bio prospecting raised both legal and political issues, in addition to environmental issues.

What is bioprospecting?

Bioprospecting, has an almost limitless number of subtly different definitions, authors often choosing a different slant to best reflect the nature of their argument. A synthesis of many suggests that bioprospecting could be simply defined as 'the purposeful evaluation of biological material in search of valuable new products'. Molecules derived from natural products, particularly those produced by plants and micro-organisms, have an excellent record of providing novel chemical structures for development as new pharmaceuticals. Many of the world's most successful and valuable pharmaceuticals have been derived directly, or indirectly, from natural product sources eg. acetylsalicilic acid (aspirin) from willow bark and

penicillin from the fungus Penicillium. (Nichols, D.S. et al. 2002)
In its modern form, bioprospecting involves the application of advanced technologies to develop new pharmaceuticals, agrochemicals, industrial enzymes, cosmetics, flavourings, fragrances, and other products from biodiversity. (Bull, A.T. et al. 1992). Companies like AnalytiCon Discovery in Germany are discovering, isolating, and determining the structures of new natural products every day. (Rouhi, A.M. 2003)

Fenwick, S. (1998) reports that Impressive statistics on the utility of natural resources emerged throughout a meeting entitled Medicines from Nature: Scientific, Legal and Ethical *Aspects* held at the Royal Society of Medicine, London, UK (9–10 June 1998). Michael Balick (New York Botanical Garden, NY, USA) indicated that of the top 150 prescription drugs sold in the USA, 57% are derived from natural resources.

Annual sales derived from traditional knowledge using genetic resources are US$ 3 billion for the cosmetic and personal care industry, US$ 20 billion for the botanical medicine sector, and US$ 75 billion for the pharmaceutical industry. (Laird, S. 2002) Sixty–two per cent of cancer drugs approved by the US Food and Drug Administration are of natural origin, or modelled on natural products. (Kate, K.T. & Laird, S.A. 1999)

Why Antarctica?

The isolated and extreme nature of Antarctica has tempted some bioprospectors away from the already heavily plundered tropical areas that characteristically have a high level of diversity in all categories of terrestrial and aquatic life. The reasons are obvious; the unique environment of Antarctica and the ocean that surrounds it, is home to a large number of organisms adapted to 'life in the freezer'. These 'extremophiles' (Cavicchioli, R. & Thomas, T. 2000) exhibit physical and chemical adaptations not found elsewhere on the planet. These unique properties make them a good bet as a source of novel bioactives that have the potential for commercial development in fields as diverse as ice-cream production and heart disease prevention.

The very nature of Antarctica has limited terrestrial life to a relatively small number of species, which exist on a tiny fraction of the available environment. Indeed, until relatively recently, Antarctica was considered to have a very low diversity of life. The exploration of the Southern Ocean, and particularly the inshore waters, has led to the discovery of far greater species diversity. Whilst this low in comparison to many tropical areas, it is the unique nature of many of these organisms that makes them worthy of commercial investigation. With a few terrestrial exceptions, Antarctic bioprospecting has mostly concentrated on marine species, and is this is likely to be the case in at least the near future.

The adaptation of various cellular processes to a permanently cold environment represents potential biotechnology products for exploitation. Two examples of such adaptation are the production of polyunsaturated fatty acids (PUFA) and of cold–active enzymes by bacteria inhabiting Antarctic ice.

A number of key Antarctic habitats that provide specific opportunities for bioprospecting have been identified, and are shown in the table below. (Bowman, J. P., 2003)

Habitat	Conditions	Opportunity for bioprospecting
Sea water & sea ice	Low temperature	Cold-active enzymes/catalysts; bioremediation; surfactants; antifreezes; poly-unsaturated fatty-acids; novel pigments
Southern Ocean Seawater	Low nutrient concentration	High affinity catalysts and ligands
Hypersaline lakes	High salinity	Halotolerant enzymes; novel metabolites
Marine sediments	Anaerobic/low temp.	Anaerobic biotransformations; novel bioactives
Soil, lithic habitats	Cold & dry	Novel bioactives

Is Antarctic bioprospecting damaging the environment?

