Proceedings of the

Asia-Pacific Forum on

Karst Ecosystems and World Heritage

Gunung Mulu National Park World Heritage Area

Sarawak, Malaysia

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Edited by

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Front Cover photo: Entrance to Deer Cave, Gunung Mulu World Heritage Area, Sarawak, Malaysia *(Jerry Wooldridge).*

Foreword

Gunung Mulu National Park, in Sarawak, Malaysia, was inscribed on the World Heritage List in December 2000, and is one of the largest karst areas in Asia and the world. This spectacular region is home to a large tract of protected tropical rainforest and has biodiversity values of global significance. Its landscape and cave systems contain several areas of exceptional natural beauty, and its caves are some of the most extensive and largest in the world. It is fitting that the Asia-Pacific Forum on Karst Ecosystems and World Heritage took place at such a magnificent location, and is a marvellous example of why the special values of karst should be protected on the World Heritage List.

The UNESCO World Heritage Centre is keen to support activities and initiatives that enable identification and nomination of categories of sites that are currently under-represented on the World Heritage list. Only 138 of the 690 sites on the World Heritage list are protected for their natural values; 60-70% of them are protected for their biodiversity values. The World Heritage Forests Conference, in Berastagi, Indonesia in December 1998 was an important meeting in dealing with thematic World Heritage issues related to biodiversity conservation. The Asia-Pacific Forum on Karst and World Heritage is another important step in recognising and protecting the unique values of thematic biodiversity, and gives significant recognition to the region's extensive, yet largely unrecognised karst areas and the biodiversity contained therein.

Many types of karst ecosystems have been recognised as extremely important for the conservation of biological diversity, both above and below the surface. The UNESCO World Heritage Committee is particularly interested to ensure that biodiversity is given adequate attention in both assessment and management of World Heritage sites. However karst sites are not well represented in the list of World Heritage Areas (WHA), even though the importance of karst biodiversity has long been established. Karst landscapes, due to their complex physical and biological characteristics, provide for high levels of radiation and endemism in both plant and animal species, including the little studied subterranean fauna of caves.

There are many nominations where karst is present, but its values have not been considered. As a result, significant biodiversity and geodiversity is often left unrecognised. For instance, of the 41 karst World Heritage sites around the world, only 18 are inscribed for biodiversity; i.e. on the basis of Natural World Heritage criterion (iv). Similarly, there are numerous examples of World Heritage sites with significant areas of karst that may well be of outstanding universal significance that are not inscribed under Natural World Heritage criteria (i) or (iii) that come closest to recognising karst values within the framework of the Convention.

The Asia-Pacific Forum on Karst Ecosystems and World Heritage was convened to recommend actions to identify and protect significant areas of karst biodiversity from threatening processes, such as habitat destruction, groundwater pollution, inappropriate visitation and quarrying. The expert group assembled at the World Heritage site of Gunung Mulu National Park, in Sarawak, Malaysia, from 26 to 30 May 2001, identified issues and challenges in the management and identification of karst in the Asia-Pacific Region, and formulated a range of recommendations for priority actions to identify and protect karst in the region.

The actions identified by the Mulu Forum will form the basis of project proposals to protect karst in the Asia-Pacific Region, and to build regional capacity in karst identification and management. The UNESCO World Heritage Centre will assist the realisation of the excellent outcomes produced at Mulu, and will facilitate IUCN and other partners to identify and mobilize financial and technical resources, based on priorities established at the Mulu Forum, to fund karst and biodiversity related projects.

I am pleased to see that the proceedings of the workshop could be published within such a short time-interval of the conclusion of the workshop in May 2001. I wish to thank IUCN, Bangkok, and the Asia Pacific Focal Point for World Heritage, Canberra, Australia, for having enabled this rapid processing of the outcomes of the workshop and the publication of its results. I wish to also register my sincere appreciation and thanks to the Governments of Sarawak, Malaysia and a whole range of partner organizations, particularly the UN Foundation which provided the financing for the workshop. I am delighted to support the outcomes of the Mulu Forum, and look forward to the realisation of the recommendations of the workshop in order to improve the range of geographical and thematic karst sites represented on the World Heritage List.

Francesco Bandarin
Director
UNESCO World Heritage Centre

Acknowledgements

Many people have contributed to the success of the meeting that took place in May 2001 in Gunung Mulu National Park, Sarawak. The original idea for this regional forum was launched at an earlier meeting in 1999 in Bangkok, where the impact of quarrying and mining on limestone biodiversity was discussed. At the end of this meeting, Tony Whitten from The World Bank, Hans Thulstrup from UNESCO and Hans Friederich from IUCN agreed that identification of priorities for karst ecosystem conservation in Asia and the Pacific would necessitate a regional discussion, and they put together a first concept outline. The concept drew inspiration from the discussions at the World Heritage and Tropical Forests meeting convened at Berastagi, Indonesia, in December 1998.

We were honoured to have His Excellency YAB Datuk Patinggi Tan Sri Haji Abdul Taib bin Mahmud, Chief Minister of Sarawak attend the forum discussions and officially open the meeting in Gunung Mulu on Saturday 26 May 2001. We would like to thank His Excellency for making time in his extremely busy schedule to attend and endorse the Mulu discussions.

The Karst Forum could also not have taken place without the generous support and assistance of the State Government of Sarawak, especially Datu Haji Abdul Aziz Bin Haji Hussain, State Secretary of Sarawak and Peter Sawal from the Office of the State Secretary. Datu Wilson Baya Dandot, Deputy State Secretary of Sarawak also deserves a very special mention. The State Government was extremely helpful in many ways including providing funding, assisting delegates with visas, and with general organisational and administrative matters. We were also very appreciative of the full support given by the Sarawak Forest Department, especially from Cheong Ek Choon, Director of Forests, and to have the presence at the forum of the Head of National Parks and Wildlife, Sapuan Bin Haji Ahmad.

Rambli Ahmad of the Sarawak Forest Department was our ever-present liaison officer who was of great assistance with the complex logistics of field trips and transport amongst other things. One of the highlights of the meeting was undoubtedly watching the spectacular evening flight of bats from the mouth of Deer Cave, although the visit to Clearwater Cave and Wind Cave was also memorable. We wish to register our special thanks for the staff of Gunung Mulu National Park to make arrangements for these trips.

Natarajan Ishwaran from the UNESCO World Heritage Centre has been instrumental in securing the financial resources for the Asia-Pacific Forum on Karst Ecosystems and World Heritage from the United Nations Foundation. Funding and support for publishing the Proceedings of the Forum were provided by Environment Australia's World Heritage Branch through the Asia-Pacific Focal Point for World Heritage Managers. Environment Australia's World Heritage Branch also provided the services of Tim Wong and Stuart Chape in relation to editing the Proceedings and other follow-up activities resulting from the meeting. The IUCN Asia Regional Office provided additional financial and in-kind contributions.

Elery Hamilton-Smith, with the support of many members from the IUCN/WCPA (World Committee on Protected Areas) Task Force on Caves and Rolf Hogan from the IUCN head office prepared the background information for the meeting. The participants to the meeting were the key to the success of this meeting. They would not have been able to provide their inputs without the Sarawak Development Institute and effective secretarial support from Zabariah Hj. Mataliand and her team. Special mention should also be made to Siwaporn Sittisart and Rosa Mary Saengsanthitham from the IUCN Asia Regional Office in Bangkok, who were responsible for flights and other logistics.

Robert Geneid, Managing Director, Borsarmulu Resort SDN BHD was instrumental in organising flights between Miri and Mulu, and the first class accommodation in Miri and Mulu was provided by Rhiga Royal Hotels, and we wish to thank manager Walter Kohli and in particular Ms January Kohli in the Royal Mulu Resort and Ms Sim Ling Ling in Rhiga Royal Hotel, Miri.

The reduced airfare rates from Malaysian Airlines (MAS) was very much appreciated, and especially the personal assistance from Michael Yong, Incentives and Convention Manager, in Kuala Lumpur. Flights from Miri to Gunung Mulu were arranged through Vision Air in Miri with assistance from Mr Geneid, and we wish to thank them for their understanding.

Special thanks also go to Jaap Vermeulen and Tony Whitten for allowing the adaptation and inclusion of sections of text in these proceedings, from their publication; *Biodiversity and Cultural Property in the Management of Limestone Resources* (1997). Thanks also to Peter Ackroyd for taking the time to draft the maps that appear in the proceedings

Julian Ingles organised an excellent post-workshop excursion to the Niah Caves near Miri, and Rambli Ahmed led an exciting and informative trip through the Wind-Clearwater cave system, providing an opportunity for a group of forum participants to more fully appreciate the complexity and beauty of this World Heritage karst area.

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Glossary of Terms Used in Proceedings

Anchialine: from Greek meaning "near the sea", refers to coastal caves and pools formed in limestone or volcanic rock, containing brackish water formed from the mixing of saltwater and freshwater, that lack direct surface connection with the open sea. They include the longest submerged caves on Earth. It is has been discovered that such caves are inhabited by a diverse array of previously unknown species from a number of new higher taxa (Iliffe 2001).

Biodiversity: the variability among living organisms including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the complexes of which they are part; this includes diversity within species, between species and of ecosystems themselves.

Cenote: partly water-filled doline, with vertical or steeply sloping sides.

Coralline limestone: formed from the calcareous structure of corals and algae.

Doline: closed depression draining underground in karst, of simple but variable form, e.g. cylindrical, conical, bowl- or dish-shaped. From a few to many hundreds of metres in dimensions.

Foraminiferous limestone: formed from the calcareous shells of marine protozoans.

Geodiversity: natural range (diversity) of geological (bedrock), geomorphological (landform) and soil features, assemblages, systems and processes. Geodiversity includes evidence for the earth (evidence of past life, ecosystems and environments) and a range of processes (biological, hydrological and atmospheric) currently acting on rocks, landforms and soils.

Impounded karst: karst area that is completely enclosed by impervious rocks.

Karst: a landscape and associated features formed from the solution of limestone - sedimentary rocks that were built up millions of years ago by corals, shells, algae and other carbonate-bearing marine organisms (see also explanation in proceedings text).

Lampenflora: The growth of algae and other non-vascular plants within caves as a result of artificial illumination as in tourist caves.

Phreatic water movement: Where water moves to the level at which all voids in the rock are completely filled with water.

Speleothem: A secondary mineral deposit formed in caves, most commonly made from calcite. Stalagmites and stalactites are two examples of speleothems.

Stromatolites: laminated, sedimentary rock structure formed primarily in Precambrian shallow pools by mats of blue-green algae, which trapped layers of silt, especially of calcium carbonate. These wavy or round formations serve as evidence for dating the first life forms on earth and are still being produced today.

Syngenetic karst: karst developed in aeolian limestone where the evolution of karst features has occurred at the same time as lithification of the limestone.

This glossary is not intended to be a detailed list of karst related terms. For a comprehensive and detailed overview of karst terminology and concepts, please consult:

David Lowe and Tony Waltham (eds.) *A Dictionary of Karst and Caves*. British Cave Research Association, London.

Acronyms

ARBC	ASEAN Regional Centre for Biodiversity Conservation
CI	Conservation International
FFI	Flora and Fauna International
GEF	Global Environment Facility funding mechanism
JICA	Japanese International Cooperation Agency
IUCN	The World Conservation Union
NBCA	National Biodiversity Conservation Areas (in Lao PDR)
UNESCO	United Nations Education, Scientific and Cultural Organisation
WCPA	World Commission on Protected Areas
WCS	Wildlife Conservation Society
WWF	World Wide Fund for Nature

Executive Summary:
Discussions at the Mulu Forum

The *Asia-Pacific Forum on Karst Ecosystems and World Heritage* (the Mulu Forum) was organised to discuss karst ecosystems in Asia and the Pacific in a World Heritage context and to agree on recommendations for action. The meeting involved some seventy global and regional experts on karst and biodiversity, as well as representatives from a number of the karst areas that are already inscribed as World Heritage Areas in Southeast and East Asia.

The discussions were guided by a number of background papers prepared by the World Commission on Protected Areas (WCPA) Working Group on Cave and Karst Protection, and included a review of tropical karst sites listed as World Heritage Areas to date and an assessment of the extent to which their management has given due consideration to biodiversity conservation. Participants discussed the issues through small workshop sessions and larger open forums over the three days. This allowed both focused analyses of particular topics and issues within smaller expert groups, and then larger discussions and debates to refine the information and outputs produced by the Forum. The result was a consensus on recommendations as follows:

1. priorities involving preparatory work and assistance to be finalised by the end of 2002, and

2. actions that can be, or are currently being, moved ahead by State Parties before the end of 2003.

These can be summarised as follows:

Priorities to be Developed within the Next Year
China
- The existing karst World Heritage Areas of Huanglong, Jiuzhaigou and Wulingyuan should be re-assessed for potential designation under the biodiversity criterion.
- Consideration should be given to a more effective buffer zone at Zhoukoudian World Heritage Areas.
- Provide assistance with pre-nomination reviews of the Guizhou and Guilin karst.

Lao PDR
- Assistance should be provided to relevant Government agencies to raise awareness about the natural heritage aspects of the Convention.
- Discussion should take place to address a possible cross-border or cluster World Heritage nomination of Hin Nam No National Park and Phong Nha/Ke Bang in northern Vietnam.
- Investigation of the karst and biodiversity values of the Khammouane karst area.
- Re-assessment of Luang Prabang as a mixed natural/cultural site.

Myanmar

- There is an urgent need to open policy dialogue with the Myanmar Government on Protected Area management and World Heritage areas.
- A scientific reconnaissance and rapid assessment of Myanmar's karst World Heritage areas could follow this.

Oceania

- A natural and cultural resources study of likely Pacific Islands and a review and capacity building exercise for relevant government agencies should take place.
- Re-assessment and management review of Henderson Island and East Rennell for additional criteria.

Philippines

- Extensive data development and review process required, including desk studies and field visits.

Thailand

- A capacity building program for Thailand to enable it to review its karst areas and National Parks system.

Papua New Guinea

- Pre-nomination reviews of the Huon Peninsula, the Kikori-Darai plateau, the Nakani-Whiteman Ranges, the Trobriand Islands, the Muller Plateau and the Hindenburg Wall should take place.

Action that can Proceed through State Parties over the Next Five Years

Australia

- Consideration for World Heritage nomination of the Nullarbor Region, Cape Range, Limestone Ranges and the Ruined City.
- Tasmanian Wilderness World Heritage Area and Mole Creek NP boundaries should be expanded to include some large, important sectors of the Mole Creek karst, and possibly the Hastings Cave Reserve and Mt Cripps also.
- Pre-nomination review of Chillagoe-Palmer River, Eastern Highlands Impounded Karst and Syngenetic Karsts.
- Investigation of the karst World Heritage values of Shark Bay and Great Barrier Reef World Heritage Areas.

Indonesia

- The Government should consider an extension to Lorenz NP to include the Baliem River system.
- Government should review the World Heritage values of Gunung Sewu (Java) and the Maros Karst (Sulawesi) and identify appropriate protection and international recognition.
- Field surveys to rectify data deficiencies in Tana Toraja (Sulawesi) and Sunkulirang in Kalimantan.

Japan

- An assessment of the Akiyoshi-Dai karst area for possible World Heritage nomination.

Korea

- A review should be undertaken of at least the Dae-i-ri area, the Dong River area, and San-gye-ri areas to ascertain whether a World Heritage Area nomination should be prepared.

New Zealand

- The Government should consider the nomination of Kahurangi (Mt Owen).

Malaysia

- Expansion of the boundary of Gunung Mulu World Heritage Area to include Gunung Buda.
- Consideration of Niah Great Cave for nomination on cultural and biodiversity grounds.
- Assessment reviews of Pulau Dayang Bunting, Gomantong Cave, and Medai.

Vietnam

- The Mulu Forum noted the re-nomination of Phong Nha/Ke Bang and the road construction through this area, a karst biodiversity study of Cuc Phong National Park, and the activities taking place at Halong Bay.
- Cao Bang may contain freshwater stromatolites, and if so, warrants a rapid reconnaissance survey for World Heritage values.

East Timor

- A rapid reconnaissance survey of East Timor's karst should be carried out when the Government requests this to happen.

Management Issues for Karst World Heritage Areas

The Forum also discussed management issues for karst World Heritage Areas, and with added information from the Guidelines for Cave and Karst protection (IUCN/WCPA 1997), produced a list of the key issues in karst management. These were divided into five key areas:

- hydrology and World Heritage Area boundaries
- impacts from developments outside of the protected area
- internal management issues
- finance
- education, training and awareness.

Other Issues

The Forum reaffirmed that a regional network for cave and karst managers and experts should be established to share expertise and experience within the region. The WCPA Cave and Karst Working Group, ASEAN Regional Biodiversity Centre (ARBC), and the

Asia-Pacific Focal Point for World Heritage Managers, Australia, were identified as the core co-ordinating bodies for this network and it appears that some further steps still need to be taken to formalise this arrangement.

A brief discussion also took place on the *Draft Atlas of Karst and Karst Conservation Vol. 1: Asian-Pacific Region* (May 2001) edited by Elery Hamilton-Smith and Peter Ackroyd, IUCN WCPA Working Group on Cave and Karst Protection. This volume is only the first of what is hoped to ultimately provide a global coverage. Negotiations are currently in progress re the drafting of some other volumes, and for publication by one of leading Geomorphological Journals as a series of supplementary volumes. Professor Hamilton-Smith asked for comments and supplementary information from participants to complete and update the document.

1. World Heritage Inscription and Karst

Introduction

Karst ecosystems are the result of weathering of limestone rocks, and they harbour many endemic and often restricted distribution species of flora and fauna. Many of these species are under threat or in danger of extinction. Few karst areas have been properly recognised or protected for their biodiversity value, and most of the karst ecosystems that have been designated as World Heritage Areas have been inscribed for other reasons than biodiversity. Several limestone areas with caves have been recognised for cultural values only.

The Convention Concerning the Protection of the World Cultural and Natural Heritage (World Heritage Convention, 1975) can be very effectively used to protect biodiversity of outstanding universal value. For example, the World Heritage Forests Conference in Berastagi, Indonesia, endorsed the World Heritage Convention as one of the most effective ways to recognise and conserve tropical forest biodiversity. The Convention is similarly applicable to biodiversity conservation in most environments, including caves and karst landscapes.

The Ramsar Convention on Wetlands (1971) is another mechanism to protect the biodiversity of karst. The Ramsar Bureau now recognises subterranean wetlands, and this provides a further avenue for international recognition in the interests of conservation. Some areas which do not fit the World Heritage natural and cultural criteria (see Annex 2 for a full list of the UNESCO World Heritage criteria) may well prove to meet the Ramsar requirements, and there is significant opportunity for complementary nominations of both World Heritage and Ramsar listing to identify and protect different elements within a site.

In order to help World Heritage Convention State Parties in Asia and the Pacific determine possible future karst sites for nomination as World Heritage Areas, a meeting was organised in Gunung Mulu National Park in Sarawak, Malaysia in May 2001. Gunung Mulu is famous for its karst biodiversity, limestone landforms and cave systems, and was inscribed as a World Heritage Area in December 2000.

