Bamboo biodiversity

Information for planning conservation and management in the Asia-Pacific region

Nadia Bystriakova, Valerie Kapos, Chris Stapleton, Igor Lysenko

Bamboo biodiversity

Information for planning conservation and management in the Asia-Pacific region

Nadia Bystriakova, Valerie Kapos, Chris Stapleton, Igor Lysenko

UNEP World Conservation Monitoring Centre
219 Huntingdon Road
Cambridge
CB3 0DL
United Kingdom
Tel: +44 (0) 1223 277314
Fax: +44 (0) 1223 277136
E-mail: info@unep-wcmc.org
Website: www.unep-wcmc.org

Director: Mark Collins

International Network for Bamboo and Rattan
Anyuan Building No 10, Anhui Beili
Asian Games Village, Chaoyang District
Beijing, People's Republic of China
Postal address: Beijing 100101-80
People's Republic of China
Tel: +86 10 64956961/82
Fax: +86 10 64956983
E-mail: info@inbar.int
Website: www.inbar.int

Director General: Ian Hunter

THE UNEP WORLD CONSERVATION MONITORING CENTRE is the biodiversity assessment and policy implementation arm of the United Nations Environment Programme (UNEP), the world's foremost intergovernmental environmental organization. UNEP-WCMC aims to help decision-makers recognize the value of biodiversity to people everywhere, and to apply this knowledge to all that they do. The Centre's challenge is to transform complex data into policy-relevant information, to build tools and systems for analysis and integration, and to support the needs of nations and the international community as they engage in joint programmes of action.

THE INTERNATIONAL NETWORK FOR BAMBOO AND RATTAN (INBAR) is a non-profit, international organization established in 1997 by Treaty. As of June 2002, INBAR's Establishment Agreement had been signed by 26 countries. INBAR's mission is to improve the well-being of producers and users of bamboo and rattan within the context of a sustainable bamboo and rattan base by consolidating, coordinating and supporting strategic and adaptive research and development.

Authors

N Bystriakova[1,2]
V Kapos[2]
C M A Stapleton[3]
I Lysenko[2]

1 **International Network for Bamboo and Rattan**
Beijing, China
2 **UNEP World Conservation Monitoring Centre**
Cambridge, UK
3 **Royal Botanic Gardens**
Kew, Surrey TW9 3AB, UK; c.stapleton@rbgkew.org.uk

Acknowledgements

The authors gratefully acknowledge financial support from the International Network for Bamboo and Rattan (INBAR), the UNEP World Conservation Monitoring Centre (UNEP-WCMC) and Missouri Botanical Garden. UNEP-WCMC and the Royal Botanical Gardens, Kew are thanked for providing working facilities.

Additional photo credits

Page 7 (left to right) 1-3: Zhu Zhaohua; 4: Jeevanandhan Duraisamy; 5: Zhu Zhaohua
Page 8 A Borissenko
Page 9 M Sanbluch/UNEP/Topham

Citation: Bystriakova, N., Kapos, V., Stapleton, C. & Lysenko, I. 2003. *Bamboo Biodiversity.* UNEP-WCMC/INBAR.

A **Banson** production
Printed in the UK by Swaingrove Imaging

Contents

Foreword

The bamboo plant supports an international trade which (even according to our currently imperfect trade statistics) is worth more than US$ 2 billion per year. Yet international trade represents only a small proportion of total bamboo usage – domestic use is estimated to account for at least 80 per cent. Bamboo is thus a major world commodity.

Despite this, very little is known about the distribution and resources of bamboo. Certain bamboo species (e.g. Chinese Moso bamboo, *Phyllostachys edulis*) have formed the basis for major industrial development and have been domesticated into plantations. Perhaps 50 or 100 bamboo species are preferred for use and are undergoing some degree of domestication. However there are estimated to be nearly 2 000 species in total. The vast majority of these occur only in their native ranges, and many may have uses of local or wider significance that have yet to be documented. Unfortunately, as obligate components of forested ecosystems, their futures are bound up with the survival of their forest habitats. This publication indicates that as forest ecosystems shrink under human pressure the survival of many potentially important bamboo species may be threatened.

This work is a first step towards quantifying bamboo resources in the world. It presents an innovative approach to quantifying the likely range of the various bamboo species. It also, through the aggregation of overlapping ranges, has something to contribute to knowledge about bamboo biodiversity.

The innovative approach used here can be applied to the study of other species associated with mapped ecosystems.

This study would not have been possible without the collaboration between INBAR and UNEP-WCMC. It was the detailed map-based databases of UNEP-WCMC that made the development of the methodology possible. Thus, this study is an excellent example of two organizations working together to combine their strengths.

Ian Hunter
Director General
International Network for Bamboo and Rattan

Preface

Bamboo – an intriguing name for a quite extraordinary group of plants! Essentially a family of giant woody grasses, they are used for every conceivable purpose, from scaffolding to boats, cooking utensils to furniture, for food, fuel, landscaping, ornamental display and a thousand other uses. Their direct and widespread importance to our social and economic well-being may be self-evident but, surprisingly, we still know relatively little about most bamboos in the wild. Although their importance to a few threatened species, such as the giant panda, is legendary, the distribution and conservation status of bamboos themselves largely remain a mystery.

The results described in this publication expand our knowledge base substantially. Information drawn from a wide range of botanical and other sources has been treated with sophisticated analytical tools to generate a new overview of the distribution of bamboos in the Asia-Pacific region. By providing insight into centres of diversity and the amount of habitat remaining for individual species, it will help to identify priorities for planning and management of bamboos. They are essentially forest plants and their future is linked to the survival of forest habitats – under pressure worldwide from the expansion of agriculture, plantation forestry and climate change.