Traditionally, medicines or other organic derivatives have been obtained by a significant harvesting of the source organism. Frequently, this has caused harm to populations, on at least a local scale. Recent developments in biotechnology and genetic engineering mean that very low quantities of original material are needed, as both the process and the eventual goal requires artificial synthesis of the bioactive ingredient.

Modern Antarctic bioprospecting certainly does not seem to be a huge environmental threat. Whilst any human activity in the area has the potential for unintentional damage through pollution etc, the removal of organisms in any quantity (likely to cause harm to either the population or the ecosystem) is no longer a necessary part of the search for bioactives.

Of particular commercial interest are marine micro-organisms such as fungi, (Fenice, M. et al 1997) algae and bacteria. (Nichols, D.S. et al. 2002) Because of their small size and high rate of reproduction, low-volume sampling can provide literally millions of organisms from the seawater or from marine sediments, and yet at the same time, be virtually undetectable. (Hemmings, A. D. 2003)

So, although bioprospecting could arguably lead to depletion of Antarctic species, and could indirectly damage the environment, the reality at the present moment in time is that this is not happening. Nor, is it likely to in the foreseeable future. Why then is such activity an issue at all?

Bioprospecting and Antarctic law

The legal status of bioprospecting, and the activities which rely upon it, are the main cause for concern. Potentially lucrative organisms are being patented from a place where no royalties are payable. There is a threat to what is meant to be the common heritage of mankind. Antarctica is a unique place in many ways, not least of which is its legal status, and the fact that it has no native (indigenous) population.

Until recently, organizations engaged in bioprospecting were under no obligation to compensate countries from which biological material had been collected. With the entry into force of the U.N. Convention on Biological Diversity (CBD) (1992), open access to biological resources was replaced by the recognition of the sovereign rights of each country to control access to the biodiversity existing within its borders. In accordance with the CBD, bioprospecting organizations are now expected to share benefits (profits) and transfer technology in exchange for access to biochemical resources. THE CBD however, does not apply to areas that lack national sovereignty. All territorial claims in Antarctica (including New Zealand's Ross Dependency) are held in abeyance under the terms of the Antarctic Treaty. (the Treaty) (Gilbert, N. 2003)

The Treaty, which entered into force in 1961, was originally signed by 12 nations including New Zealand. The original countries have been joined by a further 14 consultative parties, and 18 non-voting nations. The treaty is the core policy document for Antarctica, and to this day guides the majority of Antarctic activities. Importantly, Article VI states that the treaty applies to the area south of 60^0 south. The treaty therefore includes the ice shelves and coastal waters that have been amongst the target areas of bioprospectors. Of particular relevance to the issue of bioprospecting, is Article III, the free exchange of scientific results. It is this free exchange that is the crux of the current argument against bioprospecting activities within territory covered by the Antarctic Treaty. I will return to this later.

The Treaty, whilst still central to Antarctic policy has been added to by a number of other agreements to form a collective legal framework often referred to as the Antarctic Treaty System (ATS). The ATS currently comprises of the original treaty plus the Convention for the Conservation of Antarctic Seals (CCAS) (1972) and the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) (1980). The Convention for the Regulation of Antarctic Mineral Resource Activities (CRAMRA) (1988), although produced by Parties to the Antarctic Treaty, has never been ratified. In essence, CRAMRA was superseded by the Protocol on Environmental Protection to the Antarctic Treaty (1991) (The Protocol).

Of these later additions, The Protocol (which although agreed in 1991, did not enter into force until 1998) has potentially the greatest control on future bioprospecting in the area. Significantly, it requires that an Environmental Impact Assessment is completed for every activity likely to have an environmental impact. Annex II of The Protocol requires a permit for the 'taking of, or harmful interference of native fauna & flora'. Fortunately for bioprospectors, the wording (if not the intent) of Annex II currently applies only to birds, mammals and plants, leaving the removal of micro-organisms effectively unregulated.

It appears then, that whilst the intent of many of the framing documents that exist for the legal status of Antarctic activities is to protect and preserve the resources of the area in perpetuity, the reality is that no legal challenge is currently being enforced to prevent the removal of the material targeted by bioprospectors.