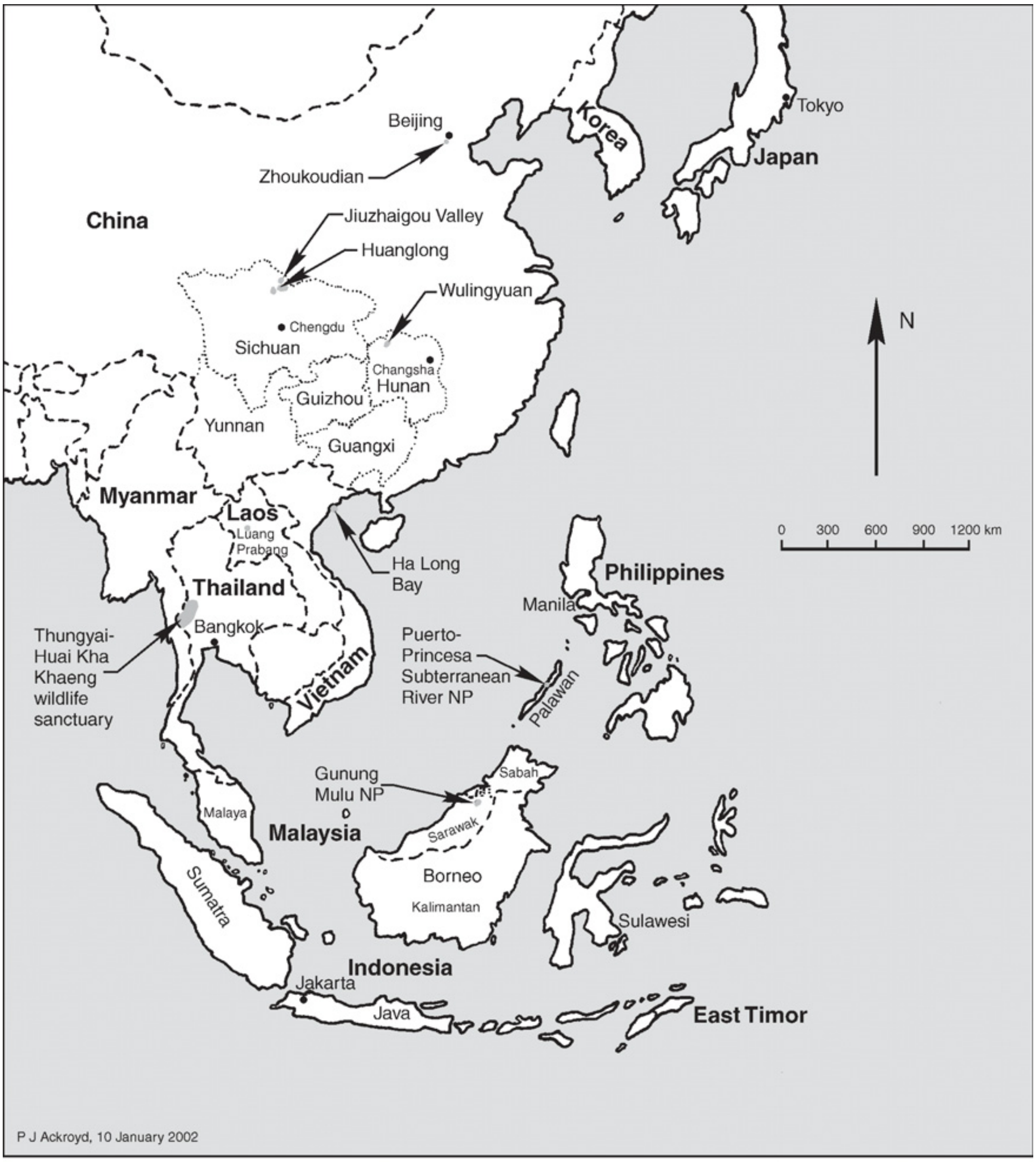
One of the interesting facets of karst World Heritage Areas is that many have been nominated for other than their karst values, even though the karst component may well be of outstanding significance. Sometimes this karst is not even recognised in the processes of nomination, assessment and registration.

Gunung Mulu National Park in Sarawak, Malaysia, Te Wahipounamu in New Zealand, East Rennell in the Solomon Islands and the Tasmanian Wilderness in Australia have each been the subject of a great deal of research over many years, which has enabled their inscription to be based upon an unusually broad range of criteria. However, many other sites might well meet those criteria if they had been subject to the same level of research. As in many issues, it is fair to comment that the grounds for inscription probably tell us more about the distribution of scientific resources than the distribution of natural or cultural resources.

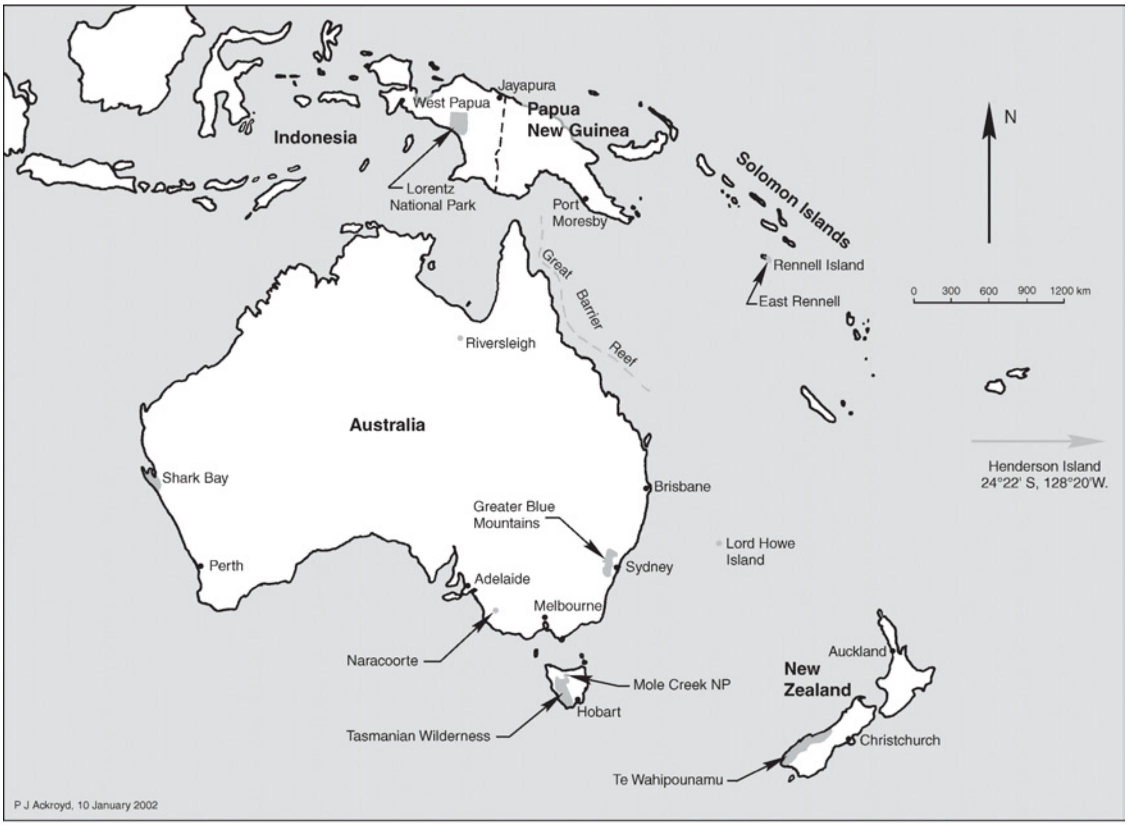
It is quite possible, for instance, that future research will indicate that Ha Long Bay in Vietnam will prove to justify listing on grounds of either or both biodiversity and cultural heritage. More notably, all three Chinese karst World Heritage Areas, inscribed at this stage only under criteria 3 ("contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance"), offer *prima facie* evidence that they are significant under at least the biodiversity criterion (see Thorsell and Sigaty 1997, Smith and Jakubowska 2000).

Background and supporting information on the World Heritage Convention, karst and karst biodiversity values can be found in the following annexes:

- ❒ Annex 1: Karst World Heritage sites in the Asian-Pacific Region
- ❒ Annex 2: World Heritage Convention Criteria
- ❒ Annex 3:
    - Table 1: World Heritage Sites (all regions) inscribed specifically for Cave and Karst Features
    - Table 2: World Heritage Sites (all regions) inscribed for other reasons, but with Significant Cave and Karst Features
    - Table 3: Cultural World Heritage Sites Containing Cave and Karst Features
- ❒ Annex 3: Existing Karst World Heritage Areas and Recognition of Biodiversity
- ❒ Annex 4: Some Major Groups of Karst Organisms



Map 1: World Heritage sites in the Asia-Pacific region with important karst features East and South-East Asia



Map 2: World Heritage sites in the Asia-Pacific region with important karst features
Australasia, New Guinea and South-West Pacific

Box 1: What is Karst?

Karst is a landscape and associated features formed from limestone - sedimentary rocks that were built up millions of years ago by corals, shells, algae and other carbonate-bearing marine organisms. Tectonic movements lifted them above sea level, often beneath a long burial beneath layers of sediment. Erosion first removed the sediment cover then sculptured the limestone spectacularly into what are called 'karst landscapes' (Vermeulen and Whitten, p.5, 1997). Karst terrain has distinctive hydrology and landforms arising from a combination of high rock solubility and well-developed secondary porosity. The key to karst is the development of its unusual sub-surface hydrology (Ford and Williams, 1989). A huge variety of landforms result, and include often amazing above ground and below ground features, such as tower pinnacles and caves. Beyond its definition, it is now recognised as a highly complex interactive system (e.g., Yuan Daoxian 1988; Eberhard 1994) *which incorporates component landforms, life, energy flows, water, gases, soils and bedrock. Perturbation of any one of these elements is likely to impact upon the others*. Recognition and understanding of the importance and vulnerability of this dynamic interaction must underpin the effective management and conservation of karst areas.

Tower karst in Khammouane Province, Lao PDR *(Photography: Stuart Chape)*

The Natural/Cultural Nexus of World Heritage Listings

Much of the cultural quality of caves is associated with prehistoric cultures, as is evident in rock art and in floor deposits, which may represent patterns of residential settlement or of religious and other rituals. Others contain historic evidence of a wide range of human uses, including mining, water extraction, refuge, residence, worship, manufacture and others. Indeed, caves have been used for shelter by indigenous people in contemporary periods, such as the Ruc and Arem people of the Chut ethnic group, who until recently lived in the caves in the Phong Nha-Ke Bang area of Viet Nam (BirdLife International and the Forest Inventory and Planning Institute 2001). Many limestone caves in the Asia-Pacific region also retain cultural values, especially in relation to traditional belief systems (see Boxes 2 and 3).

Even within the modern era, some karst areas retain historic features of considerable value – for instance, the structures and facilities of late 19th century or early 20th century tourism associated with some caves in Europe, North America and Australasia. These are rapidly disappearing from other sites, and the opportunity should be taken to properly preserve those that remain associated with caves. Even more recently, during the 21st century some caves were used as shelter during wars, such as the famous cave in Phong Nha Nature Reserve used to shelter Vietnamese troops and people during the Viet Nam War.

Such has been the level, extent and history of human interest in, or utilisation of caves that it would be somewhat unusual to find a major cave system that has no cultural significance. However, of the karst World Heritage areas listed in Annex 3 (Table 1), only one is inscribed on the grounds of both natural and cultural heritage. It may be that the cultural heritage components of some sites are not sufficiently significant to warrant recognition; but in fact, few have even been assessed on cultural criteria. At least eight of the sites may well warrant a review on this basis, although in some cases, the available knowledge does not yet provide the basis for adequate judgement.

Similarly, Zhoukoudian World Heritage Area in China – the excavation site of Peking Man has not been assessed on natural heritage criteria, but the *prima facie* evidence is that this would not be significant. While Luang Prabang World Heritage Area in Lao PDR was assessed on natural heritage criteria, it was judged to be not significant, but this assessment disregarded the special karst values and the site warrants re-assessment on this basis.

Box 2: Vatulele Island, Fiji-a Natural/Cultural Nexus in the Pacific

Although not a World Heritage area, Vatulele Island, in the Fijian archipelago, is a superb example within the under-represented Pacific island heritage context of the nexus between natural and cultural values relating to karst landscapes and ecosystems.

Vatulele is a small limestone island 32 km south of the main Fiji island of Viti Levu, and 31.6 km^2 in area. About 60% of the island is covered in dense dry forest, little affected by human activity due to the rugged karst terrain. The limestone is not coralline but foraminiferous. Geomorphologically complex, the island slopes from 30 metres high cliffs on the western side to around a metre on the east, with the western cliffs subject to successive sectional uplifts (Nunn 1987 quoted in Ewins 1995). The cliffs are renowned for indigenous paintings on the vertical limestone, showing a complex of faces, figures, marine animals and abstract forms, and the earliest paintings are thought to date to the early Lapita settlement in Fiji (Ewins 1995).

Vatulele has long attracted attention from earth scientists owing to the spectacular sequence of ancient shorelines preserved on the northwest coast as distinct notches in the limestone, up to eight metres above present main sea level (ECF 1989). The local people refer to these notches as *calevu ni yalo*: "paths of the spirits" (Ewins 1995). Recent evidence suggests that the emerged notches are mostly pre-Holocene in age; with dates from an emerged reef at Naibalebale (extreme southern tip) showing this feature (2-4 m above modern reef) to be Last Interglacial in age (about 125,000 years old). This means that Vatulele is a very ancient landscape.

South of the high cliffs is a complex of anchialine grottoes and pools, which are the habitat of the rare prawn or shrimp *Parhippolyte uveae*, restricted to anchialine pools in Fiji, Indonesia and the Philippines (Iliffe 2001, Choy 1987) and notable for its red colouration. There are several legends explaining the origin of the prawns and Fijians call the prawns *ura damudamu* (red prawn) or *ura buta* (cooked prawn). The Vatulele islanders treat them with great respect, and still practice a traditional "calling" of the prawns with chants and clapping. All islanders are forbidden to kill or harm the prawns in any way, although tourists with village guides have been allowed to enter the pools for some years.

The linkage between traditional belief systems and karst biophysical attributes and processes on Vatulele shows that a combined cultural and natural heritage perspective is often necessary in recognising and conserving values in karst landscapes. It also shows that traditional knowledge and belief systems *can* be successful in heritage conservation and should be supported. As noted by Choy (1987): "…the magico-religious taboos imposed on the red prawns have clearly been effective and have helped conserve…the rest of the anchialine flora and fauna"

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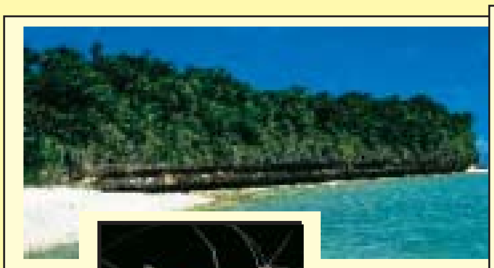
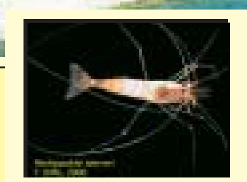
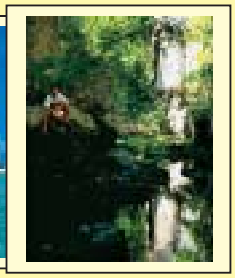
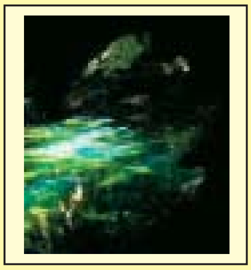








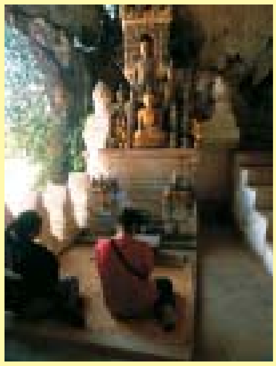
© Roderick Ewins 2001

Photos (L to R): Cliff Paintings, *R. Ewins*; Emerged notches, *S.Chape*; ***P. sterreri***, a close relative of ***P. uveae***, © *T. Iliffe* 2000, Anchialine pool, *S. Chape*; Anchialine pool, *S. Chape*.

Box 3: Tham Thing Buddha Cave, Louang Prabang, Lao PDR

Although there are a number of famous Buddhist sites throughout Laos, including Wat Sisaket in Vientiane with its cloisters holding thousands of Buddha images and Wat Xieng Thong in Luang Prabang built in 1561, one of the best known sites is Tham Thing, on the Mekong River north of Luang Prabang. Two caves, a lower and an upper chamber, lie in the cliffs of rugged karst terrain through which the Mekong River flows on its long journey south. Associated with *pii* (spirit) worship in antiquity, the cave complex contains approximately 4,000 Buddha images, and a major aspect of the cultural significance of Tham Thing is its association with past and present religious beliefs. For centuries Tham Thing received royal patronage and traditionally Lao kings would visit the caves at *Piimai* or Lao Buddhist New Year, with the last Lao king visiting the site in 1975.

Both royalty and devout commoners commissioned Buddha images to be placed inside the caves, and visitors still place images in the cave to give thanks for the granting of wishes or to make merit. The caves are also a popular place for locals to wash their household Buddha images during *Piimai*. Tham Thing has also become a popular location for tourists visiting Laos, with boats coming upriver from the old royal capital Louang Prabang, World Heritage Site, or by road to Ban Pak Ou, the village on the opposite bank of the Mekong charged by early Lao royalty to look after the caves and their cultural values.



Filled with old and new Buddha images and accessed by boat from the Mekong River, Tham Thing remains a contemporary place of worship, as well as a popular cultural and historic tourist attraction *(Photography: Stuart Chape)*

Defining Natural Heritage under the Convention

There seems to be a widely held assumption that 'nature' and 'nature conservation' both focus upon flora and fauna. Landscapes, geologic or geomorphic phenomena and soils are usually seen as valuable only as the substrate for survival of biota, in the relatively static concept of 'geological monuments', or in aesthetic terms. There is little recognition of the concepts that are currently being discussed under the umbrella of *geodiversity*. Obviously, this term suggests a parallel with biodiversity and was possibly adopted for that reason.

To take one example from the World Heritage record, Vinales Valley in Cuba was assessed on both natural and cultural criteria, but only inscribed as cultural heritage. The IUCN assessment report argued that: "*the area does not possess any significant biological diversity*" and " *there are many locations in the world with similar karst landforms such as Ha Long Bay World Heritage site*". In fact, the biodiversity assessment ignored the subterranean biota, and to claim similarity with Ha Long Bay is a broad generalisation that ignores principles of geodiversity. The final judgement may well be correct, but the evidence cited is unconvincing.

This raises two major issues:

- Karst sites, by definition, are of a geomorphic and geologic character. We should ensure that proper consideration is given to geodiversity, including geologic, geomorphic and hydrologic features.

- Invertebrate and microbiotic biota, even if subterranean, should be seen as an important consideration in assessing biodiversity.

Special Qualities of Karst and World Heritage Status

Virtually any major karst area is likely to meet natural heritage criteria (i) and (ii) (see Annex 2). These criteria were developed without any consideration of their applicability to karst, and the result is that in relation to karst areas, they do not in themselves strongly distinguish areas of outstanding significance from those of lesser significance.

This means that in practice, karst areas, perhaps even more than many other areas, are assessed on a comparative basis, which seeks to distinguish the uniqueness of a specific area.

Many karst areas will also meet natural heritage criteria (iii) and (iv). In fact, criterion (iii) raises a special problem in karst areas. Many caves are places of great beauty simply because of the speleothem decoration. However, these beautiful decorations are actually of limited scientific and environmental value. Many people will claim uniqueness simply on the basis of the aesthetic quality of speleothem decoration, even though equivalent decoration is usually abundant in caves throughout the world. Similarly, the size of cave passages is not a strong argument for World Heritage listing.

Interestingly, the most important yet most neglected component of most caves is usually the floor, which is often relatively unattractive. However, the floor sediments contain records of past geoclimatic change, changes in the vegetation of the above ground surface area, while clastic fragments may add further to the geological history of the karst system. Archaeological and palaeontological deposits occur within floor deposits, and the floor also provides an important biological habitat, often readily destroyed by thoughtless trampling.

2. Karst Biodiversity in World Heritage Areas

The UNESCO World Heritage Committee is particularly interested to ensure that biodiversity is given adequate attention in both assessment and management of World Heritage Areas.

The Convention on Biological Diversity defines biodiversity as: "…*the variability among living organisms from which all sources including,* inter alia*, terrestrial, marine and other aquatic ecosystems and the complexes of which they are part; this includes diversity within species, between species and of ecosystems themselves*". Global biodiversity is valued as an economic resource, but also as a part of the human inheritance, as something that needs to be preserved for the well-being, in the widest sense, of future generations.

Tropical limestone areas are rich in species and, in a taxonomic sense, are among the least studied in the world. The nature of karst landscapes, often remote or difficult to access, especially caves, poses special problems for the assessment of biodiversity. By necessity, collection periods are often short, and continued collection and survey over many years is often necessary to yield many new species.

Biodiversity has traditionally been judged primarily on the basis of vertebrate fauna and vascular plants. As already suggested above, karst landscapes may demand consideration based on the diversity of surface or subterranean fauna.