Conservation of biodiversity is a necessary step towards solving the problems of poverty alleviation and sustainable development – this message is clear from the Johannesburg World Summit on Sustainable Development. But conservation in today's world means the adoption of an overarching, ecosystem approach that takes into account species, their habitats and the landscapes in which they occur. The mapping approach used in the analysis undertaken here facilitates building this bigger picture for conservation. This report will help range states to recognize, and value, the bamboo genetic resources on their own doorsteps, and to conserve them for future generations.

I welcome this opportunity to collaborate with INBAR, the world's bamboo and rattan trade network. I hope that our first analysis will form the basis for future assessments of bamboo resources and their conservation status. Bamboos are a fascinating group of plants that bring benefits to people everywhere; they should be conserved as an important resource for all our futures.

Mark Collins
Director
UNEP World Conservation Monitoring Centre





Bamboo biodiversity

Bamboos are distinct and fascinating plants, with a wide range of values and uses. They play a significant role in biodiversity conservation and contribute to soil and water management. They are important for biomass production and play an increasing role in local and world economies. This study used an innovative approach to map potential current distributions of nearly 1 000 individual bamboo species that occur naturally within remaining forests of the Asia-Pacific region. The maps were also combined to generate regional maps showing potential species and generic richness. By quantifying the area of forest cover remaining within each species' range, this study shows that more than 400 bamboo species are potentially threatened by the destruction of natural forest cover. Conservation and sustainable management of wild populations of bamboo should be a high priority, especially where diversity is high or deforestation is a significant threat.

Bamboos are of conservation significance in their own right and as indicators of high biodiversity in other groups. They are an ancient group of forest plants, intrinsically vulnerable to deforestation. The vulnerability of some species is increased by the simultaneous flowering and subsequent death of entire populations in cycles of 20-120 years. Inhabiting moister, more benign habitats in old-growth forests, they are often associated with threatened plants, and there are many specialized animal species that depend upon them. The best known of these in Asia is the giant panda (*Ailuropoda melanoleuca*), but the red panda (*Ailurus fulgens*) and the Himalayan black bear (*Selenarctos thibetanus*) are also heavily dependent on bamboo. The smallest known bat (*Tylonycteris pachypus*, 3.5 cm) roosts between nodes of mature bamboo (*Gigantochloa scortechinii*), which it enters through holes created by beetles. The recent discovery of a colony in a bamboo stand in Hong Kong highlighted the conservation importance of bamboos on that island, where all bats are protected (Ades 1999). More than 15 Asian birds live almost exclusively in bamboo; many of these are rare, and many threatened birds use bamboo as a significant proportion of their habitat (BirdLife International 2000). There are also many little-known invertebrates specially adapted to the environment within hollow bamboo culms. Studying these specialized relationships, which reflect a long history of co-evolution between bamboos and other species, can shed light on evolutionary and ecological processes.

Because the extensive rhizome system of bamboos lies primarily in the top layers of soil, they often play a

The smallest known bat (*Tylonycteris pachypus*, 3.5 cm) roosts between nodes of mature bamboo (*Gigantochloa scortechinii*), which it enters through holes made by beetles.

major role in stabilizing soils on slopes and river banks, preventing erosion and land slips. This also makes them important in securing the hydrological function of catchments and rivers.

Many bamboos grow quickly and are highly productive. For example the shoots of *Bambusa tulda* elongate at an average rate of 70 cm per day (Dransfield and Widjaja 1995). Annual productivity values mostly range between 10 and 20 t/ha/yr (Hunter and Wu Junqi 2002). Bamboo stands may achieve a total standing biomass that is comparable to some tree crops (of the order of 20-150 t/ha) and therefore they may sequester substantial amounts of carbon. However, their total carbon storage is likely to be lower than that of well-grown forest on favourable sites (Hunter and Wu Junqi 2002).

Bamboos play an important role in local economies and are growing in national and international commercial importance in the Asia-Pacific region. They are multipurpose crops, with more than 1 500 documented uses. The most important traditional uses include housing, food and material for handicrafts. Worldwide, more than 2.5 billion people trade in or use bamboo (INBAR 1999). Modern manufacturing techniques allow the use of bamboo in timber-based industries, to provide bamboo flooring, board products, laminates and furniture. Bamboo is becoming a substitute for wood in pulp and paper manufacturing; about 25 per cent of the fibre used in the Indian paper industry each year comes from bamboo (FAO 1998). Bamboo shoots are now an important food crop on the international market as well as locally and nationally. China is by far the leading exporter of bamboo shoot products, with an annual export value of nearly US$ 140 million (Feng Lu 2001). Bamboo furniture is an expanding business in many countries; exports of bamboo furniture from the Philippines in 1998 were valued at US$ 1.4 million (Vantomme et al. 2002). Worldwide, domestic trade and subsistence use of bamboo are estimated to be worth US$ 4.5 billion per year. Global export of bamboo generates another US$ 2.7 billion (INBAR 1999).

Due to its many uses and its economic importance, bamboo plays a noteworthy role in improving the livelihoods of poor rural people. Much of the bamboo used is harvested by the poor, and especially by women and children.

Because of the scientific, environmental, economic and social importance of bamboos, it is essential that strategies be developed for their sustainable management. However, knowledge to support such planning is limited.