The moral/financial issues

What has started to raise the eyebrows of the world with respect to Antarctic bioprospecting, are the concepts of patents and intellectual property rights. To be more specific; the profits that can be made that are a consequence of these. Bioprospecting institutions, companies or even governments can again thank the wording of international patent law, which actually secures only the 'commercial use' of information and does not prevent the information being freely available to other interested parties. Because of this, patenting does not actually breach the wording of the Treaty. Indeed, because bioprospecting is at least the beginnings of a scientific investigation, it is in some ways supported by Article III of the Treaty!

Should bioprospecting therefore be considered a legitimate and worthwhile part of Antarctic science? Bioprospectors themselves would of course argue that it should. Those arguing against this type of activity have a strong case when it comes to harvesting or removal of significant quantity of an organism with respect to its population or community. As this appears NOT to be the case with the current approach to sample acquisition, it is difficult to argue that Antarctic bioprospecting is damaging the environment or ecosystem.

With regards to the financial and intellectual sides of the process, the former could be debated ad-nauseam, but in essence, the actual bio-sample itself is so far removed from the processes and costs involved in developing a useful end-product, that any profits derived from it could quite legitimately be attributed almost wholly to the company/group/country that has put in the work. The analysis by Simpson, et al, (1996) injected a bit of reality into the benefit-sharing debate by reminding policy makers that, like all other goods, the demand curve for biological samples is downward sloping. Given this basic economic fact, the market price for randomly collected biological samples is likely to be little more than the cost of collecting them.

Although markets for products derived from or containing biochemical resources are substantial, competition between suppliers of biological material, low probabilities of developing a new product from any given sample, and continued advances in alternative R&D technologies will continue to limit the compensation bioprospecting organizations are willing to provide for unevaluated biological samples (Artuso, 1997). This in itself provides one of the major problems for resolution when it comes to any kind of decision as to what should be a reasonable compensation or charge for access to Antarctic biota. Even if agreement could be reached as to how compensation or fees should be shared amongst Treaty nations, or how those monies should be spent within Antarctica, it would be difficult to set a fee structure that had any validity at all. Indeed, as collection of material is generally carried out for many purposes, and by consortiums (i.e. there seems to be little evidence of purely commercially orientated collecting), it is difficult to clearly distinguish between commercial and scientific activity.

Kate, K.T. & Laird, S.A. (1999) disclose that industry commonly cite two factors in determining future commercial demand patterns for access to genetic resources; namely, advancements in science and technology, and trends in law and policy. Similarly, reasons cited for a possible decrease in the demand for access to genetic resources are alternative approaches to discovering and developing products, the more selective and targeted selection of samples aimed at complementing existing collections, and increased reliance of the latter. Regarding law and policy trends, increasing bureaucracy, legal uncertainty, and lack of clarity, as well as unrealistic expectations for benefit– sharing are at the centre of decreasing demand for access to genetic resources.

Future industry trends regarding bioprospecting may well decrease globally, as the number and complexity of rules and regulations continues to grow. If the current regulations for Antarctica remain as vague as they are at present, this could create an obvious imbalance leading to over-exploitation and perhaps damage to the Antarctic environment. Rothschild, L.J. & Mancinelli, R.L. (2001) put forward the view that decision–makers (globally) must therefore be encouraged to adopt and implement simple, streamlined, and flexible regulations on access to genetic resources so that 'honeypotting' does not occur. (In other words, commercial bioprospectors are not tempted to some areas in favour of others just because of reduced (easier) regulations.)

If current practice does continue in Antarctica, then perhaps the most controversial issue is the sharing of information. Intellectual property rights are generally understood as a mechanism to promote and encourage exchange of scientific information. One of the requirements of patenting is that data is kept secret until the patent is filed. Once the patent has been filed, research data can be published, provided that it does not compromise future intellectual property rights. Patent law itself actually requires disclosure of the nature of the invention. (Jabour-Green, J. & Nicol, D. 2002) Because the Antarctic Treaty does not specify any timeframe for which the reporting of scientific results should occur, it could be argued that information disclosed post-patent is perfectly legitimate. Many would argue that this is not in the spirit of the Treaty, but as it stands, it is certainly within its legal boundaries.