Some specific examples include:

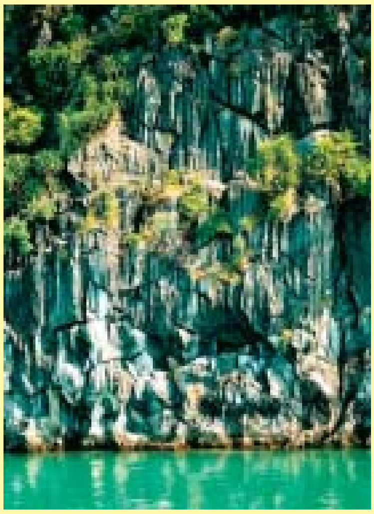
- ❒ The very rich invertebrate populations of Aggtelek World Heritage Area and Mammoth Cave World Heritage Area.
- ❒ Carlsbad Caverns which includes a remarkable diversity of both nanobacteria and bacteria.
- ❒ Cave of Early Man in Cuc Phuong National Park in Vietnam, with the greatest diversity of bats recorded in a single cave.
- ❒ Cape Range in Western Australia, which has the most diverse subterranean fauna yet recorded in any karst province.
- ❒ The remarkable radiation of species in many genera of snails both on the surface and underground in many tropical Asia-Pacific sites.
- ❒ The buried karsts of north-western Australia with the greatest diversity of amphipods recorded from any single aquifer.
- ❒ A range of Asian rainforest sites with rich and diverse invertebrate communities studied by Deharveng and Bedos (2000), including Tham Chiang Dao in Thailand and, in Indonesia: Ngalau Surat (Sumatra), Gua Salukkan Kallang/Towakkalak (Sulawesi) and Batu Lubang (Halmahera).

Box 4: Discovering Biodiversity – Halong Bay World Heritage Area

The karst islands of Ha Long Bay were nominated some years ago as a World Heritage Site due to their unique scenic value, and latterly this has recognised its high geological interest.

It is, however, also home to interesting and in many cases unique plants and wildlife, partially preserved thanks to the ruggedness of its limestone terrain and its setting as hundred of islands in a shallow sea. Surprisingly, very little is known of its caves and cave fauna. During a biological expedition sponsored by the World Bank in September 1998, the authors sampled six caves in a number of Ha Long Bay islands and in the neighbouring, larger, Cat Ba Island. This collection of subterranean biota includes 81 recognised species or morphospecies. Most of these forms appear to be new to science. A highly diverse cave-adapted and cave-restricted species was found among various groups of terrestrial animals such as snails, spiders, millipedes, woodlice, and springtails. Seventeen species of snails were recorded in caves, most of which were not found in outside samples, which would rank Ha Long karst as the richest spot by far for cave snails in Southeast Asia and possibly the world. Preliminary taxonomic investigations suggest that the extreme fragmentation of the Ha Long Bay karst may have led to early speciation among some of its cave animals, as rather remarkable, closely-related forms of spiders, millipedes and springtails were collected in different limestone units. Botanical surveys in the islands have identified new orchids, *Impatiens* and other interesting plants, including a species of ginger, four species in the African violet family, and a new species of palm, 10 metres tall, with large fan shaped leaves, and a spectacular flowering shoot.

Deharveng, Vermeulen and Whitten, in prep. (Oct 2001)



Photography: Jim Muldoon

The following section gives a brief introduction to karst biodiversity. Dr Jaap Vermeulen and Dr Tony Whitten, have kindly allowed the following adaptation of sections of text from their publication *Biodiversity and Cultural Property in the Management of Limestone Resources: Lessons from East Asia* (1997). Chapter 4 of this publication, a description of the main groups of karst organisms, is also presented in Annex 4.

Life above Ground

Soils over limestone bedrock, if present at all, are often thin, although thick accumulations occur in valleys without surface drainage. Thin limestone soils are often deficient in most nutrients except calcium and magnesium. These two elements are often present in excess, and tend to restrict the availability of important nutrients to plants. Because of the predominantly underground drainage of karst areas through cracks in the rock, organisms living on limestone are also subjected to periodic and prolonged drought. The thin and often patchy vegetation cover may also provide little shade. In general, the environment in a karst area is much harsher than in surrounding areas on other bedrock, although collapsed dolines, deep gorges and crevices may provide protected, well-shaded and damp habitats locally. In depressions in rocky plateaux without drainage, leaf litter and other organic matter sometimes gather in puddles of still water, particularly in areas with a perpetually wet climate. In Irian Jaya these have developed into extensive rain-fed bogs.

Life at Cave Entrances

Cave entrances or dolines often provide a range of stratified micro-habitats. Perhaps one of the most remarkable examples is the great dolines of Skocjanske Jame World Heritage Area in Slovenia. At the bottom of the doline cold air from the caves provides for a predominantly alpine flora while at the top, the flora has a close affinity with coastal Mediterranean ecosystems. Within this, of course, one also finds the appropriate systems of invertebrate and vertebrate fauna.

Life in Caves

Lack of light is the most determining factor for all life in caves, in small voids, in deep cracks in the rock, and in open spaces in scree fields. According to the degree of darkness and other physical conditions, the cave environment can be divided into three zones, starting at the entrance:

- the *twilight zone* near the cave entrance where light intensity, humidity, and temperature vary, and where a large and varied fauna can be found;
- the *transition zone*, of complete darkness but still variable humidity and temperature; here, a number of common species live, some of which make sorties to the outside world;
- the *deep zone*, of complete darkness and almost constant 100% humidity and constant temperature; this is the home of fully cave-adapted species which never venture outside the cave; due to the high humidity, a condition that would drown many surface creatures, the differences between terrestrial and aquatic life tends to blur: a cave fish species is known, for instance, that creeps over wet rock, above the water

level. Plants cannot grow here, although roots may and often do penetrate the cave ceiling. The most important effect of this exclusion of green plants is to make all almost cave dwellers dependent on organic material brought in from the outside[1], and to exclude all animals that feed directly on the above-ground parts of green plants. In the deepest, most isolated parts of caves the air may be stagnant, and CO_2 concentrations may be so high that, for humans, breathing is difficult. Here, too, organisms are adapted to cope with this environment.

Energy is available in localised deposits of organic material: piles of guano (dung) below the roosts of bats and swiftlets, organic material falling into the cave through crevices in the roof, drift material washed in by streams, particularly during floods, and material (insects, for instance) drawn in by draughts. Particularly in the tropics, tree roots are also an important source of organic material; many trees such as figs survive the harsh surface environment by sending roots deep into the rock, often down to the water table. Specialised organisms, including micro-organisms such as fungi, protozoa and mineral-fixing bacteria, utilize these deposits, and a food chain of giant arthropods dissipate small amounts of organic material throughout the cave system, down to the deepest recesses.

Because of the absence of light, many true cave animals do not display any daily or seasonal rhythm in their activities. Some, however, have a daily rhythm imposed upon them, for instance by the daily rhythm of air draughts, but in particular by the departure and subsequent return of bats and swiftlets. In their absence, food is not available for the free-living parasites in the roosts, and there is a halt to the rain of fresh faeces on which the numerous inhabitants of the guano piles feed.

The insulating role of the walls and roofs of caves effectively buffers the relatively wide, daily variations in temperature and humidity of the outside world. Conditions thus remain fairly stable day-to-day, especially deep within a cave, but there are still seasonal changes which can more or less alter the conditions in the cave. For example, during the rainy season the humidity and amount of free water within a cave tend to increase. Air movement is also buffered by the cave walls, but still occurs as air is drawn out of the cave during the day, when the air outside is warmer and lighter. This air movement follows a regular pattern, but leaves pockets of still air in deep caves where spiders can weave delicate and complex webs, and preserves pockets of high humidity. In these deeper areas, the concentration of CO_2 increases if there is no inflow of air except from the cave mouth.

It is likely that life in below ground communities will turn out to be richer and more diverse than scientists could ever have anticipated. Many species that are found in caves live, in fact, in small voids with a relatively high humidity and high levels of carbon dioxide, and only occasionally wander off into larger caves where they can be seen. Most limestone bodies are riddled with such small voids, even when no larger caves are present.

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[1] Self-supporting cave systems with no input from outside are known where all nutrients are provided by sulphur-fixing bacteria.

Box 5: Life in the Dark

Caves are one of the most peculiar terrestrial ecosystems. They host communities of, in our eyes, strange organisms adapted to extreme conditions. Green plants, which form the matrix of nearly all above ground ecosystems, are absent. To cope with the permanent darkness, extreme patchiness of food, and relatively constant climate of the underground voids, cave animals have all developed adaptations at physiological, behavioural and morphological levels. They lose many of the essential functions of aboveground species. Their eyes are reduced or absent. They have little or no pigment. In contrast, their ability to regulate water is enhanced: they have developed means of expelling water in 100% humidity, and to expel excess water without losing body salts. If their ancestors had wings, they have lost them. Internal biological clocks tend to blur. Their life span increases, while their fertility decreases dramatically. These adaptations have confined cave species to their habitat, they cannot survive elsewhere. If the cave in which they live is destroyed, they perish.

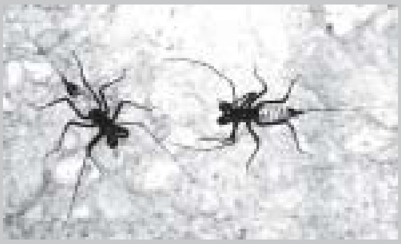
East Asiatic cave fauna includes many exceptional organisms. A few examples are given below:

- *Cave fish*. Cave fish are fragile white, or pinkish animals, with reduced eyes, devoid of scales and pigment. They are present in small populations in some caves of Thailand and China, and most species are restricted to only one or two caves. Often, they occupy niches that outside fish, which frequently enter caves, do not reach. In Lao PDR, a new genus of cave fish was encountered at the bottom of a 20m deep cave passage

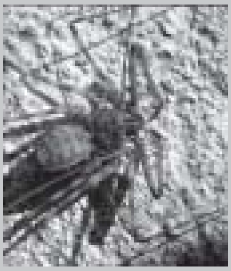
- *Giant insects.* Among the most spectacular species are the giant crickets, centipedes, spiders and whip-scorpions that roam the cave walls of the region. They need both darkness and an adequate food supply, which is provided by surrounding guano piles.

- *Aquatic woodlice*. Most of the world's woodlice are terrestrial but a truly aquatic species, *Thailandoniscus annae,* is found in Phang Nga Bay, southern Thailand. This remarkable animal is known from only one population, living in a small pool in Tapan cave, and has never been found in any other cave in the region, nor in any other pool in the same cave.

Huntsman Spider



Uropygi carrying young, Khammouane Province, Lao PDR



Amblypygid, Maros caves, South Sulawesi

(Photography: Louis Deharveng)

Endemism and Karst Landscapes

A species is endemic if its range is restricted to a specific geographical area. Endemic species are regarded as particularly precious elements of the earth's biodiversity. Depending on the context the geographical area may refer, for example, to a *site* (e.g. a mountain top), or to a *biogeographical region* (e.g. the island of New Guinea and surrounding archipelagos).

Many limestone endemics, although occupying a sizeable range, occur on only a few limestone outcrops, which together cover only a minute fraction of that range. These species occupy a very small area ; they are '*rare*' species. On the other hand, limestone outcrops in cleared land, and particularly the narrow fringes of original vegetation surrounding them, may support the last remnants of communities that previously occupied large parts of the area, both on limestone as well as on other rock types. Although not limestone inhabitants in the strict sense, the range of the species living there may have been so much reduced that they are as '*vulnerable*' to extinction as true limestone species. The occurrence and threatened status of such species should be considered when assessing limestone communities.

Karst areas under humid tropical conditions are home to numerous plant and animal species with an extraordinarily small range. This is thought to have originated in the extreme and diverse environmental conditions on tropical karst surfaces, such as:

- deleterious effects of a high concentration of calcium and magnesium in the environment;
- the marked topography of many karst areas (steep-sided hills, plateaux, and caves) and a large altitudinal range) in combination with the often intricate pattern of acid and alkaline soils;
- extreme dissection of the karst surface - particularly in tower karst numerous limestone hills are separated by valleys with a non-calcareous, alluvial top soil; to limestone dependent plants and animals such hills are as isolated from one another as are islands in a sea;
- extreme climatic conditions, such as exposure to the sun, drought due to very efficient, mainly underground drainage systems, alternating with torrential rain, etc.

Box 6: Smallest and hottest hotspot of cave biodiversity in East Asia

Over 200 caves have been surveyed for their fauna in East Asia, from Sulawesi to China. The freshwater arthropod fauna of each of these caves usually consists of only one to four endemic species. The underground system of two small caves (Tham Phulu and Tham Kubio) in eastern Thailand, is an exception. These caves are used as a sanctuary by Buddhist monks and have two small pools each, in which six highly specialised cave species live, all in large numbers. All these species but one are so far restricted to this cave. Two of them are the only representatives of a genus, and therefore of high biodiversity value

These conditions exert a strong ecological pressure on any species not adapted to them. The species may respond in two ways to the pressure: local extinction, or adaptation by accelerated evolution (often after a reduction of the numbers of individuals). In the process, isolated populations in this highly fragmented environment are likely to develop into distinct species. Some adapt so thoroughly that the land surrounding the karst area, possibly still inhabited by their evolutionary predecessors, has become inhabitable territory to them. Such limestone-restricted species cannot shift anymore to non-limestone habitats.

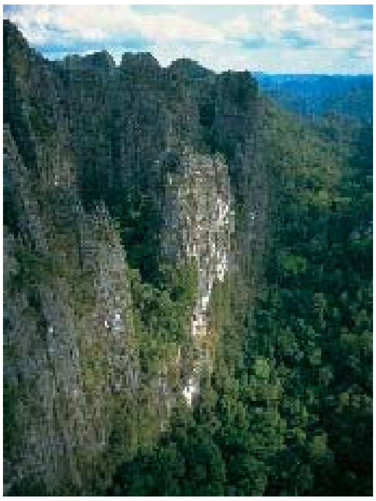
Dolomitic limestone, in which part of the calcium has been replaced by magnesium, often have less value for biodiversity conservation than high-calcium limestone.

Problems of Protection

Lists of protected species, such as the IUCN Red List, comprise species that are nationally or internationally recognised as vulnerable, endangered or presumed extinct. They are supposed to serve as a reference but, however useful for some purposes, they should be used with great care. These lists are in most cases only more or less complete for some groups of higher vertebrates. Any taxonomist working on less conspicuous groups of organisms or any group of invertebrates, can attest to the overall incompleteness of the lists. Each limestone biodiversity specialist could add to it tens, or even hundreds, of species from the groups of organisms they have studied.

A mistaken interpretation of Red List species is that, if no listed species is recorded on a site, the site cannot be a candidate for conservation. Many limestone caves and other environments, which often host extremely valuable components of the earth's biodiversity, may thus be 'legally' overlooked in conservation and other development programs.

Examples of Karst Landforms in the Asia-Pacific Region



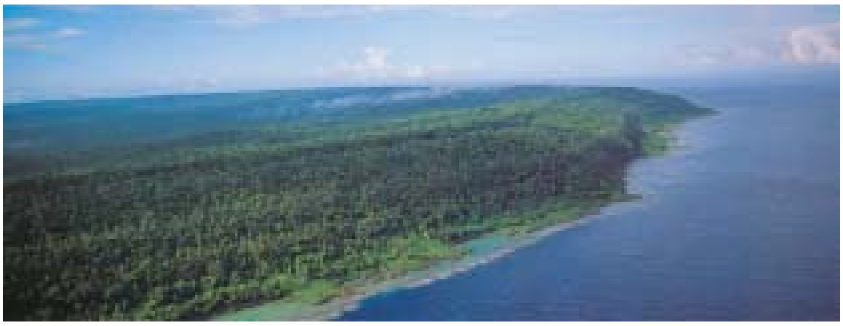
Hin Nam No NBCA, Lao PDR
(Stuart Chape)

Syngenetic karst, Nullarbor, Western Australia
(Elery Hamilton-Smith)

View to Phong Nha Nature Reserve, Viet Nam
(Stuart Chape)

Halong Bay WHA, Viet Nam
(Jim Muldoon)

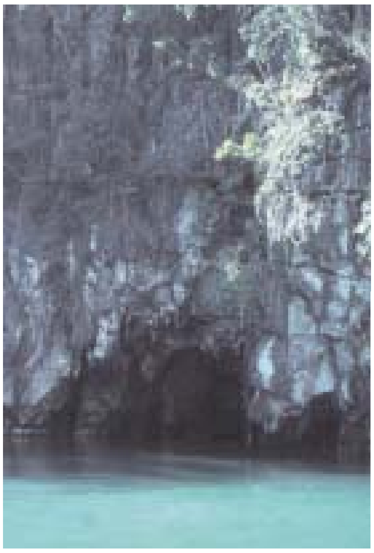
Vuaqava Island, Fiji, with saltwater lake
(Stuart Chape)



East Rennell WHA, Solomon Islands
(Paddy Ryan)

Lorentz National Park WHA and adjacent areas, West Papua, Indonesia has important karst features *(Peter Hitchcock)*

Doline field, Kah urangi (Mt Owen) New Zealand *(Peter Ackroyd)*



Puerto Princesa Subterranean River WHA, Philippines

Kwangsi travertine waterfall, Louang Prabang Province Lao PDR *(Stuart Chape)*

Lake Clifton, Western Australia, contains Stromatolites *(Stuart Chape)*

Fulaga Lagoon, Lau Group, Fiji, with numerous limestone islets *(Stuart Chape)*

Doline near Leye County, China (hot air balloon for scale) *(Prof. Zhu Xinwuen)*

Limestone arch and top entrance to Crown Cave, Guangxi Province, China *(Andy Eavis)*

Lake in Jiuzhaigou Valley Scenic and Historic Interest Area WHA, Sichuan Province, China *(Tim Wong)*

Lubang Leaputte 260 m shaft, Maros, Sulawesi *(Louis Deharveng)*

Garden of Eden with entrance to Green Cave, Melinau Paku with Mount Api in the background Gunung Mulu WHA, Sarawak *(Andy Eavis)*

River passage in the Clearwater system, Gunung Mulu WHA, Sarawak *(Andy Eavis)*

3. Issues in the Maintenance of Integrity and Adequate Management of Karst Values in World Heritage Areas

Participants at the Mulu Forum discussed the key management issues in protecting the integrity of World Heritage Karst sites. Together with the IUCN Guidelines for Cave and Karst Protection (1997), the following issues were identified. Several people emphasized the point that many of the observations relate to any protected area, but some specific issues were raised that affect World Heritage Areas and karst landscapes in particular. These can be described conveniently under five thematic headings:

Hydrology, World Heritage Area Boundaries and Designation Issues
Water is the key for karst landscapes, and the integrity of a World Heritage site relating to its hydrology is a critically important issue. Every effort should be made to ensure that the total groundwater catchment is included within the boundaries of the nominated World Heritage site so that the management authority can maintain control over the management of the groundwater on which the integrity of the karst depends. The lack of control over the catchment was the main reason for the deferral of the application for World Heritage status of the St Paul Subterranean River National Park in Palawan, Philippines. The full catchment of the underground river was brought under the control of the management authority and the area is now the Puerto Princesa Underground River World Heritage Area.

One further problem is that underground catchments do not necessarily follow surface landscape forms. An application for boundary extension of the Plitvice World Heritage Area in Croatia, based upon this principle, was approved at the 24th Session of the World Heritage Committee in December 2000, despite some concerns that the extension did not contribute to the biodiversity of the site and also involved non-pristine land areas. Such a view fails to understand the nature of karst, and further points to the fact that the groundwater divide may not coincide with any surface water divide. Underground catchments can be defined relatively easily with the use of tracer dyes.

Karst areas may well be linked, even when not contiguous. This link could be hydrological, though phreatic water movement in the saturated zone, or it could be due to a similarity in biodiversity. It raises the issue of cluster nominations, a concept which Forum participants were very supportive of, and are keen see appropriately implemented. Cluster sites consist of several sites that would merit World Heritage status but are either geographically close or are linked in a thematic manner, and could therefore be nominated as a cluster area.