STATE OF KNOWLEDGE OF BAMBOOS, BAMBOO RESOURCES AND THEIR MANAGEMENT

Very little is known about bamboo distribution and resources, especially in natural forests. As a non-timber forest product bamboo is not routinely included in forest inventories. According to FAO (2001), statistical data on bamboo are available for the period 1954 to 1971 only. Today, countries that monitor non-timber forest product (NTFP) supply and utilization at the national level remain the exception. The difficulty of assessing bamboo (and other NTFP) resources and use arises from:

- uncertainty associated with their taxonomy (see below);
- their many uses at local, national and international levels;
- the fact that many bamboo products are used or marketed outside traditional economic structures;
- the lack of common terminology and units of measurement (FAO 2001).

Although reported figures on the area of bamboo forests are inconsistent, it is widely accepted that China is the richest country in Asia in terms of bamboo resources. China's bamboo forests have an estimated area of 44 000 to 70 000 km^2 (Feng Lu 2001), mostly of *Phyllostachys* and *Dendrocalamus* spp. Their standing biomass is estimated at more than 96 million tonnes. Annual production of bamboo poles in China is 6-7 million tonnes – one-third of total known world production (FAO 2001).

Classification of bamboos using botanical nomenclature was formally initiated by Linnaeus (1753), who included one species, *Arundo bambos* (now known as *Bambusa bambos*) in his *Species Plantarum*. Since then the number of species has grown progressively, with no indication that the total number of species has yet been approached (Figure 1). Because traditional plant taxonomy has relied heavily upon floral characteristics, while bamboo flowers are only encountered at long intervals, bamboos are among the least studied of all higher plants. When flowers were available in the past and names and descriptions were given, they have often been difficult to apply until the bamboos flower again, as they may rely upon floral characteristics for the identification of species.

According to Ohrnberger (1999), the subfamily Bambusoideae (of the family Poaceae, or Gramineae) comprises both woody and herbaceous bamboos with 1 575 species altogether. In the most recent (and narrower) classification (Grass Phylogeny Working Group 2001) the subfamily Bambusoideae includes two tribes and approximately 1 200 species.

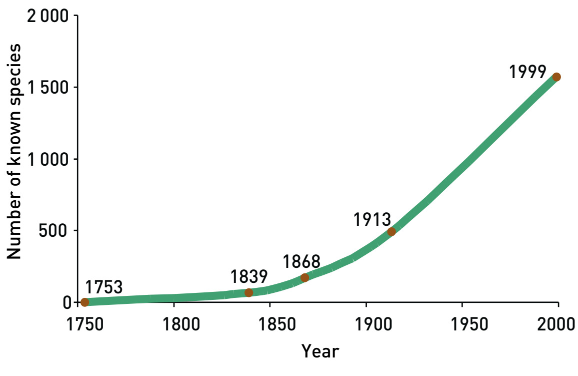
Description of bamboos is thus still an ongoing process; not only do new species remain to be discovered and described, but many earlier descriptions and classifications of species need to be improved upon. With increasingly superior techniques of identification and classification, such as DNA sequencing and fingerprinting, there will continue to be new discoveries and reorganization of bamboo names for some time.

Resources for scientific study of bamboos have been and remain severely limited. The need to target effectively the bamboo research resources available has resulted in international funding being focused on a relatively small set of 38 "priority species" of bamboo that are commercially important and widely distributed (Williams and Rao 1994; Rao et al. 1998) (Annex I). Consequently research on biodiversity and conservation of the remaining forest bamboos has been very limited.

The concentration of resources on such a narrow range of common species was justified by the assumption that future increases in productivity would be based on infra-specific genetic improvement (Williams 1998). However, their sporadic flowering and other factors mean that there has so far been little progress in improvement or selective breeding of these plants.

Most of the priority species of bamboos in Asia are found in managed plantations, large natural stands, or in and around arable land, rather than under a forest canopy. Actively cultivated for local utilization for millennia, this resource is generally in private or communal ownership, and a combination of security of tenure, access rights,

Figure 1. Numbers of species in global accounts of bamboos, from Linnaeus to the present.



Many remaining forest bamboos are highly susceptible to deforestation.

regular management and high value serve to strengthen the likelihood of genetic conservation. Of much greater concern in terms of erosion of genetic biodiversity are the remaining forest bamboos, of which many are highly susceptible to deforestation. Problems of access, ownership, forest management procedures and difficulties in commercialization mean that they are more vulnerable, even though many of them are highly productive and extremely useful.

Forest bamboos are also of importance in the conservation of the priority species. For many cultivated strains of economically important plants, one component of their conservation is the conservation of wild races and closely related species (Srivastava 2001). Therefore conservation of the forest bamboo species is necessary not only for their own intrinsic value, but also as a genetic backup in support of related cultivated bamboos, such as the priority species.

Against a background of poor knowledge of bamboo identification and distribution it is inevitable that the vast majority of bamboos have not been evaluated at all in terms of conservation status, and data deficiencies may limit the value of any *ad-hoc* assessments that have been made. Despite the growing importance of bamboos very few studies of the conservation status of individual species have been undertaken.

Currently, the *IUCN Red List of Threatened Plants* contains 16 species of bamboo (Gillet and Walter 1998) (Annex II), and all of them are from the Asia-Pacific region. However, in India alone (Banik 1995; Biswas 1995; Subramanian 1995) 25-30 species could be classified as rare, and thus potentially threatened.

SCOPE AND METHODS OF THE PRESENT STUDY

As a first step towards facilitating conservation and management planning for bamboos, the International Network for Bamboo and Rattan (INBAR) and the UNEP

World Conservation Monitoring Centre (UNEP-WCMC) have collaborated to compile and synthesize available information on the distribution of bamboo resources within remaining forested areas of the Asia-Pacific region. To determine likely present distributions and estimate the total area of remaining forest potentially containing bamboo, information on the distribution of bamboo species in the region was compiled from taxonomic and floristic literature and combined with regional data on remaining forest cover. Maps showing regional patterns of potential bamboo species richness have been generated to support decision-making in forest management and bamboo conservation (Bystriakova et al. 2003).

