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CURRENT INITIATIVES IN THE PROTECTION OF KARST BIODIVERSITY

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The Guidelines for Cave and Karst Protection prepared and published by the IUCN / WCPA working group gave some attention to biological issues, but even at the time, it was recognised that more detailed treatment of biodiversity issues was required. A recent meeting under the joint aegis of IUCN and the World Bank examined the impact of limestone quarrying upon biodiversity, and further highlighted the need for this. A proposal and outline for a further initiative from the working party is accordingly presented here.

Key words: flora, fauna, microbiota, karst, biodiversity, protection

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Smjernice za zaštitu špilja i krša koje je pripremila i objavila radna skupina IUCN / WCPA svratile su pozornost na biološka pitanja, no odmah je bilo primijećeno da je potrebna detaljnija razrada pitanja biološke raznolikosti. Nedavni sastanak pod pokroviteljstvom IUCN i Svjetske banke ispitivao je utjecaj kamenoloma u vapnencu na biološku raznolikost i naglasio potrebu daljnjih istraživanja. Ovdje se prikazuje i prijedlog te nacrt za daljnju inicijativu radnog tijela.

Ključne riječi: flora, fauna, mikrobiota, krš, biološka raznolikost, zaštita

INTRODUCTION

There has already been considerable attention given to the conservation of underground fauna (e.g., TERCAFS, 1992; SASOWSKY *et al.*, 1997), particularly bats (e.g., STEBBINS, 1988) and troglophilic invertebrates (e.g., JUBERTHIE, 1995). A further review which includes a section on conservation (WILKENS *et al.*, 2000), and the report of an IUCN / World Bank meeting (VERMEULEN & WHITTEN, 1999) on the impact of quarrying upon biodiversity will both appear shortly.

Given this body of existing literature and the new insights into the biology of karst which have emerged in recent years, it is timely to prepare a summary document with recommended policies and practices for the guidance of land managers and others concerned with or responsible for karst areas. It is now proposed that this should be developed and published by the IUCN / WCPA Working Group on Cave and Karst Protection, who were responsible for an earlier more general guideline document on karst protection (WATSON *et al.*, 1997). That volume gave some attention to biodiversity, but an expanded and more focussed document is now required. This paper, based upon an earlier presentation to the IUCN / World Bank meeting (HAMILTON-SMITH, 1999), outlines a beginning plan for such a document, and seeks input from all those interested.

The Working Party operates through an international network, relying upon both written and electronic communication. Over the first phase, a series of draft chapters are prepared, each by a lead writer. These are circulated widely, and comments are invited from those interested throughout the world. In the case of the first guidelines volume, we were fortunate enough to receive over 600 comments. These are then utilised in writing a final version of each chapter, then in a final overall edit and integration for publication..

THE KARST CONTEXT

For present (and most other) purposes, it is important to think of karst as not just caves or landscape, but rather as '... a karst system, incorporating component landforms as well as life, energy, water, gases, soils and bedrock' (EBERHARD, 1994: 8). Its integrity depends upon the preservation of the dynamic interaction between these various components, as abnormal perturbation in any one of them will have implications for all others. This dynamic / holistic approach to definition has now been widely adopted (e.g., YUAN DAOXIAN, 1988; KIERNAN, 1995; BOZOVIC, 1997)

Many rocks, including much unmetamorphised limestone, have a degree of porosity to water which hydrologists refer to as primary or intergranular porosity. Karstified rocks are more much more porous, due to solutional processes, often commencing along joint or bedding planes. These first cavities or protocaves provide for secondary porosity, and a greatly increased water movement. In turn, caverns develop and where this has occurred the increased porosity provides for turbulent flow and often very rapid movement of immense bodies of water. However, this usually co-exists with much slower flows through the still-existing protocaves or other small voids (for a comprehensive review, see FORD & WILLIAMS, 1989).

It is vital to recognise that any karst system will have, to varying degrees, three levels of caverns:

– Microcaverns: those which do not exceed 0.1 cm. in diameter or cross-sectional dimension

– Mesocaverns: those measuring 0.1–20 cm. in diameter or cross-sectional dimension

– Macrocaverns: traditional caves, exceeding 20 cm. in diameter or cross-sectional dimension (HOWARTH, 1983: 370–71).