This cluster concept, while useful in many cases, is not without its problems. To provide an example from Australia, inscription of the Greater Blue Mountains area of the State of New South Wales (NSW) was approved at the 24th Session of the WH Committee at Cairns in 2000. It includes the Jenolan Caves Reserve, which is an outstanding example of a mixed site, but is not congruent with the major justification for this inscription. In terms of integrity, it would be far better included in a nomination of the Central Eastern Highland NSW karst areas (including perhaps Wombeyan, Abercrombie and Borenore Cave areas). All of these are small areas of limestone surrounded by insoluble rocks (impounded karst), all have shared in one of the most complex processes of cave evolution and development yet demonstrated, and all share a very high range of karst values, yet only Jenolan and some very small areas were included in the inscribed area.

Another example from Australia is the Australian Fossil Mammal Sites World Heritage Area, which covers two geographically different areas, one of which is Naracoorte Caves. The integrity of the World Heritage site makes the two sites a realistic complex.

Participants at the Mulu Forum were concerned that karst values are often not recognised when karst is included in a broader site. For instance, extensive areas of karst, with very special and distinctive qualities, are included in the Lorentz National Park World Heritage Area, yet it is not referred to in the nomination and no consideration has been given to its management requirements. A similar situation prevails in Thailand where the Thung Yai Hua Kha Khaeng World Heritage Area is part of the Western Complex – a patchwork of different protected areas. Nowhere is the management of karst specifically addressed. The forum concluded that karst values, if present, should be given consideration in any World Heritage assessment or management plan.

A specific recommendation of the Mulu Forum was that limestone hills designated as protected areas should include as wide a perimeter of forest as possible, because the transition zone forest at the foot of the hills is richest in species.

The Forum also noted that appropriate zonation schemes should be developed to harmonise between protection and sustainable use activities. Buffer and multiple use zones are examples of these.

Impacts from Activities Outside of the Protected Area

The dependence of karst upon the groundwater and other drainage systems means that it may readily be impacted by events occurring outside of the karst boundary, particularly when these occur within the watershed. The following issues were identified by the Forum participants and additional points have been expanded upon from the Guidelines for Cave and Karst Protection (1997).

- Run-off from quarrying may cause serious sedimentation or pollution of karst areas. For instance, a quarry existed near the boundary of the Tasmanian Wilderness World Heritage Area and was located adjacent to the Exit Cave system. Drainage from the quarry into the groundwater resulted in sedimentation of underground streams and consequent destruction of Hydrobiid snails living in those streams. This was compounded by hydrocarbon fuel spillages, some of which wiped out the rich fauna of an adjoining cave.

- Farming, or other activities that discharge organic wastes provide an important threat. Organic waste may lead to eutrophication (enrichment) of the groundwater and consequently to algal growth. This is being observed in many karst areas under agricultural land, and has occurred at the Aggtelek-Domica World Heritage Area in Hungary. Water filled dolines and other groundwater exposures are becoming clogged with algae as a result of farming both adjoining and within the protected area. A similar situation prevails in the Mt Gambier Cenote Karst of South Australia. Here the situation appears to be compounded by the re-distribution of algae by recreational divers. More importantly, the algal mats that develop serve to effectively exclude sunlight, and will inhibit the continuing growth of the remarkable living freshwater stromatolites that occur in the cenotes.

- Another occurrence of interest is at Lake Clifton in Yalgorup National Park (Western Australia). Although the Lake with its particularly important stromatolites is in a protected area, the Eastern Sector of its watershed is not. Planning restrictions have been enacted over the watershed area to control the water balance and restrict the use of chemical fertilisers.

- Eutrophication is also compounded by the use of chemical fertilisers that dissolve and enter the groundwater. Pesticides, fertilisers or other industrial chemicals have their own impacts, particularly upon biota. Direct application may not have to occur. Further, it is now generally recommended that chemicals of this kind not be utilised in re-vegetation programs upon karst because of their potential impacts upon subterranean fauna.

- The Mulu Forum was strong in the view that industrial and commercial activities that have a direct impact on the use and quality of the water that feeds the karst area should be re-located elsewhere or mitigated. For instance, Ha Long Bay World Heritage Area in Vietnam adjoins a river estuary that drains an intensely developed hinterland, which includes the largest coal mining operation in Vietnam. The extent of chemical pollution and sedimentation is not adequately monitored, and opinions differ on its severity, but it is certainly impacting upon the sea floor and hence on the marine ecosystem. Current plans to ensure adequate monitoring and remedial action should solve the problems in due course.

Internal Management Issues

World Heritage status requires management of caves and karst landscapes to an international standard. This will require long-term management plans and well-trained staff. The inscription of a karst site on the World Heritage List signifies that the State Party assumes responsibility for the conservation of the site in perpetuity for the people of the world and, subject to any restrictions that may be necessary to ensure conservation, for public access to the site.

Arrangements for visitor access must minimise impacts of both the visitors and the infrastructure for serving those visitors. In many cases, the infrastructure pre-dates World Heritage inscription and it may be necessary to upgrade facilities in order to reduce impacts and provide a level of visitor service congruent with World Heritage status. What tourists want is not necessarily what is good for the World Heritage Area.

With even the best of infrastructure, the presence of visitors will still cause at least some environmental impacts. Impacts must be determined, monitored and assessed in order to develop a detailed understanding of the causes and nature of impacts as a basis for developing remedial action.

The Mulu Forum identified a number of issues that managers need to address within a karst World Heritage Area (see Box 8).

Invasive species was another important internal management issue identified by participants. These can be one of the very special impacts of visitors, albeit both indirect and often subtle. Perhaps one of the most famous examples is the Maladie Verte (generally known as lampenflora) of Lascaux Cave in France. In this example, the vital task of protection and preservation led to closure of the cave itself to all but a very limited number of visitors and the construction of a facsimile cave known as Lascaux 2.

However, invasive species may arrive at, and enter, protected areas in any one of an immense variety of ways, including:

- feral animals which may be predators (e.g., foxes, cats) or may have a dramatic impact upon soil stability and vegetation (e.g., goats);
- weeds, which may displace indigenous species;
- algae and vascular plants, introduced to karst waters by either agricultural practices and eutrophication or by human movements;
- insects, such as the dominant American and Australian cockroaches, have invaded cave communities in Malaysia and Madagascar, displacing comparable endemic species and preying upon others;
- pathogens which damage or even destroy indigenous species;
- micro-biota, which may have impacts that we neither recognise nor understand - certain changes to speleothems abutting the pathways in tourist caves appear to result from this.

Box 7: Critical Management Issues in World Heritage Areas Defined by the Gunung Mulu Forum

- A World Heritage Area has to have policies and regulations with regards to acceptable activities in and around the protected area. Law enforcement to punish infringement of rules and regulations is necessary, and the management authority must have the necessary mandate for enforcement.

- Advisory groups could be established to help with management advice. Scientific advisory groups could include inputs from international agencies (IUCN, WCPA, CI, WCS, and WWF) and from experts from the Region (through WCPA, ASEAN, Asia-Pacific Focal Point for World Heritage). There is also an important place where relevant, for advisory groups of indigenous peoples, residents or other local stakeholders.

- Waste disposal and treatment, especially of visitors and staff, must be considered and pollution of the underground water resources must be avoided. Commercial activities in or near the World Heritage Area, such as restaurants, bars and accommodation should follow strict EIA guidelines and have their leases withdrawn in case of non-compliance.

- Management of visitors, and determining acceptable numbers is important, especially in caves. There are two groups of cave visitors: those that follow the path to demarcated "tourist caves" and those that wish to visit "undeveloped" caves. Regulations and management prescription are required for both.

- Physical access to caves and surface karst landforms, and maintenance of the infrastructure leading to these places is important to avoid unplanned developments. Raised walkways and manually propelled boats are safe ways of transporting visitors.

- Public safety is an important issue that must not be overlooked. Defunct walkways, slippery steps, broken lights are all potential causes for accidents. Public safety has significant health and legal implications for management authorities.

- Underground lighting in caves is important. It should provide for visibility within the cave and for public safety, but have minimum negative impacts on the cave environment. Thus, as one example, the installation should be designed to ensure that lampenflora will not develop. Properly designed lighting will be low-key, enhancing the beauty and drama of the cave, and will present the key features of the cave to the public, while providing for both security of the resource and public safety.

- Opportunities for infrared cameras and TV screens away from the actual caves should be explored, so that the most sensitive aspects of the caves can remain undisturbed. These may be expensive to install, but in the long run they will create less impact and may reduce maintenance costs. Naracoorte Caves in Australia prohibits visitors from interfering with the bat population in some of its caves. Instead, infrared cameras transmit the activities of the bat colony to an enclosed surface observatory with television screens and comfortable sitting arrangements.

- Caving expeditions can be useful to generate lots of information in a short period of time, but they can also be problematic. Exploration for exploration sake may be inappropriate in World Heritage Areas. Applied research is important and if exploration can help with this, so much the better.

Finance Issues

The Mulu Forum acknowledged the important role that finance plays in funding protected area management, and identified the following specific issues:

- World Heritage listing should be used as a means to generate funds for conservation, both from the domestic budget and from external sources of finance.
- Direct relationships should be established between park income and park management by using the revenue from tourist visitors for the management of the park. This is not always possible, as in many countries tourism revenue flows either to the general Department budget or to the national Treasury Department. World Heritage status may provide the argument for "special treatment" by the Treasury Department.
- Options should be explored for management to pay for research if it is needed to answer certain management questions. Using tourist revenue for this purpose could be one solution.
- Business plans and financial projections should be developed to determine long-term investment needs for infrastructure development.
- Specific high-income activities related to karst include: adventure tourism, mining of aggregate and marble, bird nest harvesting, guano mining, and collection of orchids and other plants. In order to manage these activities in a World Heritage Area, and if they are environmentally sustainable and compatible with maintenance of World Heritage values, there is need for the business plan to provide for rigorous control and supervision.

Education, training and awareness

Education and awareness raising was seen by the Forum as a critical issue in maintaining the integrity of karst World Heritage sites. The values of karst and the ways in which people can impact upon karst areas should be related to all relevant stakeholders, including managers, visitors, resource users and external stakeholders whose activities may impact upon the karst area. Issues include:

- The need to train park rangers and staff about karst values.
- Visitors need to be informed. Presentation should be improved, and sound interpretation programs and materials developed as required.
- Education of local people, through both schools and community involvement programs, is important to build partnerships and community ownership.
- General awareness and public relations is important. Public participation in boundary demarcation, management planning and law enforcement are important in maintaining the trust from the local community.

4. Setting Priorities in Protection and World Heritage Inscription of Karst Areas in the Asia-Pacific Region

Criteria for Determining Priorities
There are a large number of criteria to be considered, the first of which are the basic formal criteria for World Heritage nomination that relate to both cultural and natural heritage.

One of the distinctive qualities of karst is the very high degree of interaction between a wide diversity of elements and linking processes described earlier in this report.

We might seek to further assess the potential World Heritage significance of karst landscapes by seeking sites which: "explicitly demonstrate, either currently or in the geomorphic or other record, the complex interactions of structural elements and processes which characterise karst".

For all areas, one must also ask to what extent the phenomena demonstrated by the site are or are not already well represented in the existing World Heritage List. In this region, it is critical that some of the karst areas in China are reviewed and that nominations are prepared, as they represent some of the most spectacular and diverse karst landscapes in the Asia-Pacific region.

Finally, the integrity of both the total surface and underground environment needs to be emphasised.

The following table details a possible evaluation and assessment checklist for karst systems, which may be a useful tool for assessing the full suite of World Heritage values (natural and cultural) present in karst landscapes.

A meeting of experts does neither have the authority or the mandate to nominate sites for inscription. The final decision to nominate a protected area for World Heritage status is the responsibility of the State Parties. Therefore, the Asia-Pacific Forum on Karst Ecosystems and World Heritage *recommends* the following actions to take place. These actions can be listed in two sub groups.

1. Priority projects, which involve preparatory work with assistance from UNESCO, IUCN, WCPA and others, with the aim to develop proposals for action by State Parties within the next year.

2. Other actions, some of which are already proceeding or can readily proceed on the initiative of the respective State Parties without outside assistance within the next two years. Still others are perhaps not yet being considered, but should be subject to pre-nomination review at some stage in the next five years.

Draft Evaluation and Assessment Checklist for Karst Systems

WH Convention: criteria and conditions of integrity	Theme	Specific Characteristics
N(i)	Overall Context of the Karst System	Regional context, continental, coastal or island situation; lithology, structure, stratigraphy, morphogenetic context, geomorphic history.
N(i)	Landform Geodiversity	Enclosed depressions, such as dolines, uvalas, poljes, blind valleys, gorges, cones, towers, case hardening, karren (both bare rock and covered forms), assemblages. Hydrologic features such as sinking streams, springs, estavelles, hot springs, submarine springs, turloughs. Depositional landforms such as phytokarst, tufa and travertines, mound springs, terraces, stromatolites.
N(ii)	Groundwater Systems and meteorology	Flow patterns, sinks and springs. Atmospheric and climatic patterns, including microclimates.
N(i)	Subterranean landforms, primarily caves	Varying plan and cross-sectional patterns, relation to aquifer, genetic types of caves, age of caves, depth and length of caves.
N(i,ii,iii) + C	Cave Contents	Sediments, clastic fills, precipitates, types of speleothems. Stratigraphy of fills. Dating potentials. Palaeontology, archaeology, other cultural relics or modifications.
N(ii, iv)	Surface Biodiversity	Surface flora and fauna. Invertebrates of terrestrial, freshwater and anchialine environments. Microbiota, including nanobacteria, bacteria, protozoa, algae. Issues of speciation, adaptation, and endemism.
N(ii, iv)	Subsurface Biodiversity	Subterranean flora and fauna, including vertebrates, invertebrates and microbiota. Speciation, adaptation, endemism.
C	Cultural, religious, historical and archaeological values	Residence, spiritual or religious, artistic, refuges. Recreation and tourism, aesthetics. Research and education.
	Negative human impacts	Damage to or fragmentation of system. Modification for human use – design quality and impacts. Invasive species impacts. Production, sanatoria, defence, water supply cheese, mushrooms. Pollution and sedimentation Hazards and health issues. Birds nest collection, Guano extraction.
	Ensuring integrity	Allogenic catchment condition draining into karst. Monitoring and control of environment. Management policies and quality.

Although a site may not meet the criteria for World Heritage inscription, it may have a number of values, which suggest that the host state should be encouraged to provide more adequate protection within its own legislative framework. Consideration may also be given to the possibility of Ramsar inscription of 'subterranean wetlands', which may provide more appropriate recognition in some situations. Within ASEAN, there is also the option to nominate a protected area as an ASEAN Heritage Site.

1. ***Priority projects, which involve preparatory work with assistance from UNESCO, IUCN, WCPA and others, with the aim to develop proposals for action by State Parties before the end of 2002 (See Maps 3 and 4)***

China

The three major karst World Heritage Areas of Huanglong, Jiuzhaigou Valley and Wulingyuan should each be subject to any necessary research and re-assessment to explore whether they should also be designated under the biodiversity criterion. The need for a more effective buffer zone and boundary redefinition should be considered at Zhoukoudian World Heritage Area.

The process of World Heritage nomination is already proceeding for the Lunan Stone Forest (Shilin National Park) of Yunnan Province.

Assistance is requested in carrying out pre-nomination reviews of the Guizhou karst plateau; and the Guilin tower karst. These reviews should help to identify boundaries, describe the World Heritage values, and assist with the definition of management priorities.

Lao PDR

The spectacular karst areas of Lao PDR appear to have an extremely high biodiversity and doubtless more adequate assessment will demonstrate that some will meet criteria for international recognition. However, currently the government does not appear to be ready to deal with protection and recognition of Natural World Heritage Areas, and assistance should be provided to the relevant Government agencies to raise awareness about the natural heritage aspects of the Convention.

In particular, the future option of a co-operative Lao PDR-Vietnam cross-border or cluster karst World Heritage Area, comprising the contiguous Hin Nam No NBCA in Lao PDR and Phong Nha/Ke Bang in Vietnam, should be addressed in discussions with government. Other important areas in Khammouane Province include the Phou Hin Phoun NBCA (Hin Nam No is also in Khammouane Province) and the possible boundary expansion and re-assessment of Luang Prabang as a mixed site.

Myanmar

There is urgent need to open a policy dialogue with the Government on protected areas management and natural World Heritage Areas, to ascertain whether there is interest in pursuing these issues. In collaboration with the Government of Myanmar and relevant institutions within Myanmar**,** this should be associated with a scientific reconnaissance visit by a small group of international experts to carry out a rapid assessment of karst areas. Only after such a reconnaissance will we know whether there is a potential karst World Heritage Area in Myanmar.

Oceania

There is need for a natural and cultural karst resources study of the many islands in the Pacific, a review of the overall situation and a capacity building exercise for relevant Government agencies. There is likely to be scope for designation of mixed natural and cultural World Heritage sites. Potential cultural World Heritage Areas would be referred to ICOMOS for review.

This overall review should include a reassessment and management review of Henderson Island World Heritage Area and East Rennell World Heritage Area as both may meet wider criteria than are currently recognised. Such a study would be need to be done with the consent of, and in collaboration with, the Pacific Island governments as well as with key partners such as SPREP and the UNESCO Pacific Office in Apia, Samoa.

Philippines

While considerable karst occurs in the Philippines, there is a lack of data about its values. There is need for an extensive data development and review process, including desk studies of all existing information; site visits to some of the most promising sites and limited survey work, all within the framework of the newly proclaimed cave protection legislation. On the basis of this information priorities can be set.

Thailand

There is strong *prima facie* evidence that Thailand has several protected areas that could be nominated for karst World Heritage status. The Royal Forest Department has urgently requested assistance with a capacity building programme to strengthen its own capacity for reviewing Thailand's karst areas and its national parks system. This capacity building programme would probably comprise an 18-24 months series of educational programs at various levels, seminars, on-the-job training exercises and other field-work..

Papua New Guinea

There are several areas that may possibly merit World Heritage nomination, including the Huon Peninsula; the Kikori–Darai plateau; the Nakani-Whiteman Ranges; the Trobriand Islands; the Muller Plateau and the Hindenburg Wall. Pre-nomination reviews of all these areas are recommended, but this process requires careful consideration and management.

2. ***Action that is proceeding or can readily proceed on the initiative of the respective State Parties and those which need to be followed through over the next five years (See Maps 3 and 4)***

Australia

Consideration of nomination as karst World Heritage Areas of the following:

- Nullarbor Region
- Cape Range
- Limestone Ranges (A Devonian Coral reef, located in west Kimberley, which has not suffered any tectonic or other structural change)
- Ruined City (karst area in Arnhem Land).

The Tasmanian Wilderness World Heritage Area and Mole Creek National Park both exclude some of the very important and significant sectors of the Mole Creek Karst. The World Heritage Area should be expanded to include some of these areas. Consideration should also be given to inclusion of the Hastings Caves Reserve and Mt Cripps Karst.

The following sites in Australia have relatively adequate data, but there is a need for a pre-nomination review of their potential as World Heritage sites:

- Chillagoe-Mitchell Palmer – a striking karst system of considerable natural and cultural importance. It includes one of the finest examples of semi-arid vine thicket vegetation that is Australia‘s only deciduous forest.

- Eastern Highlands Impounded Karsts – A number cave systems with complex geological origin, rich fauna, high levels of aesthetic qualities and a rich cultural history are located in south eastern Australia. Some of these have already been included in the Greater Blue Mountains World Heritage Area, but consideration should be given to these and others being brought together as a separate karst site on the basis of their very special karst values

- Syngenetic karsts – Australia has the best-developed examples of syngenetic karst, which is formed when the processes of consolidation of Aeolian limestone and their dissolution proceed concurrently.

- Both Shark Bay and the Great Barrier Reef are already World Heritage areas, but each includes some important karst features that may warrant special consideration.

Indonesia

The Government should consider boundary extension of Lorentz World Heritage Area, in order to include the Baliem River system and other areas of karst currently excluded from the Park.

The Government should review the possible World Heritage values of Gunung Sewu (Java) and the Maros karst (A particularly outstanding site for geodiversity and cave fauna in Sulawesi), and identify appropriate protection status and international recognition. Information is available, but it is not clear whether the sites will pass the integrity criteria. Both sites are subject to strong human pressure, and Gunung Sewu is under intensive agricultural production and heavily populated.