This study was confined to woody bamboos, as these are most important from the socio-economic point of view, and the present section focuses only on those species that occur naturally in the forests of the Asia-Pacific region. Of the 88 genera in the Bambuseae, the tribe of woody bamboos (Ohrnberger 1999), only the 60 genera occurring in the Asia-Pacific region (24 countries plus the Russian Sakhalin and Kuril Islands) were included in this study (Annex III). We gathered data on 1 012 species that occur naturally in the region.

For each species bibliographic sources were searched to acquire data about its distribution. These data were principally political units (country, province, locale), altitudinal range (minimum and maximum altitude) and forest type. They were entered into an Access database containing 13 fields and multiple records for each species (a total of 2 190 records). For some species and locations the information available in the bibliographic sources was more detailed than for others: only 980 records (45 per cent) contain information about altitudinal range, while 1 846 records (84 per cent) have data about species distribution at the provincial level.

For each species in the database, a single potential distribution map was generated using ArcView geographic information systems (GIS) software to combine data on political units, altitude and forest type according to the information about natural distribution of the species. The information about the distribution of existing forest cover provided by UNEP-WCMC (Iremonger et al. 1997; UNEP-WCMC 2000) was used as a mask to eliminate areas not forested. In cases where there was no information about distribution of a species within the country, the whole country was regarded as a smallest distribution unit. When multiple data on altitudinal range existed for the same species, the broadest range was applied.

It is important to recognize that many bamboo species persist outside forest, and the study did not address this. For the purposes of this publication an attempt was made to map the distribution of some economically important bamboo species outside forest cover (Annex IV), but the synthesis maps do not reflect this.

DISTRIBUTION OF BAMBOO DIVERSITY IN THE ASIA-PACIFIC REGION

The potential current distributions of nearly 1 000 individual bamboo species within natural forest were mapped. The largest national complement of species was for China, which had 626 described species (Table 1), followed by India (102 species) and Japan (84 species). Species varied in extent of potential distribution from those widely distributed across the region, such as *Cephalostachyum pergracile* with a total of nearly 1.5 million km^2 of forest within its distribution range (see Map 19, Annex IV), to those apparently confined to very limited remnants of natural forest (e.g. *Dinochloa dielsiana* (just over 4 600 km^2; see Map 28, Annex IV). For a few species (e.g. *Dendrocalamus giganteus*, Map 23, Annex IV) it was possible to show that maintenance of bamboo stocks within cultivated landscapes has apparently vastly increased the extent of their present potential distribution.

Table 1. Numbers of species of Bambuseae occurring in the countries of the Asia-Pacific region

Country/ territory	Number of naturally occurring species	Country/ territory	Number of naturally occurring species
Australia	3	Korea, DPR	2
Bangladesh	18	Pakistan	3
Bhutan	21	Papua New Guinea	22
Brunei	6	Philippines	26
Cambodia	4	Russia (Sakhalin and Kuril Islands)	1
China	626	Singapore	3
Hong Kong	9	Korea, Rep.	6
India	102	Sri Lanka	11
Indonesia	56	Thailand	36
Japan	84	Viet Nam	69
Laos	13		
Malaysia	50		
Myanmar	75		
Nepal	25		
Total species in all countries			**1 012**

Source: Ohrnberger 1999

Individual grids (maps) for each species were sorted and merged by genus to generate potential distribution maps for the 60 genera of the tribe Bambuseae that occur within the region. The genera range from widely distributed (e.g. *Bambusa*, Map 1, Annex IV) to nationally endemic (e.g. *Ochlandra*, Map 6, Annex IV). Most genera were distributed across several countries but not the whole region (Maps