Much of the study of karst biota has focussed upon the macrocaverns, simply because these are the only caverns directly accessible to biologists. However, Howarth and other workers since have demonstrated the immense importance of the smaller voids as a habitat for invertebrates; much of the terrestrial cave fauna is in fact a mesocavernous fauna, adapted to live in these minute cavities with their relatively high humidity and high level of carbon dioxide. One can even suggest that many of the fauna found in caves are there simply because they '...sometimes tumble into, or enter in their search for food, spaces large enough for humans to find them.'

This distinction may well be vital in assessing any karst areas from a biological perspective. An outstanding example occurs at the Cape Range karst in NW Australia, where proponents of quarrying had argued that the area in which they planned to quarry had no caves, and therefore quarrying at that site did not threaten the remarkable cavernous fauna of the region. Even a superficial examination showed that the rock was riddled with mesocaverns, and so provided for a rich fauna indeed (HAMILTON-SMITH *et al.*, 1998).

Most biological work has focussed upon the subterranean fauna, particularly bats and troglobitic invertebrates. However, there is a range of other extremely important and often neglected karst-dependent species :

– microbiota (nanobia, fungi. bacteria, algae and other protozoa)

– plants, including brypohytes and a wide range of vascular plants, each of which are adapted to and require an alkaline environment, and many of which have a capacity to survive in cyclically arid conditions

– invertebrates which depend upon the karst vegetation, or in some other way are limited to karst terrains

– vertebrates which may depend upon specific vegetation associations, or utilise the karst terrain for shelter.

OVERVIEW OF THE PROPOSED DOCUMENT

The document will be developed along similar lines to the initial guidelines, namely:

– Introduction

– Karst environments and their special characteristics

– Importance of karst biota

– The pattern of karst biota

– Threats to karst biota

– Protective policies and practices

Some indicative preliminary material follows, but each section demands wide input. This draft in inevitably generalised, and specialists are invited prepare draft material for incorporation into the first draft of the overall publication.

IMPORTANCE OF KARST BIOTA

The need for preservation of obscure, or often even large and familiar, species of plants and animals is sometimes questioned. However, the intrinsic right of all species to survival is now being much more widely accepted as a basic principle in environmental management. One Australian speleologist (POULTER, 1991) has attracted some attention to this issue by using the phrase 'Cave rights for Troglobites!' The central discussion of this paper is therefore not so much on why we should ensure the survival of species, but how this might be best implemented.

However, it is useful to also note some of the anthropocentric arguments which might usefully support efforts in protection. Karst biota provides a natural laboratory of great richness which can support research into evolutionary processes, environmental adaptation, geoclimatic history and population dynamics to name but a few areas. The contribution of maintaining bio-diversity within the overall gene reservoir has been argued extensively in other contexts. Cave microbiota hold specific promise in the very practical and economically valuable pharmaceutical industry.

Then human interest in many karst species – watching the spectacle of bat flights, the occurrence of orchids and slipper plants, the intriguing and often beautiful character of many cave invertebrates and doubtless many other possibilities -all give a new dimension to their importance. I find it most interesting that Danielopol (1998) argues that more attention should be paid to the aesthetics of cave biota through its relationship with art – an idea which seems to resonate with the recent discoveries of cave bear skulls arranged in aesthetically pleasing patterns by our forefathers of 75,000 years ago (LASCU, 1996).