The following sites are data deficient, and require further survey and field studies:

- Tana Toraja (Sulawesi);

- in particular, the Sangkulirang karst in Kalimantan is remarkably rich in cave paintings but probably in other values also. It demands review of both cultural and natural heritage values An expedition is currently being planned to carry out an appropriate review.

Japan

A full assessment of the Akiyoshi-Dai karst area that took account of the evidence of geo-climatic history, the subterranean biodiversity and the cultural history might well demonstrate that it warrants nomination as a World Heritage Area.

Korea

A review should be undertaken of at least the Dae-i-ri area, the Dong River area, and San-gye-ri areas to ascertain whether a World Heritage Area nomination should be prepared. Also, although Jeju Island is predominantly volcanic and has a remarkable number of lava tunnels, it is overlain with aeolian sands and thus many of the lava tubes (caves) have karst speleothems, and its potential for World Heritage status should be assessed.

New Zealand

Government should consider the nomination of Kahurangi (Mt Owen). This comprises a $100km^2$ glaciated marble karst area, which is the best example of a glaciated karst in the Southern Hemisphere. It contains major caves, including the more than 55 kilometres of Bulmer Cave.

Malaysia

The boundary of Gunung Mulu World Heritage Area should be expanded to include Gunung Buda.

Consideration is being given to the nomination of Niah Great Cave (Sarawak) as cultural heritage. It certainly also warrants consideration on biodiversity grounds, and a study should be commissioned to determine the potential Natural Heritage values.

Other sites that demand review to assess whether they are likely to meet World Heritage criteria include:

- Pulau Dayang Bunting;

- Gomantong Cave (Sabah) needs to be studied in more detail; this is a remarkable cave on both morphological and biological grounds, but there is currently inadequate data available on its regional context;
- Medai (Sabah).

The application of the cluster concept was a recurring theme throughout the Malaysian discussions, given the similarities and proximity of some of the potential WH sites.

Vietnam

The Government has re-nominated Phong Nha/Ke Bang Massif, but the nomination was recently withdrawn for reconsideration by the State Party.

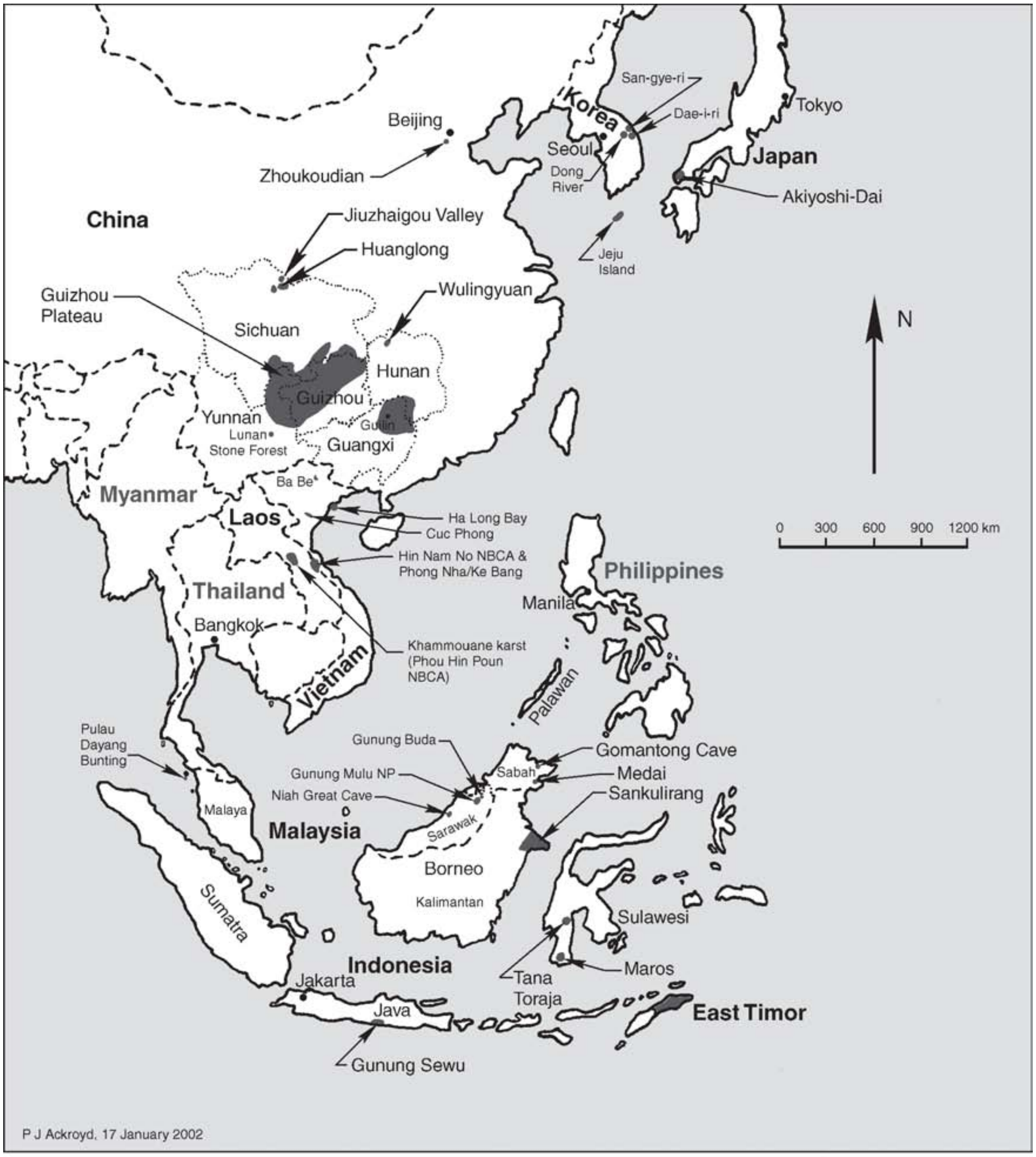
A study on the karst biodiversity values of Cuc Phong National Park and adjacent limestone outcrops is ongoing. This is a World Bank/GEF funded project, executed by Flora and Fauna International in collaboration with the Vietnamese Forest Protection Department.

Monitoring of development pressures, and biodiversity studies of Ha Long Bay are important. JICA is providing financial and technical assistance to develop an environmental monitoring centre in Halong City. A request for a cave survey and underground biodiversity studies is being prepared. The possibility for extension of the World Heritage Area to include Cat Ba Island is currently also under discussion.

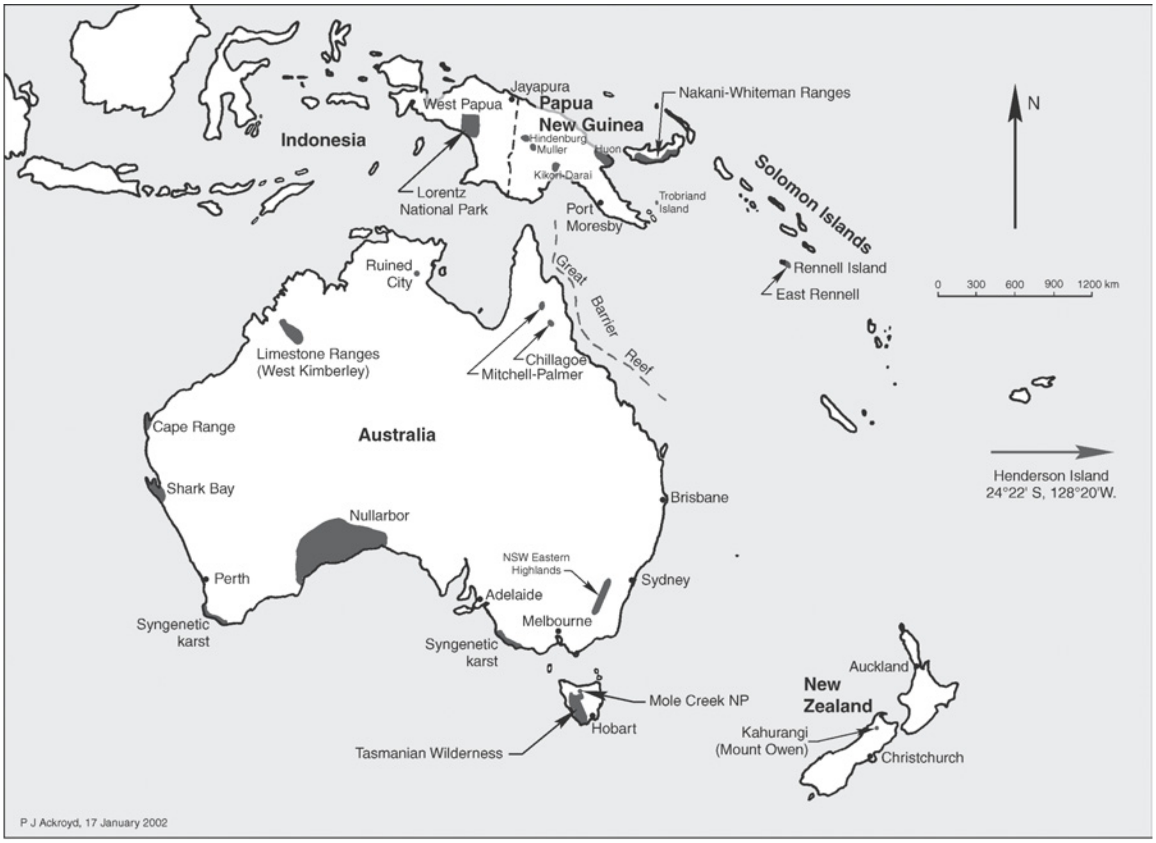
Ba Be National Park in northern Vietnam may contain freshwater stromatolites. A study is needed on this and if they are present, a review of the potential World Heritage values should be carried out.

East Timor

East Timor consists of limestone, and although not a signatory to the World Heritage Convention, may have important karst sites worthy of World Heritage status. Consideration of this is presumably not an immediate priority for the new Government, although it may wish to ratify the World Heritage Convention in the future. If and when the authorities wish to review the options, a rapid reconnaissance survey should be carried out.



Map 3: Asia-Pacific karst sites under consideration or requiring action
East and South-East Asia



Map 4: Asia-Pacific karst sites under consideration or requiring action
Australasia, New Guinea and South-West Pacific

5. CASE STUDIES:

MANAGEMENT OF THE KARST AREA OF HA LONG BAY WORLD HERITAGE SITE, VIET NAM

Nguyen Van Tuan
Head of Ha Long Bay Management Department, Viet Nam

1. Background

Ha Long Bay is a marine and coastal island area in northeast Viet Nam, located in Quang Ninh Province, it is 165 km from Ha Noi. It is a natural wonder of Viet Nam, and covers an area 60 km in length, 25 - 30 km wide, totalling 1,553 km^2. It includes 1,969 islands, 95% of which are limestone.

Ha Long has many great values: its geology, landscape, biodiversity, culture and history, but its landscape and geological values are the most special:

- *Landscape*: Ha Long Bay has an outstanding landscape, thousands of islands of boundless shapes rising out of the quiet blue water of the Bay. Within the islands of the Bay there are hundreds of caves, including over 20 famous, beautiful caves with rich potential.
- *Geology and geomorphology*: Ha Long is one of the major limestone karst areas of the world which has been invaded by the sea.
- *Biodiversity*: Ha Long is also an area of rich bio-diversity, especially its coral and the flora on the limestone mountains. Most recently, IUCN experts have discovered and recorded seven unique species in Ha Long Bay for the first time.
- *Culture*: Ha Long is a home of the ancient peoples of Viet Nam, stretching from 25,000 to 2,500 years ago, covering three cultures: Soi Nhu, Cai Beo and Ha Long.

Because of these outstanding values, in December 1994 UNESCO recognised Ha Long Bay as a World Natural Heritage Site under criteria (iii) of aesthetic value. In November 2000 Ha Long Bay was further recognised as a World Heritage Site because of its geology and geomorphology value under criteria (i) of the World Heritage Convention. The World Heritage Area extends over 434 km^2 and includes 775 islands, all of which are limestone karst. Today, the biodiversity and cultural values continue to be researched and protection plans made.

Ha Long is next to the largest coal mining area in Viet Nam and the urban and industrial areas are still developing, so it faces many challenges.

2. Management - Strengths and Challenges

Strengths:

- Ha Long is a World Heritage Site and also is a limestone karst area on the sea. There is no exploitation of underground water resources. The continuous circulation of water helps to keep the environment of the Bay balanced. Climatic conditions and humidity are also stable.
- The land areas on the limestone islands face limited exploitation and erosion. The flora covering the karst islands is well protected.
- Protecting the integral elements of the karst environment is straightforward.
- The Government has issued regulations and restrictions to protect this area, and local authorities are concerned with the conservation and management of the World Heritage Area.
- Caves and grottoes are well protected and have been altered little.

Challenges:

- High speed urbanisation necessitated by the expansion of human settlements in a city invaded by the sea and the destruction of some mangrove forests is creating pressures on the environment, especially those of waste and sewage.
- Coal mining: waste stores (dumps) are encroaching into the sea. Stone and coal also are swept into the sea causing changes to eco-systems of the coastal areas around. However, this area is beyond the World Heritage Site.
- Exploiting forest (on the land) causes land erosion and silt is swept into the sea, creating sediment on the bed of the Bay, which impacts on the eco-system's environment, especially its coral.
- Tourist development: Ha Long is a major tourism centre of Viet Nam. In 1998, 430,000 visitors came to Ha Long, in 2000 this number doubled to 870,000. Half of these were foreigners. It is estimated that in 2001, Ha Long will receive 1.1 million tourists. But rapid tourist development is one of the causes of pressure on the environment, especially waste and oil spreads from tourist boats.
- Over exploitation of marine products is causing to a decline in marine resources. There is also still some plundering of coral and some use of explosives in fishing.
- The development of transport, ports and other industries causes major pressures on the environment.
- Lack of, and inadequate enforcement rules and regulations
- The awareness of the community concerning the protection of the landscape and environment are limited by a lack of understanding about the World Heritage Site. Most local people are unwilling to attend to this matter voluntarily.
- The capacity of the management Department does not meet the needs of managing a World Heritage Site. There is a lack of professional and management expertise.

The above challenges are great and are possibly increasing. If there is not a management strategy with effective measures, the karst values of the World Heritage Site will be lost or damaged. Maintaining the balance between conservation and development in this area must be a focus and a matter for decision.

3. Management Strategy and Effective Measures

With this background and these existing challenges, our management strategy objective is to establish a legal management framework and long-term conservation plans, limit the negative impact from economic activities, involve the community in the participation of the conservation of the WHA, strengthen management capacity building and consolidate international partnerships. We will focus on the following key measures:

- Constructing a master plan for WHA management, conservation and promotion to the year of 2020 based on archived study data. The plan has identified the orientation, objectives, scope, criteria, conservation measures and budget resources. The Prime Minister of the Vietnamese Government will approve it.
- Requiring the Government (Ministry of Culture and Information, Ministry of Science, Technology and Environment) and Quang Ninh authorities to issue regulations on protection and exploitation of the World Heritage Area: defining boundaries, scale of Heritage Area, methods for encouraging conservation activities and dealing with illegal activities.
- Establishing a Management Department with sufficient capacity, equipment, staff and funding, as well as defining its functions and powers. Today, the Ha Long Bay Management Department has nearly 200 staff with a suitable organisation framework to protect and develop Heritage values.
- Strengthening collaborative activities between the management of heritage with other organisational units, such as: the Marine Police, Transportation, Tourism, Forestry and other local authorities concerned with the implementation and checking of economic activities in the area.
- Carrying out publicity programs to involve local communities in protecting the World Heritage Site. Focusing on the following measures:
  - Taking education programs on the WHA into the local schools.
  - Cooperating with newspapers and television companies to establish the subject of World Heritage with weekly reports in newspapers and on local television.
  - Improving publicity of the WHA by issuing documents, brochures, a guide sign system and providing tourist guides.
- Carrying out projects concerning the treatment of sewage and collection of waste, pushing activities concerning the exploitation and mining of coal far away from the WHA. Using methods to limit the economic activities causing harmful impacts on the environment.

- Protecting by regulations the caves and grottoes, islands and vegetation on the limestone islands. Choosing suitable measures and technology to construct or equip the paths and light systems in the caves and islands to protect the natural conditions.
- Co-operating with institutions and international organizations to research and investigate the Heritage's values and write scientific documents on the WHA. Establishing a list of islands on Ha Long Bay with full information on location, area, and height etc.
- Training management staff and specialists, developing organisational mechanisms, investing in equipment and information systems to control all activities in this area.
- The main methodology of study and development for the project is that of Ha Long Bay as an Eco-museum, in which the natural and cultural values are the values of the museum and the people. The community will be the owners of the Museum. The guidelines are bringing people and their environment together. This project will develop a focus on the interpretation of heritage through an Eco-museum Hub with other outside themes to help visitors and communities understand more about the outstanding values of the WHA. The Eco-museum is the general means of conserving and developing the Heritage's values.

  This project will be implemented, assisted by funding and technical support from international organizations, starting from 2002 - 2005.

4. Conclusion

The above measures have created the base conditions for protecting the karst area and its heritage. In the last five years, Ha Long Bay's environment has continued to improve, illegal actions have decreased and an orderly management system has been established. This has created awareness in the community and there have been collaborative activities with both domestic and foreign organizations.

However, the challenges are still great and there will be many new pressures on Ha Long Bay's environment so we must always strengthen and apply the necessary measures to improve the management capacity of the World Heritage Area.

NARACOORTE CAVES NATIONAL PARK, SOUTH AUSTRALIA

Australian Fossil Mammal Sites World Heritage Area (Riversleigh/Naracoorte)

Brian Clark
District Ranger, Southeast Region, Department of Environment and Heritage, South Australia

1. Introduction

Situated in the southeast corner of South Australia, a province best described almost entirely as a karst landscape, Naracoorte Caves National Park is one of the smaller World Heritage Areas inscribed for its natural values. At the time of inscription the park was just 350 ha in size amidst an area of diverse and very rapidly changing and threatening land uses. Competing land uses on the karst include:

- Wool and meat production on cleared, improved pasture
- Cereal crop production
- Irrigated crop production
- Pine plantations
- Vineyards
- Hardwood forestry
- Limestone quarrying for building materials, road making etc.

This is soft country! The limestone is in itself soft but the landscape is also soft. It is flat, easily accessible and readily tamed. - or so we think. The changes that have been inflicted on the region in a very short time will have far reaching implications yet to be revealed or understood and much of the current land-use is not sustainable.

The key values of the park are, obviously, the limestone caves together with the expected array of speleothems, but more particularly their associated attributes. The caves contain extensive and thoroughly researched vertebrate fossil deposits of varying age but up to 500,000 years old. It is these deposits and the interpretation of their origin and significance that comprise the park's 'world Heritage status. Particular characteristics include:

- a population of small insectivorous bats which breed within one particular cave on the Park;

- a diverse (by Australian standards) variety of cave dependant or obligate invertebrate fauna;

- a safe, or, if you like, "well tamed", opportunity for visitors to experience a cave environment; and

- a significant contributor to the regional and state tourism economy.

The park has (again, by Australian standards at least) a long history as an attraction. Little is known or documented about the caves' importance to pre-white occupation aboriginal people, but this is something we hope to address in time. "Discovered" by the early white settlers in the mid 1840s, the caves at Naracoorte quickly became a focal point of local tourism, despite the fact that "tourism" was yet to be conceptually acknowledged for some time to come. Many local businesses were cashing in on the phenomena of the Naracoorte Caves from the early 1860s, so much so that the local community as early as the 1870s recognised that damage to the caves caused by the ill-informed were destroying an important natural resource.

By 1885, after more than one attempt, they succeeded in securing government intervention and the core of the current WHA was placed under a protected areas Act of the State parliament. In the following year formal guided tours were provided for visitors to many of the then known caves but it is not clear whether any restrictions were placed on unsupervised access to caves within the protected area.

Guano harvesting became an important business within the protected area with significant degradation of the caves resulting from limited understanding of caves as a geological process and their associated ecosystems. Fortunately, guano harvesting at Naracoorte became economically unviable with the development of more intensive agricultural land use, which required greater quantities of commercially produced chemical alternatives.