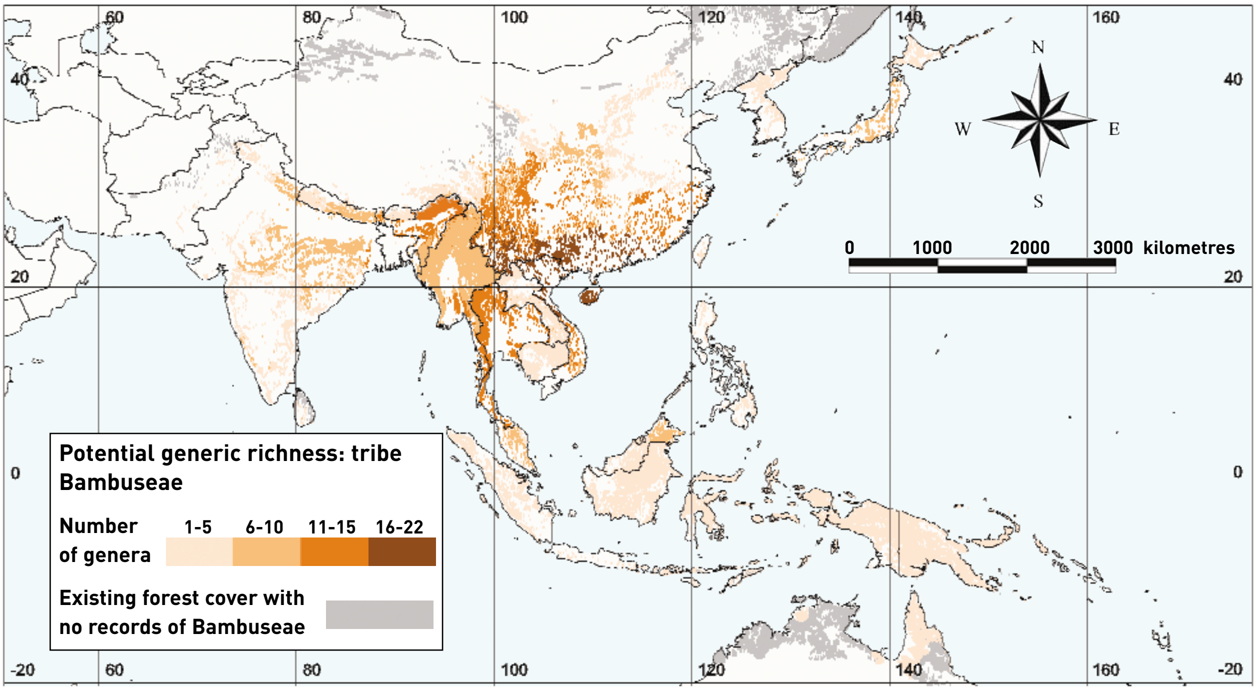
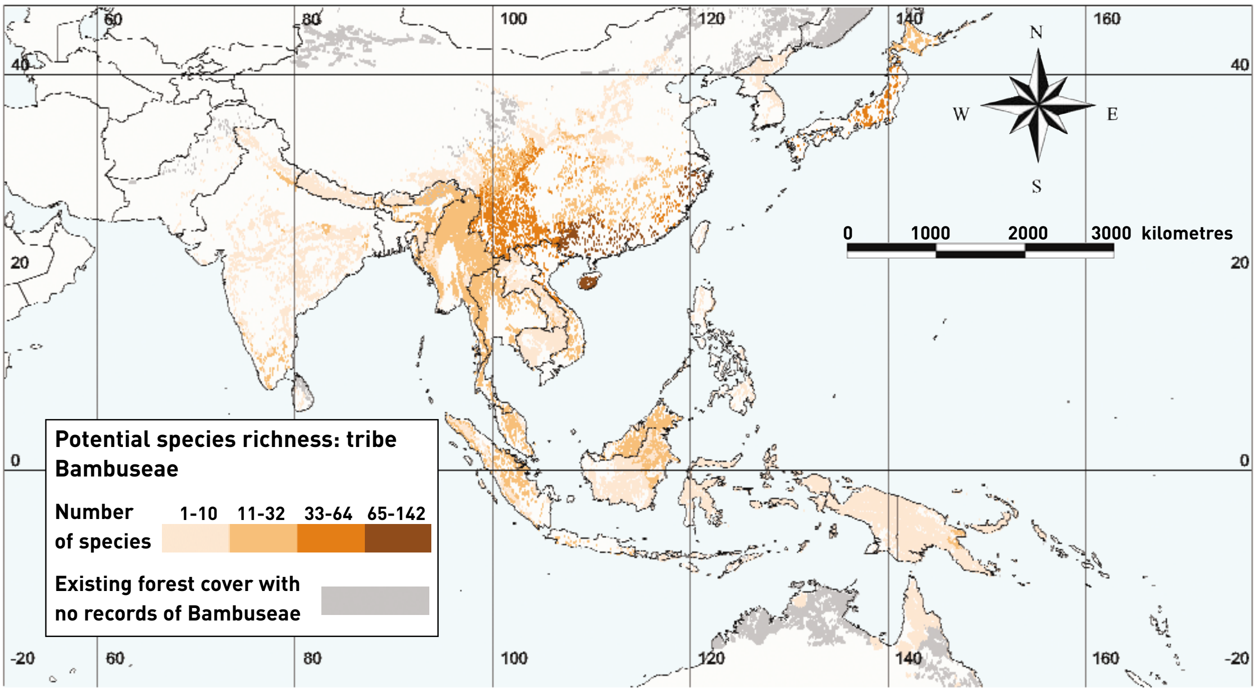


Figure 2. Map of potential generic richness for the Asia-Pacific region, derived by integrating all 60 genera in a single grid.

Figure 3. Regional scale map of potential bamboo species richness, derived by integrating all 998 species in a single grid.



1-8, Annex IV). Integration of all genera in a single grid provided a map of potential generic richness for the whole Asia-Pacific region (Figure 2), which showed a maximum generic richness of 22 genera per km^2 found in southern China. About a quarter of the bamboo-containing forest of the Asia-Pacific region potentially contains one to two genera.

Integration of 998 species in a single grid generated a regional-scale potential species richness map (Figure 3), which was broadly similar to the generic richness map, suggesting that richness at either taxonomic level may be an adequate indicator of biodiversity distribution in bamboos, at least at broad geographical scales.

The regional map of potential bamboo species richness (Figure 3) shows that more than 5.3 million km^2 of forest in the Asia-Pacific region potentially contains bamboo. The maximum potential species richness in the region, 142 species per km^2, was recorded for a total area of about 900 km^2 in southern China. More than 28 per cent (1.5 million km^2) of the total area of forest would have from 1 to 5 species per km^2 (Figure 4), while potential species richness of more than 50 species per km^2 was recorded for 189 000 km^2 (3.5 per cent of the regional total).

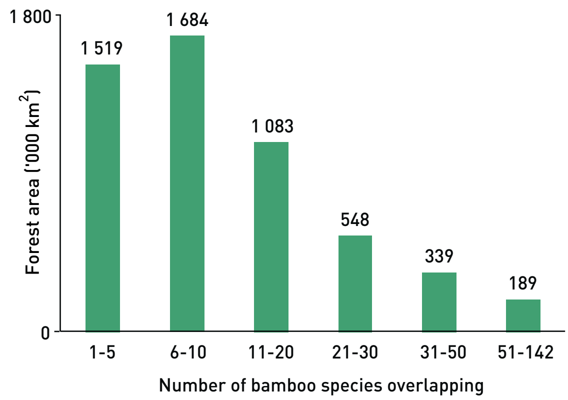


Figure 4. Total area of the Asia-Pacific region covered by forest in each potential bamboo species richness class. The classes refer to the number of species whose distributions overlap in each 1 km^2 cell of the ArcView grid.