THE PATTERN OF KARST BIOTA

– The micro-biota include, as in any community, an immense diversity of bacteria, fungi, algae, protozoans and other forms. There has been an interest in microbiota since the pioneering work of Dudich in the 1930s and this is reviewed in the *Encyclopaedia Biospeologica* (JUBERTHIE & DECU, 1994). Regrettably, we know relatively little about even the species composition of this component of the biota. Although many species appear to be confined to karst environments, we know even less about their ecology, but CHAPMAN (1993) provides a very accessible discussion of what is known about the role of microbiota in the ecology of cave communities. The attention of karst managers has mainly been attracted by invasive species, such as the *lampenflora* of show caves or the famous 'maladie verte' of Lascaux (LEFEVRE & LAPORTE, 1969). Most recently, the work in progress at Movile Cave in Romania (SARBU & POPA, 1992) and by Northup and her colleagues at Lechuguilla Cave and elsewhere (NORTHUP *et al.*, 1994; CUNNINGHAM *et al.*, 1995; NORTHUP *et al.*, 1997a) clearly points to important contemporary and future directions of study. NORTHUP *et al.* (1997b) provides an excellent overview of the geomicrobiological aspects of this work, including such recently noted and spectacular occurrences of micro-biota as those of Cueva de Villa Luz in Mexico (PISAROWICZ, 1994; HOSE & PISAROWICZ, 1999), Weebubbie Cave on the Nullarbor Plain, Australia (JAMES & ROGERS, 1996) and the Black Hole of the Bahamas (SCHWABE, 1998). A demonstration of the rapidly growing interest in this issue is that at the recent Convention of the NATIONAL SPELEOLOGICAL SOCIETY (1998), nine papers were presented on various aspects of spelean microbiota. Regrettably, a seminal review of the role of microbes in mineralisation (BANFIELD & NEALSON, 1997) demonstrates how little is known of microbiota in karst environments. But it now appears likely that microbiota play a much greater role than previously thought not only in the food web of subterranean communities, but also speleothem development and other geo-mineralogical processes within karst, perhaps even in speleogenesis. A further promising area of investigation is the search for spelean microbiota of pharmaceutical value (BIGELOW, 1998).

– Most biological investigation in karst has focussed upon the considerable spectrum of terrestrial invertebrates, ranging from the interstital species of soils and micro-caverns to the well-known and widely studied troglobites and troglophiles. These pose a special problem in protection because of the remarkable degree of adaptive radiation and endemism – species are commonly confined to a single cave or single karst outcrop. A well known example are the Diplommatinid and other snails of the Malaysian-Indonesian region. Then there is a similar diversity, together with various species of fish and amphibians, found in aquatic environments, of which more below. Most work on spelean fauna concentrates entirely on these two groups.

– The aquatic environment occurs in a range of forms. Streams and rivers are important in many karst provinces, but especially in impounded karsts, while diffuse groundwater aquifers are widely known in extensive karsts. GIBERT *et al.* (1994) provide an extremely useful review of the ecology of groundwater environments. Island karsts have a distinctive pattern of water movement, and may demand special consideration. Then in many island and coastal karsts, the anchialine zone, where fresh and salt-water mix, provides for a distinctive faunal community, as in e.g., Cape Range in Western Australia, Bahamas, many Pacific and Caribbean countries (see also SKET, 1997b). Finally, there is the little known fauna and flora of submarine caves.

– Trogloxenes, particularly birds and bats, have attracted an immense amount of study, and we know that the survival of many species is dependent upon the availability of appropriate cave environments. It is also clear that the trogloxenes provide the greater mass of food inputs to many cave ecosystems.

– The surface vegetation of karst is often distinctive and supports a wide range of karst-endemic species. Only the Eastern European countries have a long-standing recognition of the special features of karst vegetation and a long record of research (see, e.g., SKET, 1997a). Again, there is a high degree of localised endemism, due at least in part to the diversity of microclimate in karst areas (REDZIC, 1997). An outstanding example is the diverse sequence of environments in the large dolines of the Škocjan Regional park in Slovenia, where a single doline may support a range from Mediterranean coastal flora to alpine flora (with a corresponding diversity of birds and other fauna, as noted below). Interest in this component of the biota is growing rapidly, partly because a range of particularly interesting and often attractive plants, such as orchids and pitcher plants, are included in karst flora.

– The distinctive vegetation together with the often highly dissected terrain of karst leads in turn to an especially attractive environment for specific species of at least invertebrates, reptiles, birds and mammals. At least some species appear to be wholly confined to karst regions. There is also the phenomenon of particularly complex and unusual communities being found only in karst terrain, e.g., the bird population of the major dolines at Škocjanske Jama.

This section of the document should also include a series of fauna reviews for specific kinds of karst environment, e.g., Tropical rain-forests, semi-arid tropical karsts, temperate karsts, probably with special reference to peri-glacial areas, and Cold rain-forests.