Cave tourism, focused on presentation of the caves as some sort of fairy land - with some attempt to present them as a natural phenomena - had been ongoing with varied degrees of success, but generally visitation was steadily declining until the re-discovery of the rich fossil deposits in 1969. Australian society was now more ready to recognise the scientific value of this aspect of the park's many values. The focus of site presentation quickly changed from fantasy and ill-conceived notions of the natural processes which formed the caves, to well researched presentation of the site's karst processes and palaeontology, and visitation rapidly increased to a peak of 70.000 in the mid 1970s. However, not everyone wanted a "science lesson" and visitation was again declining through the 1980s.

In 1994 the park was inscribed onto the World Heritage List and the methods used to present the site to visitors in a meaningful way became an evolving process. Visitation has grown from around 40,000 at the time of inscription to 80,000 in 2000, while the yield (income derived per visitor) has increased from $3.75 to $6.00 in an inflation environment of under 3%.

2. Problems

- At the time of establishing the park a poor understanding of the caves as part of the area's karst nature led to poor surface management practices and pine plantation forestry was established above and adjacent to the caves.

- The park boundary was determined based on securing cave entrances rather than the subterranean extent of the caves and no consideration was or has been given to a buffer zone to protect ongoing hydrological processes.

- The focus on the tourism value of the caves lacked sound business practice. Failure to adapt to changes in community values and expectations resulted in several episodes of peaking and troughing in gross visitation. Each episode of declining visitation was met by a retraction of services, including protective management of the basic resource – the caves; and nothing seems to deteriorate faster or more severely than an abandoned show cave.

3. Solutions

The park has a poorly planned boundary resulting originally from the initial establishment of a protected area based on securing only the known entrances to caves and compounded by a series of *ad hoc* opportunistic additions to the park. This is an ongoing issue as we continue to identify desirable land for addition to the park to secure the subterranean extent of the caves together with at least some notion of a buffer zone.

Inappropriate surface use has and continues to be rectified by removal of pine plantations and re-establishment of natural vegetation associations.

The focus on tourism use of State controlled protected areas continues to be problematic in a society where economic (ir)rationalism drives decision making based on the life expectancy of any currently elected government. To turn this around, from the cave conservation /tourism perspective at least, it is important to address a couple of key points.

1. Economic viability of the enterprise should not be looked at in isolation from the broader community economic gain. For example, at Naracoorte we take an average of $5.90 per visitor, yet visitors to the region spend around $110 per day. At 70,000-80,000 visitors per annum we can provide a well run "operational cost" recovery enterprise, yet near sighted administration would advocate that we should be contributing a direct profit on investment. Few can recognise the tax input to government from those businesses collecting the rest of that $110 spent in the region.

   The management team at Naracoorte endeavour to counter this with close collaboration with the local and regional business to ensure that at least they are aware of the importance of maintaining both tourism service and strong conservation management of the resource.

2. Of equal importance is to clarify why the protected area, in this case the caves, should be used as a tourism asset. Why provide cave tours at all? If it is just to generate revenue, either as a cost recovery strategy or to provide an input of export dollars into the local economy, the managing agency is likely to be at serious risk of developing an unsustainable product at the cost of the resource.

It is probably more sensible to build a theme park to bring in export dollars - and the best of *all* cost recovery strategies is to avoid the cost in the first place. For protected area managers 'tourism' should not be viewed as an outcome but simply a tool we use to attract visitors to a given set of values about which we need to change community perceptions and behaviour. Ecotourism has been the buzzword of the last decade, but it is more an academic concept than an on-ground reality. Perhaps the concept of *edutourism* will displace it in the foreseeable future.

At Naracoorte we present a range of cave and cave related experiences all with the objective of enhancing community understanding, support for conservation and change in behaviour.

Infrastructure is substantial and ranges from cave access facilities and lighting systems to remote observation facilities to hands on inter-active displays. Not all of the caves used for active presentation have lighting systems, and only those caves which can be used to present a distinctly different value from others, or provide visitors with an acceptable alternative to a guided tour, are used for active presentation. Where lighting systems are used (in four of the eight caves actively presented) lighting is 12v and designed to minimise lampenflora issues, with a side benefit of much reduced power consumption.

The role of the cave as a habitat for bats and the significance of the bats themselves is presented by a remotely controlled, closed circuit television system with lighting provided by infra-red light emitting diodes.
In addition to presenting the vertebrate fossil values *in situ*, we extend their comprehension of the park's significance by means of a walk-through interactive diorama presenting climate change and its role in evolution and species extinction.

Of particular importance is the need for adequate legislative protection regarding access to the caves and even more so, the development and maintenance of well trained competent site presenters. A *cave guide* might get you safely in, through and out again, but a good site presenter will change your understanding of what it all means and what *we* can to do to protect *our* caves and their associated values.

PUERTO PRINCESA SUBTERRANEAN RIVER NATIONAL PARK, PALAWAN, PHILIPPINES

Summary of a Presentation by James Mendoza

Note: The following short summary has been written from meeting notes, and information from the World Heritage Centre and the World Conservation Monitoring Centre (Editors).

1. Introduction

Puerto Princesa River National Park is a spectacular karst World Heritage area, situated on the island of Palawan, in the southwest of the Philippines archipelago. The National Park was inscribed on the World Heritage List in 1999, under natural criteria, including:

- Criterion (iii): The Saint Paul Mountain Range features a spectacular limestone karst landscape. The underground river, flowing into the sea, and its associated tidal influence, make this a significant natural phenomenon.

- Criterion (iv): The park represents a significant habitat for biodiversity conservation. It contains a full mountain to the sea ecosystem and protects the most significant forest area within the Palawan Biogeographic Province.

The Park is 20,202 ha in area, and features a spectacular limestone karst landscape with an eight kilometre long underground river. A distinguishing feature of the river is that it emerges directly into the sea, and the lower portion of the river is subject to tidal influences. The underground river is known as the Subterranean River or St Paul Cave. It includes major formations of stalactites and stalagmites, and several large chambers exist, up to 120 metres in width and 60 metres in height. The Park is covered in lowland and karst forests and also has significant mangrove areas, with the dramatic karst features of the St Paul's Mountain Range rising above this.

2. Biodiversity

The area also represents a significant habitat for biodiversity conservation. The site contains a full "mountain-to the-sea" ecosystem and protects some of the most significant forests in Asia, as well as containing sea grass beds and coral reefs. For example, the Park displays seven types of forest ecosystems, including 800 plant species and 295 tree species. The area is also rich in fauna, containing 168 species of birds, 30 species of mammals, 19 species of reptiles, and 10 species of amphibians.

3. Conservation and management

The core area of the site is owned by the City Government of Puerto Princesa, and hence falls under the authority of the City Mayor. All decisions are made by the Mayor in consultation with the Protected Areas Management Board. The main management strategy is the expansion of the area to include tribal lands and to focus the management concern on the predicament of the vanishing tribes. Other objectives include: protection of the watershed to prevent flooding and erosion and to protect water supplies; protection of ecosystems, biological diversity and rare and endemic species; protection and contributing to the livelihood of local communities, and securing their cooperation in management; and support of ecotourism. Several ranger stations have also been established. Management was strengthened considerably when the park became the subject of an internationally financed 'Debt-for-Nature' swap programme during 1989. A detailed management plan has been compiled by the Protected Area Management Board of the local government, in accordance with National Integrated Protected Areas System Act adopted in 1992. Recently a new management plan has been drawn by the national park management authority under the Palawan Tropical Forestry Protection Programme assisted by the European Union.

4. Management constraints

Issues that need to be addressed include:

- logging and mining;
- forest product licensing (for rattan collection);
- uncontrolled tourism development in Sabang and San Rafael; and
- damage to watersheds.

Agricultural activities of local residents may threaten the site, as does the collecting of forest products such as rattans. There are also threats to the natural vegetation; the small patches of coastal forest have been designated as recreation areas and extensive under brushing has been compounded with inappropriate planting. Although the site is currently administered at the local level, this is nevertheless considered effective, largely reflecting a strong local political support for the site. Any future changes in local management perspectives might change this. There is a relatively large staff (approximately 50 people, including administration, rangers and assistant staff), although the need for further staff training has been noted in an IUCN Technical Evaluation in 1999.

5. Lessons Learned

Mr Mendoza, in his explanation of the process to better manage the National Park and World Heritage area, identified the following factors that were critical for a successful outcome:

- People empowerment – including real local participation in decision making and management.

- A strong political will from senior decision makers, and also significant support from Local Government Units.
- Partnerships, especially with the NGO community.
- Sustainable information management, including learning management lessons, and retaining capacity within management authorities and the community (community education).
- Flexibility in park management.
- Site specific plans.
- A holistic approach.

This approach has led to improved community relations, a high level of environmental awareness, an increased National Park area and buffer zones, development of management plans and World Heritage status.

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ANNEX 1

Existing World Heritage Karst Sites in the Asia-Pacific Region

Sites Inscribed primarily or largely for karst values	
	Criteria
Malaysia: Gunung Mulu National Park	N i, ii, iii, iv
Philippines: Puerto-Princesa Subterranean River National Park	N iii, iv
Vietnam: Ha Long Bay	N i, iii
China: Huanglong *Jiuzhaigou Valley* *Wulingyuan*	N iii N iii N iii
Australia: Riversleigh & Naracoorte fossil mammal sites	N i, ii
Sites including significant karst areas but not inscribed for this reason	
Australia: Greater Blue Mountains	**N ii, iv**
Australia: The Tasmanian Wilderness	C iii, iv, vi N i, ii, iii, iv
Australia: Lord Howe Island	**N iii,iv**
China: Zhoukoudian (Note – in karst, but of minimal karst value)	**C iii, vi**
Indonesia (Irian Jaya): Lorentz National Park [Note – the extensive karst of this park is not recorded in the nomination or inscription documents, nor by the WCMC]	N i, ii, iv
Thailand: Thungyai-Huai Kha Khaeng wildlife sanctuary	N ii, iii, iv
Laos: Luang Prabang (on karst and some caves of at least cultural significance)	C iii, iv, v
New Zealand: Te Wahipounamu	N i, ii, iii, iv
(U.K.) *Pitcairn Islands:* Henderson Island	N iii, iv
Solomon Island: East Rennell Island	N i, ii, iii, iv
In the above list, N = Natural heritage and C = Cultural Heritage. Numbers indicate the criteria on which inscription was based.	

ANNEX 2

Criteria of the Convention Concerning the Protection of the World Cultural and Natural Heritage

Natural World Heritage Criteria

In order to be inscribed as natural heritage, a site should meet at least one and preferably several of the following criteria:

(i) be outstanding examples representing major stages of Earth's history, including the record of life, significant on-going geological processes in the development of land forms, or significant geomorphic or physiographic features; or

(ii) be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals; or

(iii) contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance; or

(iv) contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation.

Cultural World Heritage Criteria

Cultural Heritage sites are assessed on the following set of criteria:

(i) represent a masterpiece of human creative genius; or

(ii) exhibit an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design; or

(iii) bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared; or

(iv) be an outstanding example of a type of building or architectural or technological ensemble or landscape which illustrates (a) significant stage(s)in human history; or

(v) be an outstanding example of a traditional human settlement or land-use which is representative of a culture (or cultures), especially when it has become vulnerable under the impact of irreversible change; or

(vi) be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance (the Committee considers that this criterion should justify inclusion in the List only in exceptional circumstances and in conjunction with other criteria cultural or natural).

ANNEX 3

Existing World Heritage Sites and Karst Values

Table 1: All World Heritage Sites Inscribed Specifically for their Cave and Karst Features

World Heritage Site	State Party	Year	Key Features/Justification for Inscription	Criteria
Puerto-Princesa Subterranean River National Park	Philippines	1999	Spectacular karst landscape, underground river & caves (iii). Most significant forest in Palawan Biogeographical Province (iv).	iii, iv
Gunung Mulu	Malaysia	2000	295km explored caves, Sarawak Chamber - world's largest; Speleothems with spectacular aragonite & calcite needles. 1.5 myo sediment sequence, giant doline-karst collapse, lateral planation (i); Bats and swiftlets energy transfer from forest to cave (ii); Karst, bats, pinnacle forest (iii); Forest & cave biodiversity (iv).	i,ii,iii,iv.
Desembarco del Granma National park and System of Marine Terraces of Cabo Cruz	Cuba	1999	Uplifted marine terraces and ongoing development of karst topography (i). Aesthetic value of stair-step terraces and cliffs (iii).	i, iii
Carlsbad Caverns National Park	USA	1995	81 caves. Huge caverns & decorative mineral features, scenic values esp. Lechuguilla. (Most types of limestone cave formation are found here, including long passages with huge chambers, vertical shafts, stalagmites, stalactites and gypsum 'flowers' and 'needles'. Excellent examples of karstification by sulphur acids. Rich microfauna.)	i, iii
Mammoth Cave National Park	USA	1981	Continuous cave formation (100 mya-present). Large level passages & jagged dome pits. Rich troglobitic fauna.	i,iii,iv

Plitvice Lakes National Park,	Croatia	1979/ 2000	Travertine barriers and lake systems.	ii, iii
Caves of Aggtelek and Slovak Karst	Hungary/ Slovakia	1995/ 2000	712 caves. Variety and concentration of cave types, speleothems and an array of typical temperate zone karst features. (Includes aragonite and sinter formations and an ice filled abyss.)	i
Skocjan Caves	Slovenia	1986	Awesome river canyons, textbook portrayal of karst hydrogeology. On-going process (ii); Collapsed dolines & caverns (iii).	ii, iii
Ha Long Bay	Vietnam	1994/ 2000	Most extensive and best-known example of marine invaded tower karst and one of the most important areas of *fengcong* and *fenglin* karst in the world.	i, iii

Table 2: World Heritage Sites Inscribed for Other Reasons, but with Significant Cave and Karst Features

World Heritage Site	State Party	Date	Key Features	Criteria
1. Australian Fossil Mammal Sites	Australia	1994	Vertebrate Fossil deposits at Riversleigh (Oligocene-Miocene) & Naracoorte (Pleistocene). Both have a diversity of karst landforms and Naracoorte has high current biodiversity.	i, ii
2. Tasmanian Wilderness	Australia	1982	Many areas of karst in limestone and dolomite. High geodiversity and biodiversity values.	i, ii, iii, iv C iii, v, vi
3. Greater Blue Mountains	Australia	2000	Includes Jenolan Caves and a number of smaller karst sites	ii, iv
4. Lord Howe Island	Australia	1982	Small area of karst in aeolian calcarenite and coralline limestone	iii, iv
5. Pirin National Park	Bulgaria	1983	Various areas of karst, some of which have been shaped by glaciation	i, ii, iii
6. Canadian Rockies	Canada	1984	Castleguard and other caves	i, ii, iii
7. Nahanni National Park	Canada	1978	Spectacular karst landforms, including an immense gorge and caves	ii, iii

8. Wulingyuan Scenic and Historic Interest Area	China	1992	At least one-third of the site is on limestone, with extremely large caves and two natural bridges, one of which is 357m. high.	iii
9. Huanglong	China	1992	Famous for its extensive and spectacular travertine deposits; many other karst features	iii
10. Jiuzhaigou Valley	China	1992	Largely on dolomite and calcareous travertine	iii
11. Pyrenees-Mount Perdu	France/ Spain	1997 /99	Alpine karst site with lakes, gorges, waterfalls, cirques and canyons	i, iii C iii, iv, v
12. Lorentz National Park	Indonesia	1999	Much of the park is high altitude karst, with spectacular landforms. Regrettably, the finest of the karst is adjacent to but not included in the park	i, ii, iii, iv
13. Tsingy de Bemaraha	Madagascar	1990	Pinnacle karst that is difficult to access; little investigation to date.	iii, iv
14. Sian Ka'an	Mexico	1987	Situated on the edge of the great cenote karst of the Yucatan Peninsula. Only a small part of this karst is within the World Heritage Area.	iii, iv
15. Te Wahipounamu	New Zealand	1990	Includes a number of small areas of karst, including the Aurora Cave at Te Anau.	i, ii, iii, iv
16. Western Caucasus	Russian Federation	1999	The Northern section consists entirely of karst with some of the world's great deep and extensive caves. Some of these have important Neanderthal sites and so are of considerable archaeological value.	i, ii, iii, iv
17. East Rennell	Solomon Islands	1998	A particularly large and diverse raised coral atoll.	ii
18. Thung Yai Hua Kha Khaeng	Thailand	1991	One of the various protected areas over the Western karst region – an area with great diversity and value on many criteria.	ii, iii, iv
19. Pamukkale	Turkey	1988	Spectacular travertine terraces	iii C iii, iv
20. Henderson Island	UK: Pitcairn Islands	1988	Relatively undisturbed example of a raised coral atoll.	iii. iv
21. Grand Canyon	USA	1979	Caves are found throughout the Redwall limestone beds containing numerous archaeological relics.	i, ii, iii, iv

22. Canaima National Park	Venezuela	1994	The most outstanding example in the world of karst in quartzitic sandstones.	i, ii, iii, iv
23. Durmitor National Park	Yugoslavia (Montenegro	1980	Deep limestone beds span a remarkable geological sequence. Glacial lakes, caves and the Tara Canyon dominate the landscape.	ii,. iii, iv

Table 3: Cultural World Heritage Sites Containing Cave and Karst Features

World Heritage Site	State Party		Key Features	Criteria
1. Zhoukoudian	China	1987	Peking Man excavation site situated in ancient karst	C iii, iv
2. Viñales Valley	Cuba	1999	Karst landscape with conical hills (Mogotes) in a wide flat-floored valley. It is a ‘type locality’ of Mogote karst and has a rich subterranean biodiversity.	C iv
3. Caves of the Vézère	France	1979	Some 147 identified and significant prehistoric sites, including the famous Lascaux and many other painted caves	C i, iii
4. Luang Prabang	Laos	1995	Built on karst with various landforms; a number of the caves are important temple sites.	C ii, iv, v
5. Chichen Itza	Mexico	1988	Situated around an immense cenote that was a major site of sacrificial rituals.	C i, ii, iii
6. The Fossil Hominid Sites of Sterkfontein, Swartkrans, Kromdraai, and Environs	South Africa	1999	A cluster of karst sites containing remains of some of the earliest humanoids.	C iii, iv
7. Altamira Cave	Spain	1985	One of the most famous and diverse collections of cave art	C i, iii
8. Atapuerca Caves	Spain	2000	Contains earliest and richest evidence of human being in Europe.	C iii, iv
9. Södra Ölands Odlingslandskap	Sweden	2000	The only extensive area of limestone in Sweden – a large pavement with various surface karst features.	C iv,v

ANNEX 3

Table 4: Existing karst World Heritage Areas and recognition of biodiversity

<table>
<tr><th></th><th>Asian-Pacific Region</th><th>Rest of World</th></tr>
<tr><td>Karst World Heritage Areas</td><td>17 (see Table 1)</td><td>24</td></tr>
<tr><td>Karst World Heritage Areas inscribed for biodiversity values</td><td>10</td><td>8</td></tr>
<tr><td rowspan="6">Karst World Heritage Areas may be inscribed for biodiversity values after further review</td><td colspan="2">Subterranean fauna only</td></tr>
<tr><td></td><td>Aggtelek
Carlsbad Caverns</td></tr>
<tr><td colspan="2">Both subterranean and surface biota</td></tr>
<tr><td>Huanglong
Jiuzhaigou Valley
Wulingyuan
Ha Long Bay
Luang Prabang</td><td>Skocjanske (Already a Ramsar site)</td></tr>
<tr><td colspan="2">Probably Surface biota only</td></tr>
<tr><td></td><td>Nahanni
Rocky Mountains
Plitvice
Desembarco
Pyrenees
Pirin</td></tr>
<tr><td>Karst World Heritage Areas unlikely to warrant inscription on biodiversity grounds</td><td>Riversleigh and Naracoorte
Zhoukoudian</td><td>8</td></tr>
</table>

ANNEX 4
SOME MAJOR GROUPS OF KARST ORGANISMS

Courtesy of J. Vermeulen and T. Whitten:

***Biodiversity and Cultural Property in the Management of Limestone Resources* (1997)**

Many species of animal and plant groups are represented in karst landscapes and a relatively large proportion is endemic to small areas. These may consist of small, inconspicuous species, and even include species which are regarded as unpleasant (e.g. large spiders) by some. Some arthropods (insects, spiders, crabs, shrimps, centipedes, millipedes and related organisms with jointed external skeletons) have added significance not only because of the sheer number of species they include, but also because they are a fundamental part of many food chains. Their importance, and that of many other groups of small species, is being increasingly recognised. The animal and plant groups below serve only as examples of limestone biodiversity; other groups may be equally interesting and important.