SIGNIFICANCE OF THE RESULTS

This study served principally as a pilot study to assess the value of the technique and identify gaps in current knowledge. It was not intended to produce finalized distribution maps or to allow detailed or definitive conclusions to be drawn on the conservation status of individual bamboo species. However, it does contribute to an understanding of where bamboo is most likely to be a significant component of forest biodiversity, and suggests that certain species may be highly vulnerable because of their limited distributions (as currently known) and the restricted availability of forest habitat within their distribution range. In conjunction with knowledge of deforestation and practicalities of implementing biodiversity and conservation activities, the results constitute a useful planning tool.

One of the major achievements of this study is the development of an approach that makes it possible to generalize, combine and visualize information about distribution of individual species. Compared with the dot maps commonly used to record potential occurrence of species, the resulting distribution polygons provide better possibilities for analysis of patterns, threats and potential management options. This approach can also help to analyse and compare data, and to detect inconsistencies among datasets.

The results on species distributions and diversity patterns should be regarded as a first approximation of the possible regional distribution of bamboo species and genera in natural forests of the Asia-Pacific region. They reflect the present level of compiled knowledge about taxonomy and distribution of the subfamily Bambusoideae in the Asia-Pacific region (Ohrnberger 1999) and are subject to its limitations. The rather sharp differences in species richness levels on opposite sides of national boundaries (Figure 3) reflect the great variation in standards of biodiversity knowledge and taxonomic approach in different countries. To improve the situation, collaborative international biodiversity research and conservation programmes should replace fragmentary national studies, which often yield contradictory results across national boundaries.

The regional synthesis maps of species and generic richness (Figures 2 and 3) support the existing theories of bamboo species distribution (Ohrnberger 1999), in which the highest diversity of Asian woody bamboos is attributed to the monsoon belt of Southeast Asia and southern China. The highest overall diversity of Asian bamboos is seen in southern China (Guangxi, Guangdong and Hainan), but relatively high levels of deforestation there may mean that some species do not, in fact, persist in forest areas where they could potentially occur. The importance of bamboos persisting in cultivated landscapes is therefore increased. Myanmar and Borneo also have relatively high levels of bamboo diversity as well as more substantial areas of remaining forest (Figure 3).

Bamboos have not yet been the subject of detailed biogeographical studies, but it has often been assumed that areas that have high current diversity represent ancestral homes of woody bamboos (Wen 1983; 1985). In fact,

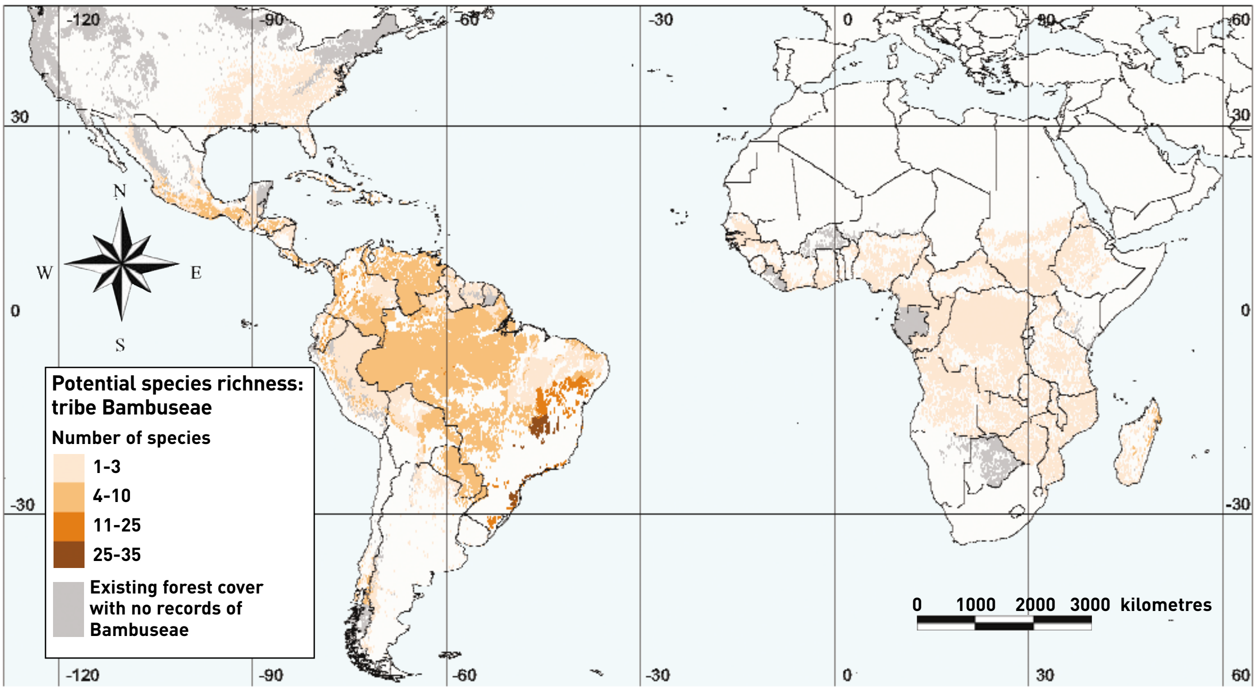


Figure 5. Map of potential bamboo species richness in Africa and the Americas, derived by integrating 370 individual species maps.

however, bamboos may not have existed in these areas for any great length of time. The current global distribution of woody bamboos (Figures 3 and 5), with a second important, though less rich, centre of bamboo biodiversity in South America (Bystriakova et al. 2002a), suggests that early ancestors of woody bamboos evolved in Gondwanaland in the southern hemisphere in post-Cretaceous times. High biodiversity in southern China may only reflect relatively recent diversification there, unless woody bamboos have evolved more than once in separate, unrelated lineages. Such considerations are currently under investigation.