Future policy and action?

The benefits of bioprospecting in terms of potential to create effective new drugs, useful chemical products, and for profits in a number of other areas are undoubtedly large. The threats to the Antarctic environment at present, are minimal, if not completely insignificant. The threat to the political stability of the Treaty and its membership is however a completely different story!

To avoid a political meltdown, and to avoid current levels of bioprospecting escalating to a level where damage to the environment becomes a reality, it will be necessary to modify (or introduce new) Antarctic legislation. Jabour-Green, J. & Nicol, D. (2002) Suggest that a key question for future policy makers for Antarctica (and other areas outside of national jurisdiction) has to be: 'Should there be limitations on ownership rights over biological resources from global commons areas to ensure that benefits are shared equitably among humankind?' The authors then follow this question with: 'If the answer to the above question is yes, how should bioprospecting in areas outside national jurisdiction be regulated?'

Irrespective of whether or not bioprospecting actually breaches any existing wording of the ATS, if it offends the way that Antarctic Treaty parties view the underlying philosophy and principles of the Treaty, then they should act quickly to address the issue. The greatest hurdle to resolving the problem, is the fact that Antarctic sovereignty does not, and cannot easily, exist in international law. The legal issues are likely to become more acute if bioprospecting develops further. It would seem prudent then to prioritise the development of Antarctic policy on bioprospecting, so that a legal framework for regulation can be introduced in the near future. With these concerns a sensible and sensitive approach must be conducted in the exploitation of Antarctic biological diversity. Bowman, J. P (2003) suggests that whatever the nature of regulation, care should be taken to include that:

- Material/samples taken from Antarctic environment for biodiversity analysis should be minimised. In other words, bioprospecting should be contained to a limited level.
- Environmental impact assessments should be completed (as handled by the appropriate coordinating national Antarctic science organization eg Antarctica New Zealand, Australian Antarctic Division, British Antarctic Survey etc).
- Biotechnology based research should only be conducted on organisms derived from the original source material. Re-collecting should be discouraged.

After seven years of negotiations, the UN Food and Agriculture Organization (FAO) Conference (through Resolution 3/2001) adopted the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), in November 2001. (FAO website, 2003) This legally binding treaty covers all plant genetic resources relevant for food and agriculture. It was created to harmonize with the Convention on Biological Diversity. The ITPGRFA is vital in ensuring the continued availability of the plant genetic resources that countries will need to feed their people. It provides an interesting model for multilateral benefit sharing, but only covers a specific set of genetic resources. These plant genetic resources are the raw material that farmers and plant breeders use to improve the quality and productivity of our crops. The future of agriculture depends on international cooperation and on the open exchange of the crops and their genes that farmers all over the world have developed and exchanged over 10,000 years. No country is sufficient in itself. All depend on crops and the genetic diversity within these crops from other countries and regions.

Conclusions

The speed with which countries have signed this agreement (ITPGRFA), the fruit of 23 years of discussions and formal negotiations, shows that countries have a mutual interest in preserving their plant genetic resources. At this stage, the genetic or other biological resources that are removed from Antarctica are unlikely to be considered as crucial, whatever products or treatments may be developed from them, so it will be interesting to see if a political and international consensus can be reached in the coming months and years.

Before such a consensus is reached, the vehicle of policy will first have to be decided. The Antarctic Treaty, the Protocol and CCAMLR are existing ATS documents that have the potential to be modified by relatively minor additions. The Protocol however is currently devoid of any enforcement mechanism, and CCAMLR applies only to marine areas. Such issues add to the complexity of reaching a broad-spectrum, adoptable policy on bioprospecting in Antarctica. The extent of the legal framework needs to be carefully assessed, not just on a needs basis, but also because of the fact that excessive restrictions are likely to lead to non-acceptance or non-compliance. Clearly, bioprospecting is likely to remain a key topic of future discussion especially if biotechnology interests increase from studies of microscopic organisms, to larger forms of life such as inshore marine fauna and flora that are already protected under CCAMLR and other areas of the ATS.

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