THREATS TO THE SURVIVAL OF KARST BIOTA

Many of the threats to karst biota are the large-scale events which threaten the very integrity or even survival of the karst itself. These have already been reviewed in WATSON *et al*. (1997) and so they are summarised here without extended discussion:

Total Destruction of Karst	as a result of mining, quarrying, submersion beneath water storages
Major land or hydrological disturbance	monoculture forestry, quarrying, land clearance, construction, waste disposal or other land fill; war; lowering of water table; extractive industries including speleothem harvesting, guano mining, removal of karren, birds nest harvesting, etc.
Pollution	Sewage and domestic drainage, farm or industrial wastes, hydrocarbons from fuel spillage, microbial pollution.
Human Entry to caves or other utilisation	military use, religious observances and monuments, sanitoria, burial, manufacturing, dwelling sites, farming, wine-making, smuggling, research, tourism, concert auditoria, recreation and tourism

This listing does not make any judgement about the desirability and acceptability of any specific practice; it simply points to a range of phenomena which will have a threatening impact of greater or lesser degree. Many of the phenomena mentioned are of long-standing practice, are culturally approved, and often extremely desirable in their own right. But all demand due assessment when a new activity is contemplated or initiated, and continuing re-assessment through their continuing existence.

Threats of specific significance to the biota of karst include all of the above, many of which may have a both direct and indirect impacts. For instance, clearing of vegetation obviously destroys the flora, some of which will recover given the opportunity for re-vegetation, but other elements of the flora may never return. But the destruction of vegetation also impacts upon soil quality and the biological dynamics of the soil. This in turn changes the water regime within underlying caves and impacts directly upon microflora. The whole food chain of the fauna thus changes, and again species may well be destroyed. Generally, studies of karst biota have only taken place long after disturbance of the surface environments, and so many of the communities upon which we have based our understandings have already been very significantly modified and may well have suffered impoverishment. Thus, we should recognise that there may well be very special opportunities for research and protection in undisturbed areas.

Even when an area is placed under protection, the development activities and constructions which provide for visitors and a range of other management initiatives can have a drastic impact. The construction of roadways, car-parks and buildings, if not undertaken with wisdom and sensitivity, can have remarkably destructive impacts on the karst environment. In brief, declaration of protected areas is not enough in itself – it must be accompanied by environmentally sensitive management.

Pollution, whether by soluble or liquid substances or by increased sedimentation, is likely to have severe impacts, often over very large areas and JUBERTHIE (1995: 36–39) provides an excellent review of this problem in relation to troglobitic faunas. However, there is some evidence that providing a karst system remains otherwise relatively intact, recovery from pollution may be more likely than recovery from major disturbance of the surface environment (LEWIS, 1996). One of the more insidious forms of pollution is the eutropification of major aquifers by the use of agricultural fertilisers. In two regions of Australia where stromatolites are living in karst lakes or cenotes, this has resulted in the growth of dense mats of invasive species of algae and other water plants and in turn this reduce the sunlight to the point where the algae responsible for stromatolites may well be killed (MACNAMARA, 1992; THURGATE, 1995).

Another common source of pollution results from the development of pathways and other structures for tourist access to caves; potentially dangerous pollutants are often introduced to the cave. These include copper from discarded waste left by electrician, zinc and cadmium from galvanised metals, hydrocarbon spillage. A recent review of this problem at least raises a warning to those responsible, and develops a series of proposals for improved practice (SPATE *et al.*, 1998).

Human entry to caves may have drastic impacts. Part of the problem is that many people see speleothems as the karst resource of most importance and totally ignore the value of the cave floor. As a generalisation, in spite of the very real aesthetic value of speleothems, they are both incredibly abundant and of little other value. Floors, on the other hand, are often an incredible library of natural records of the past – layered sediments, pollens, sub-fossils from many phyla of the animal kingdom, and human or proto-human bones or artifacts. From the perspective of this paper, they are one of the more important biotopes, often the key habitat for both microbiota and a diversity of invertebrates.

In caves which have been developed for tourism, pathways have usually been laid on the cave floor with no regard to what may be destroyed in the process. However, with proper path construction, the environment may well provide more effectively for continuing survival of biota than might otherwise be the case. A remarkable relict community of guanophilic invertebrates which had survived for 100 years after the departure of the bats on which they had depended for food (HAMILTON-SMITH, 1968) was wiped out in a couple of years by indiscriminate trampling of the cave floor. A simple pathway system would have prevented this catastrophe.

Turning to threats which are specific to biota, two problems seem to be pre-eminent. The first, regrettably, is over-zealous or poorly planned research and collecting. Many of us have encountered this problem, and it is alarming that generally those responsible are professional scientists. There is probably a smaller problem with collecting for commercial purposes – there is no market for most cave species in the way that there is for mineral specimens – but this did seriously threaten the survival of Kitti's bat (*Craseonycteris thonglongyai*) until the government of Thailand stepped in to control collection and trafficking, apparently with reasonable success.