Many of the individual species maps (Annex IV) show very restricted potential ranges. A similar preponderance of very small ranges has been found in South America (Clark 2001), where Andean woody bamboos were shown to have nearly four times the endemicity of other grasses. Possible reasons for this include scarcity of effective dispersal mechanisms, isolation of populations in often dissected, mountainous terrain and, for many species, relatively recent radiation into new habitats following tectonic and orogenic activity.

The results of this study can also be used to identify areas of high forest bamboo biodiversity where deforestation may be threatening many bamboo species. Of particular concern are those areas where biodiversity, deforestation and taxonomic uncertainties are highest. Myanmar is unfortunately a case in point, despite the high dependence upon bamboo in its rural economy and culture, and its rich forest biodiversity. Northeast India is another such area – biodiversity is high (although bamboo taxonomy still has substantial shortcomings), and recent intense deforestation has prompted a total ban on tree felling that may have intensified pressure on non-tree species such as bamboos. China evidently has the highest bamboo biodiversity levels, as well as a high degree of deforestation and degradation of habitats, but conservation is now seen as a priority, political stability makes interventions feasible, and taxonomic studies are progressing. Areas such as the Upper Yangtze watershed are receiving more protection, primarily for downstream flood limitation purposes.

The data produced in this study give an indication of the maximum possible forest habitat remaining for each bamboo species. This corresponds approximately to “extent of occurrence”, one of the criteria used by IUCN–The World Conservation Union to identify species that are endangered or threatened with extinction (IUCN 2001). Among the woody bamboos of the Asia-Pacific region, many species appear to have very small areas of remaining habitat (Figure 6), giving a very heavily skewed, almost exponential frequency distribution of remaining habitat area among species. Nearly 450 species (Annex V) have within their ranges less than the 20 000 km^2 of remaining forest habitat that would correspond to the threshold extent of occurrence used by

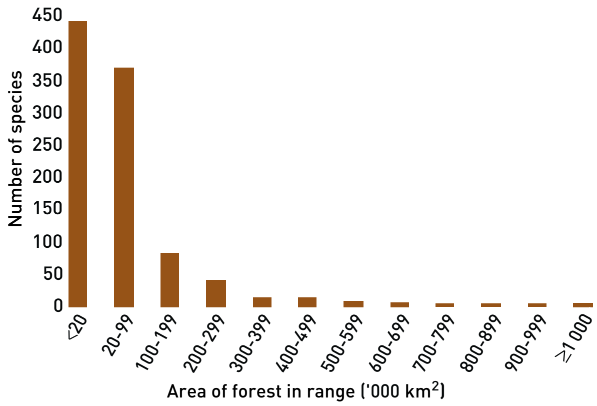


Figure 6. Numbers of bamboo species in the Asia-Pacific region according to the area of forest habitat remaining within their ranges.

IUCN as a criterion for inclusion in the *Red List* (IUCN 2001). This suggests that many uncultivated forest bamboos may be particularly susceptible to erosion of their habitat and their genetic diversity, and therefore may need to be considered threatened.

The remaining forest habitat extents for species currently on the *IUCN Red List* (Figure 7) are very similarly distributed to those of all bamboo species (Figure 6). This is counter to the expectation that a subset of highly threatened species would have a substantially higher proportion with severely limited remaining habitat area. The pattern is heavily influenced by *Chimonobambusa quadrangularis* (Map 20, Annex IV) and *Brachystachyum densiflorum* (Map 17), which have relatively wide distributions. Indeed, *Chimonobambusa quadrangularis* is considered an invasive weed in Hawaii and other areas where it has been introduced. These contrasts highlight the need for a better understanding of bamboo distributions and conservation

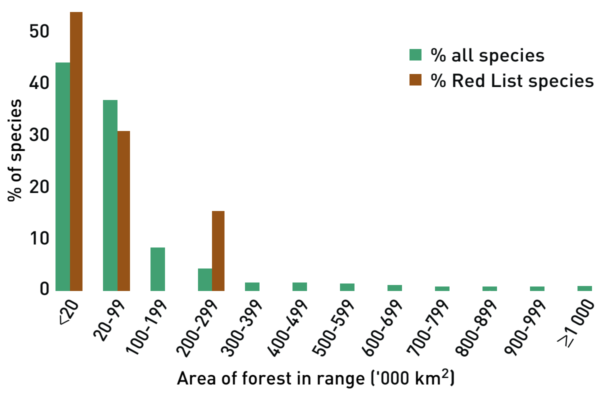


Figure 7. Frequency distribution of all species and species listed as threatened by IUCN (1998) according to the area of forest cover remaining within their ranges.

status. All the currently included *Red List* bamboos require verification of their claim to specific status, possible synonymy with other bamboos, distribution and conservation status. Bamboos with restricted remaining habitat as shown by this study should be prioritized in future processes to evaluate and address bamboo conservation needs. There is also substantial scope for refining the assessment of available habitat size by including data such as climatic and soil tolerances, where these are available for particular species.