Arthropods: the bulk of biodiversity
Arthropods are by far the most diverse among the numerous groups of organisms, and live in virtually all terrestrial and aquatic ecosystems. Preserving arthropod diversity is clearly preserving the core of biodiversity. Their environmental importance is inestimable: arthropods have an essential function in all major biological processes.

The available data suggest arthropods represent well over 60% of all living organisms in the aboveground habitats of East Asia, and each year numerous new species are discovered.. In underground habitats, where higher plants are absent, this proportion probably reaches well over 90%. Each biological sample collected in an area not previously studied, appears to yield over 50-90% species new to science. The basic work of biological inventory is far from complete, but all evidence points to a high arthropod diversity.

It is uncertain whether limestone areas host more arthropod species, or a more diverse arthropod fauna than areas on other types of bedrock. The data are not conclusive, but limestone areas, more than areas on other bedrock types, are very often reservoirs of biodiversity, encircled by land with a very low biodiversity value under permanent human influence.

The total number of species for each karst area is likely to be rather similar throughout East Asia. However, the composition of the fauna differs greatly from region to region. Each hosts a fauna with unique properties, such as the species composition, the number of endemics, and the vulnerability of individual species as well as species communities. On a smaller scale, this pattern is partially repeated: some, but not all individual karst hills have a fauna with unique elements. Particularly in extensive karst areas the disturbance of a single site within the area may have little impact on the arthropod biodiversity of the area as a whole. An exception to this rule are guano-communities, that may occur very locally, for instance restricted to the guano piles of a few bat or swiftlet colonies.

Annex 4 Box 1: Long-tailed whip scorpions as caring mothers

Giant long-tailed whip scorpions (up to 10 cm without tail) have recently been found to be a regular inhabitants of the huge cave systems of southern Lao PDR. Small groups of females bearing their eggs and young on their backs are found in the deep parts of the caves, resting motionless for days on the walls if left undisturbed. How these concentrations of large, non cave-adapted arachnids form in such remote and unfavourable environments remains unknown.

Arthropods and endemism. The arthropod fauna of the limestone areas of East Asia includes a very high proportion of site endemic and locally endemic species. All karst areas sampled so far have yielded a number of such species. The little evidence available indicates that tropical cave arthropods tend to have smaller ranges than cave arthropods in temperate climates.

Patterns of arthropod biodiversity. In relation to arthropods, three major ecosystems can be distinguished in limestone areas. Each hosts a distinct arthropod assemblage, and is vulnerable to disturbance in its own, characteristic way. Each ecosystem includes both land and freshwater habitats.

- *The above ground ecosystem*. The vast majority of the arthropod species of limestone areas lives aboveground, in the forests (primary and secondary) that cover most of the limestone areas of East Asia. Most species live on the vegetation, in leaf litter, or in soil. They are often host-specific and are restricted to the range of their plant or animal host. Their range is not usually restricted to limestone areas. Nonetheless there are species, which are restricted to habitats on or near outcropping limestone rocks.

- *The underground ecosystem*. In caves and underground voids, arthropods are represented by a much smaller number of species. These, however, have a high biodiversity value because of the prevalence of highly specialised endemics. The underground environment can be divided in two, mainly characterised by the availability of energy:

    - The low-energy ecosystem. In the deepest recesses of caves and small voids food is scarce. The fauna consists of small numbers of scattered individuals. Arthropods are by far the dominant animals. Extreme conditions have led to the development of often spectacular adaptations: very long life cycles, reduction of eyes and wings, white colouring through loss of pigment, long antennae to keep in touch with the surroundings in pitch darkness. Because of this, and because most species are endemic to a small area only, their value as unique functional groups largely surpasses that of mere species number.

    - The high-energy ecosystem. Guano piles produced by bats and swiftlets feed huge, localised populations of narrowly specialised, unique organisms: species of crickets, cockroaches, millipedes, beetles, moths, flies, and springtails. They are preyed upon by the impressive giant carnivorous arthropods of tropical caves, such as tail-less and long-tailed whip scorpions, giant long-leg and short-leg centipedes, giant spiders, and by a number of poorly-known mites and other small predators. Adaptations of species specialising on guano deposits are the opposite of those of the low-energy ecosystem: life cycles are short, eyes, wings and pigment are usually not reduced. This implies a somewhat higher environmental mobility in these animals, which may explain the lower proportion of site endemic species.

Land and freshwater molluscs
Land and freshwater molluscs (snails and clams) contribute to the biodiversity of karst areas because of the large numbers of species and individuals, and because of the occurrence of site and local endemism. All shell-bearing species need calcium carbonate (limestone) to build their shells, but their dependence on the vicinity of a limestone outcrop varies greatly. For some species the presence of outcropping limestone seems vital, whereas others have developed the means to obtain construction materials elsewhere.

Their ecological importance is considerable; snails, themselves being herbivores, omnivores or carnivores, are preyed upon by a large number of other animals ranging from insects to birds and mammals. Our knowledge of the life cycle and behaviour of the East Asian species is largely restricted to some salient features not commonly associated with these animals: a Malaysian species, for instance, with a luminescent body; various other species that are able to creep with (for a snail) extraordinary speed, or to wriggle violently or even to jump when threatened. A Philippine species emits a high-pitched sound when picked up! Carnivorous species may be found pursuing an earthworm or attacking other, much larger snails. Some western Indonesian species, living on the foliage of trees, construct nests hanging from a branch by folding together two leaves; and some species in the western Pacific carry their eggs in the hollow lower surface of the shell. Another group of species in the Pacific lays one egg at a time and bestows great parental care on the young.

Numbers of mollusc species and individuals in limestone areas. It is estimated that some 8000 species of land and freshwater molluscs occur in East Asia, and about half of these are found most frequently in limestone environments. The number of species entirely restricted to these environments is likely to exceed 2000.

Non-limestone environments almost invariably host fewer species than limestone environments under similar conditions. The snail fauna of a single, undisturbed karst hill in East Asia averages 60 different species, and may reach over 100 species. In a worldwide perspective, this is probably above average. A comparable site on young volcanic soil yields only 30 species on average, reaching 50 species occasionally; a site on any other rock type will rarely yield more than 20 species.

The number of individuals living on any limestone hill is also larger than elsewhere under similar external environments. A bucketful of processed soil (to remove pebbles, clay and earth) from near a rock outcrop typically contains 1000-10,000 shells (empty shells and living animals together), whereas a similar amount of soil from forest on volcanic rock usually yields 10-100 shells, and one from forest on any other rock type only occasionally has more than 10 shells. This holds even when a correcting factor is applied for the fact that soil sampling is a less adequate collecting method in non-limestone environments.

Annex 4 Box 2: Beautiful limestone snails from Borneo

Land snails of the family Diplommatinidae are often spectacularly shaped and would be highly prized collectors items if only they were larger than their 1 to 8 mm in height. Hundreds of species occur throughout SE Asia, living an inconspicuous life on vegetation, in leaf litter, or on rock outcrops. Feeding on minute algae, they are harmless enough (species of some other families, with equally small shells, are ravenously carnivorous). They lay eggs, and have a very short life cycle developing into adults within a few months after hatching (the shell growing at a rate of 1 rib a day), mate, lay their eggs and die, all within a year. Most species have taken on camouflage colouring, or are almost invisible because they glue soil particles between the ribs of their shells. Some, however, have projecting ribs and are extremely conspicuous: in the morning sun they stand out against dark rock as minute, brilliantly white fans, or tufts of pure white cotton wool, often covered with glistening droplets of dew. It is tempting to speculate that these mimic a species of aphid living in the same environments, which has its body covered in sticky, white scales, and thus proclaims its foul taste to potential predators.

Recent research has shown that Borneo is inhabited by at least 150 species of this family. About 100 of these were found to be new to science. Many more new species can be expected once the limestone hills in Borneo's deep interior are surveyed. The numerous species which live only on moss- and algae-covered limestone surfaces are often restricted to one or a few small limestone hills. While some are comparatively safe, others are much less so, and some are already extinct because of habitat destruction.

- *Diplommatina miraculumdei* occurs in numerous, widely scattered populations on the limestone hills surrounding, like a necklace, the crest of the 200 km long Meratus Mts. in SE Borneo. Although the limestone environments are threatened by the combined effects of shifting cultivation, wildfire, logging, and mining the species is under no immediate threat of extinction: many populations may be wiped out, but some will survive.
- *Opisthostoma. grandispinosum* is an example of the more than 50 species which only occur on Gunung (= Mount) Subis (Batu Niah), in Sarawak. This 15 km^2 limestone hill is now a nature reserve. Although a part of the hill is quarried for cement, most of the area is maintained in a semi-pristine condition because it includes the Niah Caves, which are a major tourist attraction. The endemic snails are relatively safe.
- *Opisthostoma lituus* is one of six snail species which are restricted to an isolated limestone hill (meaning distant from other limestone outcrops) of about 0.2 km^2 ground surface. The hill may be threatened: the area has been opened up for various purposes. The species is vulnerable.
- *Opisthostoma mirabile* occurred restricted to two limestone hills in East Sabah. The smallest hill was destroyed to provide road metal. The snail still survives on the larger hill (Gunung Suanlamba), which is now protected because its caves (Gomantong caves) host large colonies of swifts. The vegetation on the hill itself, however, is depleted and the snail faces an uncertain future, as do nine other snail species which are endemic to this hill.
- *Diplommatina calvula* is one of those 9 species. Two shells were collected a century ago, but were mixed up with a series of another species and were stored in a museum without having been recognised as a distinct species. It has not been found since and is probably extinct. It was given its scientific name *post mortem* a few years ago.

Endemism among molluscs. The unique conditions in limestone environments have caused the development of numerous mollusc species that are restricted to small areas, particularly in the tropics.

- *Species endemic to a site* occur frequently among karst molluscs. In Sarawak, a limestone hill of about 15 km^2 is probably inhabited by over 50 snail species that occur nowhere else in the world, and another, 0.2 km^2 hill by six such species. Elsewhere, the occurrence of site endemic snails has been ascertained in Peninsular Malaysia (up to seven species endemic to a single hill), and they undoubtedly occur in other countries. The number of site endemics on a karst hill appears to increase with distance from other karst hills. In East Asia, no non-limestone environments are known to harbour site endemic snail species, with the possible exception of a few volcanic mountains.

- *Local and regional endemism* is also common; up to two-thirds of the species at a site may fall within these categories. In many cases, their actual area of occupation may be restricted to some tens of $km^{2,}$ i.e. a few widely scattered, small-sized karst hills.

In addition to the above categories, the fauna at a site consists of widespread species, and species that are unintentionally spread by people.

Endemism among molluscs in relation to ecological and taxonomic groups. Within the limestone environment, land and freshwater molluscs can be roughly grouped according to their ecological niche. Some groups are notably more vulnerable to habitat destruction than others:

- *Land snails living above-ground, and entirely restricted to limestone environments*. Generally, these live on mossy rock surfaces, or in thin, calcareous soil covering limestone rock. Site endemism and local endemism seems to be the rule; relatively few species are widespread.

- *Land and freshwater cave snails*. For a long time, only very few freshwater species were known to be adapted to living in caves. Recent surveys into cave systems in Thailand brought to light the first terrestrial snails that can be assumed to live in deep soil, small voids and caves. They belong to various families. In 1998 a single cave in Vietnam yielded 17 cave species, 15 of which belong to a single family.[2] As a rule, true cave molluscs are site endemics or local endemics. Some optional cave dwellers occur in association with guano deposits in caves; these are generally widespread species. Occasionally, other above-ground species may venture quite deep into limestone caves, or may fall in through clefts in the rock.

- *Land snails living above-ground, on limestone as well as on other bedrock.* This group includes large numbers of species living in thick soil, and on vegetation. Many are widespread, or endemic to a large region. A smaller proportion is locally endemic and site endemics are rare within this group.

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[2] Insufficient collecting has undoubtedly caused their late discovery, next to this, shells of cave molluscs may have been collected already with soil samples, but have remained unrecognised because they have not been found alive and *in situ*.

- *Freshwater snails living above-ground, and restricted to limestone environments*. This group includes minute species occurring, often by the thousands, in small springs and associated streams. Recently, shells of various species new to science have been collected in Malaysia and Vietnam, belonging to a family that in Europe and North America is well known for the large number of site endemics and local endemics it includes.

- *Freshwater snails and clams living above-ground, on limestone as well as on other bedrock.* These often occur in large numbers in rivers through and downstream of limestone areas. The distribution of many may be related to limestone, such as an unnamed clam species found only in collapsed dolines lining a subterranean river in southeast Kalimantan; others may have survived habitat destruction elsewhere in the relatively clean waters of karst areas. Most species are widespread, but some families tend to site or local endemism. A dramatic example occurs is the Mekong drainage system where narrowly endemic freshwater mollusc species occur by the hundreds.

Fishes in limestone areas

Fish species known exclusively from underground waters have developed morphological adaptations to this very peculiar habitat. The absence of light has made their eyes useless and most species now have very reduced or non-functional eyes; many simply have no eyes. Similarly, as a result of the absence of light, all cave fishes are more or less completely unpigmented, their body appearing pinkish-white. Several species are also devoid of scales. To compensate for the absence of eyes, several species have developed their other senses and the lateral line (which fishes use to detect movements in the water) is more developed in some species. Others have elongated and slender paired fins which they possibly use to touch the bottom and search for food. Several Chinese cave species of the genus *Sinocyclocheilus* have a marked head hump which is supposed to have a hydrodynamic function and to help the fish keep their position in the very swift current; many species of this genus have also developed head protuberances of unknown function, one of them looking like a unicorn. A cave loach from Thailand (*Cryptotora thamicola*) has been observed out of the water, using its large, laterally extended, paired fins to climb up moist cliffs, looking either for food or for suitable water bodies.

Fish habitats in limestone areas can be divided into three main categories: underground waters, surface waters, and marine habitats. Only the first two are dealt with below.

Table: SE and E Asiatic fish species known exclusively from subterranean waters. Asterisks (*) indicate species presently known from a single cave.

Family Cyprinidae	**Location**
Poropuntius speleops (Roberts 1991)	Thailand
**Poropuntius* sp.	Thailand
**Puntius* aff. *Binotatus* (Kottelat & Bariche, ms.)	Indonesia: Java
**Sinocyclocheilus anatirostris* (Lin & Luo, 1986)	China:
**Sinocyclocheilus angularis* (Zheng & Wang 1990)	China:
**Sinocyclocheilus anophthalmus* (Chen & Chu 1988)	China:
**Sinocyclocheilus cyphotergous* (Dai, 1988)	China:
**Sinocyclocheilus hyalinus* (Chen & Yang 1993)	China:
**Sinocyclocheilus microphthalmus* Li (1989)	China:
**Typhlobarbus nudiventris* Chu & Chen (1982)	China: Yunnan
**Troglocyclocheilus khammouanensis* (Kottelat & Bréhier 1999)	Laos
Family Balitoridae	
'Cryptotora' thamicola (Kottelat 1988)	Thailand
**Nemacheilus troglocataractus* (Kottelat & Géry 1989)	Thailand
**Oreonectes anophthalmus* (Zheng 1981)	China:
Schistura oedipus (Kottelat 1988)	Thailand
**Schistura jarutanini* (Kottelat 1990)	Thailand
**Schistura* sp.	Thailand: Phitsanulok
**Triplophysa gejiuensis* (Chu & Chen 1979)	China: Yunnan
**Triplophysa xiangxiensis* (Yang, Yuan & Liao 1986)	China:
**Triplophysa yunannensis* (Yang 1990)	China: Yunnan
**Triplophysa shilinensis* (Chen & Yang 1992)	China: Yunnan
* *Sundoreonectes tiomanensis* (Kottelat 1990)	Malaysia (Tioman I.)
Family Cobitidae	
* *Protocobitis typhlops* (Yang & Chen 1993)	China:
Family Gobiidae	
* *Bostrychus* sp. n.	Indonesia (Sulawesi)
* *Caecogobius cryptophthalmus* (Berti & Ercolini 1991)	Philippines (Samar)
* *Oxyeleotris caeca* (Allen 1996)	Papua New Guinea
Cave-adapted population of a surface species	
Pterocryptis buccata	Thailand

Fishes in underground waters. Numerous fish species are known from underground limestone environments, which include caves and water-filled voids. The fish species range from surface species which occasionally enter caves by accident, to those that are entirely adapted to the underground environment and never see daylight. World-wide, some 70 species are known exclusively from underground environments. In East Asia, 27 species have been found so far but it is expected that the actual number of Asian cave fishes might be two or three times higher. All but three are currently known from a single cave. In addition, a cave-adapted population is known for at least one species which otherwise lives in surface waters. Most caves host a single cave fish species, a few host two, and in one cave three, different species have been found.

Fishes in surface waters. Fish communities from flowing surface waters in limestone areas are generally similar to communities elsewhere. Patterns of endemism follow the same rules, and any basin with an independent geomorphologic history, should be expected to harbour a few endemic species. Surface waters in limestone areas are characterised by the poor development of a permanent network of water bodies, which are reduced to disconnected ponds and puddles during the dry season, or which dry out entirely. This creates a very harsh environment for fishes.
Several permanent lakes in limestone areas, or fringing them, are inhabited by unique fish communities with a large number of endemic species. Examples are Lake Inle in Myanmar (about 35 native species, including 9 endemic species and 3 endemic genera), as well as several lakes in Yunnan, China, like lake Dianchi (about 25 native species, including 12 endemic species and 1 endemic genus), Lake Fuxian (25 native species, including 12 endemics), Lake Erhai (16 native species, including at least 7 endemics), and several smaller lakes. Some of these endemic species have a very small area of occupation; this may be as little as 6 m^2.

A distinctive and peculiar fish community also exists in some coastal rivers in limestone areas. Fish species normally occurring in estuaries or even in the sea have been found in pure fresh water beyond tidal influence in several limestone areas. The high mineral content of the water, caused by the dissolution of the limestone, results in a comparable osmotic pressure so that these fishes are able to live here.

Swiftlets and caves
Swiftlets are small members of the swift family which, because of their short legs, can perch only on vertical surfaces such as cave walls and cliffs. Swiftlets nest in colonies, on perpendicular or overhanging cliffs, and on the walls and ceilings of caves. Once a site has been chosen, it will serve as a permanent roosting place and nesting site season after season, year after year. The only migratory swiftlets are the Himalayan representatives of Hume's swiftlet, which range south to the Andaman Islands, Sumatra, and Peninsular Malaysia during the northern winter. Swiftlets' nests are small, shallowly cup-shaped, and glued to the wall. They are made of vegetable material held together by glutinous nest cement secreted from a pair of salivary glands under their tongue. All species use at least some saliva in their nests. The renowned edible-nest swiftlet produces a nest consisting of almost pure saliva with a few feathers.

Table: Species of East Asian cave swiftlets of the genus *Hydrochous*, *Collocalia* and *Aerodramus*.