The second is the problem of invasive species. The ubiquitous cockroach *Periplaneta americana* has invaded the Batu Caves of Malaysia in enormous numbers, and appears to be largely responsible for the crash in populations of both the Malasian cave cockroach, *Pycnoscelus striatus*, and the remarkable *Liphistius batuensis* spiders for which this cave was famous (YUSSOF, 1997: 7–8, 29–30). At another level, DOWNING (1997, 1998) has described the way in which invasive species have led to a massive decline in the endemic species of bryophytic flora on karst. There are doubtless hundreds of other examples and many may be unrecognised because the invasion occurred prior to biological research. As an Australian example, the dominance of the ubiquitous scavenger *Alphitobius diaperinus* in Bat Cleft Cave at Mt. Etna, Queensland, which may be part of the original fauna, but it is more likely to have arrived since Western settlement (HAMILTON-SMITH, 1970).

ENSURING PROTECTION

There is a hierarchy of possible protection strategies which may be utilised (EBERHARD & HAMILTON-SMITH, 2000).

Legislative protection of species

JUBERTHIE (1995) draws attention to the 'systematic pillaging of certain caves in the Pyrennes by entomologists' and expresses concern at the absence of any legislation which might provide for protection of invertebrates. While many countries have in fact enacted species protection of a number of vertebrates and plants, probably Tasmania (Australia) is the only place where cavernicolous invertebrates have been proclaimed as protected species. However, the effectiveness of this approach has been questioned on a number of grounds: species must be individually identified in the legislation and this may pose taxonomic difficulties while many species of cavernicoles are undescribed and so cannot be listed; enforcement is virtually impossible; and species protection cannot be invoked to prevent the destruction of habitat. However, there are now moves to develop legislative protection of specific ecological communities, and if able to successfully implemented, this will be an effective response to some of the difficulties inherent in species protection, and may offer excellent possibilities in relation to karst communities.

Recovery planning for threatened species

The development of systematic recovery plans for species or groups of species is being developed in some countries. Although the effectiveness of this is often constrained by lack of research and the very complexity of ecological communities, there may well be occasions on which it might be very usefully invoked.

Protection of Specific Habitat Areas

In itself, this group of strategies provides a considerable hierarchy of approaches. At the smallest level, it includes actions such as:

– track marking in caves to prevent trampling

– development and voluntary observance of minimum impact codes for cavers or researchers. This is an important initiative which targets populations of cavers and researchers. An Australian example is provided in WATSON *et al.* (1997) while many other fine examples have been developed, certainly including those of the United Kingdom and Switzerland.

– closure of caves or karst areas (often at specific seasons for the special purpose of protecting crucial bat sites). One such example, voluntarily instituted by cavers, resulted in the recovery of a bat population after a 20-year gap (HAMILTON-SMITH, 1991).

– finding means to minimise, control or eliminate invasive species

One of the dilemmas which we currently face is that having recognised the importance of microbiota, we lack the detailed knowledge to develop sound protection programs. But both invasive species and pollution represent clear threats, and the latter must be more broadly defined than is often the case. Invasive species are also a significant threat. Pollution includes any importation of organic matter, even including the skin flakes, hair and lint left behind by any human entry. It also includes any materials, e.g., clothes which are not freshly laundered, or dirty boots, which may serve to carry invasive species of microbiota. NORTHUP *et al.* (1997c) have developed a series of practical guidelines for use by cavers and researchers. These are unlikely to be widely observed in many situations – and some caves have already been so impacted that any damage has probably already been done. However, they may be of great importance in entering and assessing new and previously uninvestigated cave systems. There is a further major threat in alteration of air movements in any previously closed or severely constricted cave (see SARBU & POPA, 1997).

However, it may also be developed on a broad-scale level, and the proper siting of limestone quarries is an excellent example of this. Quarrying is one of the major threats to the integrity of karst in many countries, and often demonstrates a virtually irreconcilable conflict of interest. Well known examples in the Asian-Pacific region include the long standing dispute at Batu Caves in Malaysia (YUSSOF, 1998:

5–7), the quarrying of the Ha Tien and Hon Chong karst in Vietnam (currently being further assessed) and major disputes in Australia at Mt. Etna (Queensland), Yessabah, Colong, Bungonia and Wombeyan (N.S.W.), Sellick's Hill (in South Australia) and Ida Bay (Tasmania). But it must be recorded that five of these Australian examples are no longer being actively quarried, and three are receiving extensive and thorough rehabilitation.

Rehabilitation and Restoration

Which brings us to the growing importance of rehabilitation and restoration. Both tourism managers and speleologists have been involved in aesthetic restoration of caves, often with conspicuous success, and in turn this may well restore biotic habitat.

More importantly, there are now outstanding examples of restoration of total karst habitat, including:

– Waitomo Cave, New Zealand, where the famous glow-worm population was seriously threatened by degradation of the wetland habitats which produced the rich population of Diptera upon they depended for food

– The Horse Cave and Hidden River system in Kentucky, U.S.A., where cessation of the practice of using the cave for sewage and waste disposal had led to an extensive recovery of the faunal community (LEWIS, 1966)

– Ida Bay Caves, in the Tasmanian World Heritage Area, where cessation of quarrying and rehabilitation of the former quarry led to a remarkably rapid recovery of biotic communities. The decision was made to not utilise the artificial fertilisers demanded by forest ecologists as their use would have had negative impacts on the troglobitic and other underground biota. This project demonstrates in various ways the importance of adapting rehabilitation technology to a research-based understanding of the site concerned, rather than seeking any set of rigorous and universalised procedures.

Declaration of National Parks and other Protected Areas

This is clearly the option which has the best potential to protect total environmental systems, such a karst province. However, several warnings must be noted:

– It is all too common for a government to declare parks, encourage (even just by making the decision) the public to visit them, yet not provide adequate resources for safeguarding of park values. The result may well be an increase in degradation of the environment. In other words, declaration is not enough : it must be accompanied by adequate resourcing for management and protection of park values. There are often major issues here in the lack of expertise on issues in karst management, and consequently a very real need for development of professional education for karst managers.

– The boundaries of karst drainage systems often do not co-incide with surface drainage systems. Unless the total watershed is included within park boundaries, this may lead to significant changes in the water regime within the park as a result of off-park actions (NEALE, 1985). Waitomo (New Zealand) provides a well-documented example, where the karst system was seriously threatened by increased sedimentation. However, this also demonstrates that where it is not realistic to include the total watershed within park boundaries, a problem may be solved by negotiation with neighbouring landholders and/or using available planning ordinances (SIMMONS & LOHREY, 1985).

On the more positive side, not only has there been an immense increase world-wide in the total area under some form of permanent resource protection, but there has been a steady increase in global expenditure on resource protection and a rapidly growing body of research and knowledge.

International agencies have provided a valuable resource in supporting this development, while international treaties have provided for World Heritage Recognition, usually with substantial strengthening of management. The recent recognition, initially in Australia (AUSTRALIAN NATURE CONSERVATION AGENCY, 1996), of some major karst aquifers as wetlands under the Ramsar Convention provides a further tool for protection and this is currently under examination in Eastern Europe also.

Public Education

The importance of public education can never be neglected. The development of more effective karst protection, in the log run, depends upon the legitimisation of governmental action by the public as a whole. This must encompass a spectrum from the inclusion of karst understandings in science education, the education of park managers, cavers, tourism operations and others actively involved in karst utilisation, land owners (ZOKAITES, 1997), to wider public education through interpretation at parks, journalism, electronic media and popular books for all ages. The International Spelological Heritage Association (http://www.microresearch.be/isha/) is now playing a key role in enhancing and improving the quality of public communication about caves and karst.

CONCLUSION

This paper provides an all too brief overview of some key issues in karst protection. It is probably too dependent upon Australian examples, but there are two reasons for this – one is simply personal convenience and familiarity. The other is that some of us commenced working actively to promote better protection and management over 40 years ago – it has been a long road, so we have both a lot of experience and a lot of mistakes from which we have learned more. We still have a long way to continue travelling along that road, even turning back at regular intervals to revisit parts already travelled.

Regrettably, one of the things we have learned is that resource protection is a continuing struggle with human greed and global industrialisation (see also BONHARDY, 1993: 145–146). Although the last 25 years have seen immense advances in protection, we have also seen reversals by governments who are all too readily persuaded that mining and other industrial activities matter more than preservation of our natural heritage. So protection is not just a matter of knowledge, it also demands political will and political skills.

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