Hydrochous gigas	Giant Swiftlet	Java; Sumatra; Peninsular Malaysia; Borneo.
Collocalia esculenta	White-bellied Swiftlet	Throughout SE Asia;
Collocalia linchi	Linchi Swiftlet	Java and parts of Sumatra and Borneo.
Collocalia troglodytes	Pygmy Swiftlet	Endemic to the Philippines.
Aerodramus mearnsi	Philippine Grey Swiftlet	Endemic to Philippines.
Aerodramus infuscata	Moluccan Swiftlet	Endemic to SE Sulawesi and Moluccan Islands.
Aerodramus hirundinacea	Mountain Swiftlet	Endemic to New Guinea
Aerodramus spodiopygius	White-rumped Swiftlet	Extensive range on islands on Papuasia, Melanesia and Polynesia.
Aerodramus brevirostris	Himalayan Swiftlet	From Nepal and N.E. India to SW China, northern Laos, Myanmar and western Thailand.
Aerodramus whiteheadi	Whitehead's Swiftlet	Endemic to the Philippines.
Aerodramus nuditarsus	Bare-legged Swiftlet	S and SE New Guinea.
Aerodramus orientalis	Mayr's Swiftlet	Two locations on Melanesian Islands.
Aerodramus salanganus	Mossy-nest Swiftlet	Endemic to Greater Sundas (Sumatra; Java; Borneo).
Aerodramus vanikorensis	Uniform Swiftlet	Philippines; E Indonesia; New Guinea; Melanesia.
Aerodramus pelewensis	Palau Swiftlet	Endemic to Palau Islands.
Aerodramus bartschi	Guam Swiftlet	Endemic to S Mariana Islands.
Aerodramus inquietus	Caroline Swiftlet	Endemic to Caroline Islands.
Aerodramus sawtelli	Sawtell's Swiftlet	Endemic to Atiu Islands in Cook Archipelago.
Aerodramus leucophaeus	Polynesian Swiftlet	Endemic to the Polynesian Islands.
Aerodramus maximus	Black-nest Swiftlet	Throughout SE Asia
Aerodramus fuciphagus	Edible-nest Swiftlet	Andaman and Nicobar Islands; coastal SE Asia; SE Hainan coast; Indo-China; islands off Peninsular Malaysia; Greater Sundas; Philippines.
Aerodramus papuensis	Papuan Swiftlet	Endemic to New Guinea.

The colonies of most species are found in the dimly-lit portions of caves, relatively close to the entrance. These readily occupy man-made structures like abandoned buildings, tunnels, eaves and coverts of ceilings. Several species, however, can navigate through pitch darkness by echo-location, and prefer the deepest parts of caves in which to nest. No other bird except the Oil-bird from South America has this capability, although it may be that the Rockfowl *Picathartes* of central Africa finds its way around the dark zone of caves in a similar manner. Unlike the high-pitched sounds produced by bats, the frequencies of the echo-location calls of swiftlets can be heard as a series of clicks in rapid succession culminating in a staccato rattle. Calls can be heard as soon as a swiftlet approaches the cave entrance. When negotiating a bend in dim light, or approaching a wall or their nests, the frequency of clicking increases to give a clearer 'picture'.

Annex 4 Box 3: A day in the life of swiftlets

The swiftlets leave their roosting cave at dawn, to flutter and glide above the forest canopy or meander around the edge of the forest vegetation nearby foraging for insects, which they take in flight. When the sun goes up, they move towards the river and forage above the vegetation along the banks, until they disperse around midday. They may fly long distances, swiftlets have been observed at 27 km distance from their roosting cave. Returning swiftlets begin to arrive at the vicinity of their roosting cave one or two hours before twilight but they are still swirling high in the sky. They often assemble in large flocks over water. They skilfully glide down and skim over the surface of the water, drinking in flight. At the lowest point of their dive both wings are swept upwards while their bills dip down to flick up a mouthful of water. Occasionally, a clumsy individual will hit the water hard before taking to the air again. After the afternoon splash, the swiftlets retreat back to their roosting cave, unleashing a crescendo of clicks while whirling near the entrance. As dusk falls, streams of swiftlets enter the cave to roost; carefully avoiding the emerging bats.

The outward flight continues even when there is a drizzle and is only delayed if there is a heavy downpour. If this persists for several hours, the swiftlets will brave it as soon as it has subsided a little. A late start usually means a late return, dashing into the cave speedily, without revolving around its entrance. When a thunderstorm is imminent during the afternoon, the swiftlets will return earlier than usual.

Inside the cave, the squeaking, chirping and staccato rattle calls of thousands of swiftlets frantically swirling in search of their roosting sites within the confinement of echo-bouncing cave walls produce a cacophony of sound. Cave swiftlets roost in pairs. The nest site serves as a roosting place; if a nest is present, both birds sometimes snug inside, or one clings to the outside the nest. If no nest is present, both will cling side by side on the uneven surface of the cave wall. Squabbles about nest sites are common. If the second of a pair tries to alight, the bird already roosting will squeak and peck until the mutual bond is established. Afterwards, one will help to preen the head and neck of its partner, while chirping softly. The breeding cycle is long, three or four months elapsing from the start of nest construction until the nestlings are ready to fledge.

Numbers of swiftlet species and endemism. Altogether 26 species of swiftlets range throughout the tropical Indo-Pacific region from the Seychelles to the western Pacific. A few are common and widespread, such as the white-bellied swiftlet, the mossy-nest swiftlet, the black-nest swiftlet, and the edible-nest swiftlet. Most species are local or regional endemics.

Bats and caves

In the minds of many people, bats and caves are intimately associated. Indeed, many of the almost 1,000 species of bats inhabiting the world choose caves for a home either in limestone (by far the most numerous), or in other rock. In the tropics a single cave may house a dozen or more species. In fact, in East Asia, caves harbour more bats and bat species than any other type of roost type. Bat colonies may number hundreds of thousands to millions of individuals, and in East Asia, such colonies are found exclusively in caves. The bats use the cave to roost during the day, while foraging outside during the night. Each bat has its own place in the cave to roost, and more often than not returns to the same cave throughout its life. In the reproductive season, males and females of a particular species may form single-sex groups, and the females then form maternity colonies.

Even in the subtropics and tropics of East Asia, several of the bat species living at higher altitudes (over 800 m above sea level) can enter a state of torpor to save energy, for instance during periods of food scarcity. This is similar to the hibernation by bats in temperate areas. During such hibernation the bats' body temperature decreases considerably; and they are then extremely vulnerable to disturbance: any arousal costs energy, energy which is vital to survive the cold period.

Bats have few natural enemies: bat hawks, nocturnal birds like owls, some small carnivorous mammals (including even some other bat species), snakes, and some insects. Birds and bats may catch bats during flight. Other animals may snatch them from their roosts. Cave floors and walls may be inhabited by various arthropods which eat bat carcasses, but also attack living young bats which have fallen.

Bat biodiversity. Bats are mammals. Biologists divide bats into two groups: the generally small insect eating bats, and the often large fruit eating bats. Some insect-eating bats have specialised on other prey animals, while some 'fruit' bats eat pollen and nectar rather than fruit. An educated guess of the numbers of East Asian bat species using caves for roosting is 262, among which there are 237 insect-eating species and 25 'fruit-eating'. Some species are very common and widespread, others are extremely rare, and are known from one or a few populations only.

Table: Numbers of bat species known or expected to roost in caves (many inhabiting more than one country).

Country	Insect bats	Fruit bats*
Mongolia	11	0
China	76	2 (3)
Burma	70	3 (4)
Thailand	99	4 (7)
Laos	38	2 (3)
Cambodia	28	2 (3)

Vietnam	49	2 (3)
Malaysia (incl. Brunei)	95	6 (9)
Singapore	14	2 (3)
Indonesia	110	19 (21)
Philippines	45	4 (5)
Papua New Guinea	51	8

Annex 4 Box 4: Small but fussy: a rare cave bat

Kitti's or the bumblebee bat, *Craseonycteris thonglongyai*, is the world's smallest mammal, weighing barely 2 grams with a length of 3 cm. When it was discovered in 1973 it had to be placed in an entirely new family because it had no known relatives. It is known from many caves all located in forested areas of Sai Yok National Park, Thailand. The bat feeds above the canopy of orchard and other trees. It is extremely fussy as to its roosting environment and chooses caves with narrow specifications. The bat is threatened by changes in its roost environment, due to deforestation, hydrological changes, and other forces.

Other vertebrates

East Asia has few non-flying mammals that are primarily associated with limestone. The threatened François' leaf monkey, *Trachypithecus francoisi*, is found in southern China, northern Vietnam and Laos and appears to be restricted to limestone hills. The serow, *Naemorhaedus sumatraensis*, a black wild mountain goat, is most often found in limestone areas in East Asia but occurs in other mountain areas in the Himalayas in the west of its range. Among the birds, only the Sooty babbler *Stachyris herbertsi*, which is endemic to central Laos, and the Limestone wren-babbler of Thailand, are found exclusively on limestone outcrops. The Bat hawk *Macheiramphus alcinus* is a widely distributed species frequently seen diving at departing bats as they swarm from their caves at dusk.

At this point only three limestone-associated reptiles are known from East Asia: a gecko, *Cyrtodactylus cavernicolus*, from Niah Cave and from a gorge in Mulu NP, both in Sarawak, and a skink, *Lygosoma khoratense,* from Saraburi Province, Thailand. The snake *Elaphe taeniura* is often found in the lighter parts of caves in Southeast Asia where it catches bats while wedging its tail into crevices in the cave wall.

Flowering plants

Features of limestone vegetation. Limestone vegetation is unique in many respects. Its appearance and species composition are distinctive compared with other vegetation types; the number of species found is extremely high, particularly when measured per surface unit, and so is the concentration of endemic species, which includes many species of economic value.

Because of the shallow soil often overlying limestone bedrock, and soils that are generally deficient in several important nutrients, the vegetation in limestone areas often has a rather straggly appearance. Many of the trees are small, twisted and gnarled with sparse crowns. This is particularly obvious where limestone vegetation is surrounded by high tropical lowland forest.

Conspicuous and attractive, perched on the jagged edge of the towering cliffs can be seen stout cycads and low fan palms and, in the more tropical regions, pandans. It is also the habitat of the very rare slipper orchids (especially *Paphiopedilum* spp.). In tropical regions lithophytes (plants growing on rocks) and epiphytes (plants growing on other plants), particularly ferns and orchids, add to the richness of the limestone flora. The lush herb community around the base of the cliffs rivals any botanic garden rockery in its variety and beautiful species, many of which belong to groups well known as ornamental plants such as begonias, balsams (*Impatiens* spp.), orchids, and relatives of the African violet (Gesneriaceae). Many of these herbs are extremely rare and limited in distribution; some known from only a single hill. Hill summits at about 1000 m altitude are often covered with dense, shrubby vegetation. Deeper soils between limestone hills and in pits and dolines, may support some high, usually species-rich, forest. The more gentle slopes may support scattered tall trees.

Not only does the limestone flora different in appearance from that of the surrounding forest, it is strikingly different when the species are compared. In the first place, this is due to the unique prevailing conditions: limestone provides a habitat for species that grow on rock surfaces, and for species that can withstand periodic water stress. The incomplete tree canopy of limestone vegetation also allows the growth of shade intolerant species, which are excluded from the surrounding tall forest. Interestingly, there is no evidence that many of these plants actually require an alkaline or chalky soil; they rather tolerate it.

On summit plateaux leaf litter may accumulate over the limestone to form a layer of acid peat which isolates the plants growing on it from the alkaline bedrock. This peat often supports a suite of definitely acid-loving species such as camellias, rhododendrons and carnivorous sundews and pitcher plants.

The varied topography of many karst areas, often in combination with intricate patterns of substrates (from bare rock or screes to a thick soil layer) and degree of exposure, create a wide array of microhabitats and, as different species are adapted to specific niches, result in extreme species richness. For example, in China’s Zhuang Autonomous Region the limestone areas support a much higher percentage of southern tropical species (88%) than adjacent non-limestone areas, many of which reach the northern limit of their range. In northern Thailand, limestone areas are the southernmost locality of many temperate species, and in Peninsular Malaysia limestone areas are the southernmost locality for several Indo-Chinese plants.

Annex 4 Box 5: Plant adaptations to life on limestone

The shallow soils, free-draining nature of the rock substrate and exposure to full sunlight subject plants to severe water stress and high temperatures, particularly in dry periods. Plants on limestone show several adaptations to overcome this:

- Figs that grow on the summit and cliff faces produce an extensive root system that forces its way into fissures and cracks to tap water sources deep within the rock.
- Tropical karst typically supports plants representing different life forms but with succulent leaves that have the same kind of photosynthetic pathway as many desert plants. These include shrubby *Euphorbia* spp, many lianoid *Hoya* spp., herbaceous, terrestrial and epiphytic *Peperomia* spp. and numerous lithophytic and epiphytic orchids. Certain carnivorous plant species occur in extreme habitats, usually with very acid soils. Typical among these is in the pitcher plant (*Nepenthes* spp.) that also occurs in extreme calcic environments.
- Many woody species are deciduous, with large thin, short-lived leaves, and avoid drought by storing water in their stems and maintaining photosynthesis via a green outer- or under- bark (*Gyrocarpus, Hernandia*). Other, evergreen species such as *Syzygium* tolerate drought by having small, long-lived leaves and often smooth stems, also with green photosynthetic bark.
- Shallow soils on karst also support many plant species with secondary metabolites (chemical products that are not primarily required for photosynthesis or respiration) that are often toxic to leaf-eating, mammals and insects such as moths and butterflies. Some are widely exploited for their medicinal value including *Canarium*, *Cycas, Strychnos*, and many species of Asclepiadaceae, Apocynaceae Ebenaceae Rubiaceae and Simaroubaceae.
- Plants of the genus *Boea* and *Paraboea* are characteristic of cliff faces. They have leaves that can tolerate extreme drought by rolling up to expose the thick silvery hairs on the underside. These reflect light and insulate the leaf from high temperatures. In wet weather, the leaves unroll, revive and resume growth. Several species of the fern *Doodia* are also similarly capable of rehydrating rapidly after drought.
- Some plants cope with dry periods by dying down and entering a state of dormancy. This group includes plants that have tubers buried deep in rock crevices, such as the Elephant yam *Amorphophallus* spp., or fleshy herbs, such as *Chiritas* species that survive as seeds, readily germinating once the soil becomes wet again.
- Tough rosette-leaved plants, such as cycads, palms, dracaenas and pandans survive drought without wilting. Some *Pandanus* species also exhibit aerial or adventitious rooting and photosynthetic stems.
- Many of the species with specific adaptive features exhibited by plants in karst environments are also found in shoreline habitats and in some extreme, fire-prone, forest-grassland transition zones in dry seasonal climates. Typical species assemblages are included in the genera *Amorphophallus, Cycas, Casuarina, Cerbera, Cochlospermum, Diospyros, Gymnostoma, Gyrocarpus, Tacca* and *Pandanus*.



Pandanus (left), *Asplenium* (above) and a vine species (right) growing on karst in Fiji
(Photography: Stuart Chape)

Biodiversity and biodiversity value of the limestone flora. Compared with other vegetation types, the limestone flora is one of the richest in terms of species numbers, especially when the comparison is made per unit area. Unfortunately, apart from Peninsular Malaysia there is no country in Asia where sufficiently complete data are available to even know the number of species that grow on limestone (Table x). Figures from Peninsular Malaysia are striking: 13-14% of the total seed plant flora is found on limestone, which covers a mere 0.3% of the land area. Besides, the species composition differs from hill to hill and no single hill is home to more 20% of the total limestone flora of Peninsular Malaysia.

Table: State of knowledge of the flora of limestone areas in East Asia

Country	Region	Status
Cambodia		no publication available
China	Zhuang Autonomous Region	summary of conservation value
	Xishuangbanna	vegetation study
	Gueilin	no publication available
Laos		no publication available
Thailand	Doi Chiengdao	floristic survey
	Southern Thailand & islands	no publication available
Vietnam	Cuc Phuong	floristic survey
	Hon Chong-Ha Tien	floristic survey
	Other sites	no publication available
Malaysia	Peninsular	almost complete checklist
	Sarawak	general account
	Sabah	preliminary account
Philippines	Palawan	no publication available
	other islands	no publication available
Indonesia	Sumatra	no publication available
	Kalimantan	no publication available
	Java	brief account
	Sulawesi	brief account
	Lesser Sunda Islands	brief account
	Moluccas	no publication available
	Irian Jaya	no publication available
Papua New Guinea		no publication available

Endemism. A large number of endemic and rare species are entirely restricted to limestone, some are even confined to a single limestone hill, or a group of neighbouring hills. Many of these endemics have commercial value as ornamentals, such as the much sought-after slipper orchids, balsams with flowers that span the spectrum of colours from white to yellow to peachy pink to crimson to bluish purple, or begonias prized for the variegated and variously shaped foliage, or the aroids for those who relish the bizarre, not to mention the cycads and palms. In some cases, even entire groups of plants are characteristic for limestone areas, such as about 30 species of camellia in China, or begonias in Malaysia. They are characteristic either because many species may grow together in limestone areas, or because the whole group is confined to limestone areas, with no species growing anywhere else.

Annex 4 Box 6: Endemic plants on limestone

Several groups of plants are notable because they include a large number of species that occur entirely restricted to limestone. They are often known from one or a few limestone hills only, and they include some extremely attractive species that have horticultural potential because of their beautiful flowers or beautiful leaves.

- The delicate balsams grow in damp conditions around the base of limestone hills. Throughout East Asia, endemic species occur on limestone, including several species new to science. The Gouty balsam, *Impatiens mirabilis*, endemic to Peninsular Thailand and northern Peninsular Malaysia, is a remarkable balsam with a fleshy trunk and a tree-like canopy.
- Begonias grow in a variety of habitats on limestone, from the damp and shaded base of the hills to crevices in cliff faces and, in Borneo, even on the exposed summit. *Begonia keithii*, known only from a single hill in Sabah, Borneo, has beautiful lacquer-red stems and carmine, heart-shaped male flowers.
- *Paraboea* is a genus almost entirely confined to limestone. *Paraboea brachycarpa* is characteristic of sheer cliff faces. Many species have silvery leaves and produce pretty purple flowers.
- The genus *Monophyllaea* is remarkable because, as the name suggests, the plants produce only a single leaf during their entire lives.
- Three new limestone genera endemic to Peninsular Malaysia have recently been discovered. Each is at present known from a single species. One of the species, *Spelaeanthus chinii,* occupies a very narrow niche: it grows only on dry cliff faces around cave mouths at the base of limestone massifs.

In Peninsular Malaysia, more than 10% of the limestone flora comprises species endemic to limestone areas. For East Asia, the numbers for some plants groups per country are recorded in Table ???. The numbers are certain to increase because many of the limestone areas there have yet to be explored botanically, and many specimens remain unidentified. Many species new to science can also be expected. It is important to note how restricted many endemics are in their distribution. The great majority of the endemic species are herbs (woody plants tend to be more widespread).

Table: Species endemic to limestone in East Asia*

	SW China	**N.Thailand**	**Laos**	**Vietnam**	**South Thailand**
Slipper orchids	6	5**	-	1	4
Paraboea	1	-	1	-	9
Chirita	1	-	-	2	7 +2***
Amorphophallus	-	1**	-	-	4
Balsams	?	3	?	?	3
Palms	1	-	-	1	2+1***

*No species from Cambodia are recorded
**Species on limestone in SW China and N. Thailand
***Species on limestone in S. Thailand and N. Peninsular Malaysia

Lower plants - Bryophytes
Bryophytes are small ancient plants that can be divided into two groups - the true mosses and the liverworts – both of which have a life cycle divided in two phases. Many species contain chemical compounds protecting them against predation by most insects, snails, etc, and they display a variety of growth forms: some produce creeping stems, fixed to the substratum with root-like outgrowths, others grow like leafy poles, or miniature trees and shrubs.

Weathered rocks (and mortar brick walls) around the world, but especially in moist climates, are substrates on which numerous different mosses can be found. In tropical limestone areas various habitats harbour distinctive moss flora, such as plateaux, scree slopes, gullies, cliffs and vertical slopes of different exposure to the sun, winds, and rain. Some limestone mosses can withstand the heat of bare sun or, at high altitudes, frost. To protect themselves against desiccation, they curl up their leaves, and expand them again during a shower. Other species can survive only in permanently cool and wet places; these prefer overhanging wet rocks, or deep shady gullies. Species may display a preference for loamy soils fertilised with the phosphates leached out of guano piles; some of these retain water in moisture pouches at the base of their leaves. A few species grow only along calcareous springs, or below dripping stalactites in dim light near cave entrances. Special adaptations to deal with excess limestone dissolved in water also exist, with some species able to excrete calcium. Mosses preferring an acid soil may grow in abundance in waterlogged bogs on limestone plateaux without sufficient drainage.

Endemism of the limestone moss flora. Only a few moss species are known solely from limestone substrate. Most species display a much less marked preference for limestone, or are indifferent to the substrate on which they grow. In fact the moss flora of limestone hills is most clearly defined by the absence of the many species which cannot tolerate high levels of calcium in their substrate.