Thus, the results of this study can both contribute to an understanding of where bamboo is most likely to be a significant component of forest biodiversity, and help to identify which species are most likely to be at risk. For threatened bamboo species, protection of their natural populations *in situ* is apparently the only feasible conservation technique at present, as *ex-situ* conservation techniques are currently not practical for bamboos (Stapleton and Rao 1996). Bamboo seed is infrequently produced and has poor viability, and plantations are difficult to raise and protect on a large enough scale. Therefore, areas where high bamboo richness and species potentially at risk coincide should be among the highest priorities for action to secure the persistence of wild populations of bamboo and improve the knowledge base for their conservation and management. Forests of Hainan Island and the Upper Yangtze are among the areas where bamboo conservation activities are required, practicable and likely to be successful.

As well as providing information from which to plan conservation strategies, the data and maps produced by this study may also constitute a first step in quantifying national, regional and global forest bamboo resources more effectively. Such quantification is important both for managing those resources and for adequately assessing the importance of forests in terms of their provision of non-timber forest products and attendant social and economic benefits. However, at present the field-based abundance information that would be necessary to build on this initial step is almost universally lacking. The mechanisms for gathering and compiling such information require improvement.

FAO (2001) and a number of forest-related international processes have stressed the importance of improving national forest resource assessments and the ways they address non-timber products and values of forests. Improving capacity to analyse and use forest resource information, as well as to share it internationally, has also been identified as a priority. Actively pursuing the incorporation of bamboos into national forest inventory activities may be the only realistic way of improving the available information on them. Forestry personnel responsible for implementing any inventories related to

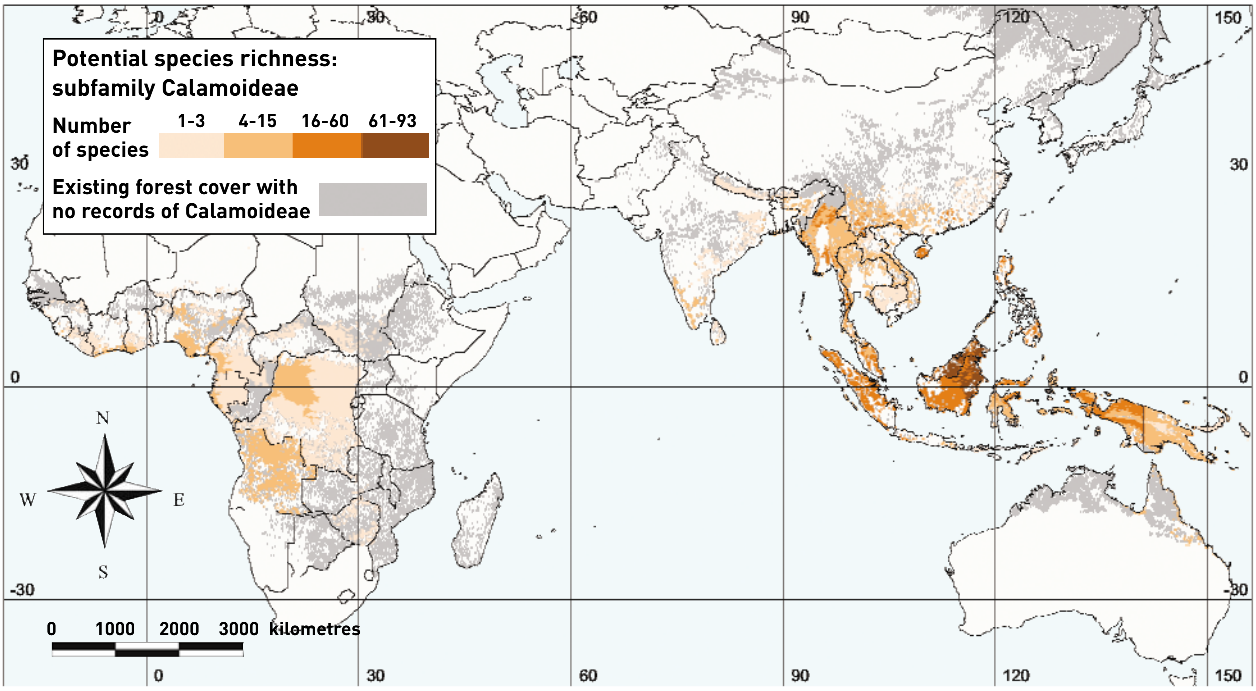


Figure 8. Global distribution of potential rattan species richness, based on maps of more than 600 species (Bystriakova et al. 2002b).

bamboos would need back-up information on bamboo identification as well as special training.

The methodology developed in the study could be successfully applied to develop information to support management of other species including non-timber forest products. For example, Bystriakova et al. (2002b) used a similar approach to map distributions of nearly 600 species of rattan (subfamily Calamoideae) within natural forests in Africa and the Asia-Pacific region (Figure 8). This effort showed that the greatest potential species richness of rattans (perhaps as many as 90 species per km^2) is concentrated in forests of Sarawak, Malaysia, with other areas of high potential richness in northern and eastern Borneo (Sabah and Kalimantan). The contrast between these results and those for bamboo highlights the importance of developing policy, planning and management strategies targeted at individual groups based on appropriate specialized information sources.

CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

This study makes clear that information on distribution, abundance and conservation status of bamboo resources is far from complete. Significant effort is still required to assemble an adequate information base as a foundation for policy and management decisions affecting bamboo and to ensure the survival of their full biological diversity. Future efforts should include:

1. Verifying the taxonomic and conservation status of current *Red List* species.

2. Verifying the taxonomic and conservation status of species with the smallest estimated geographical ranges and remaining habitat.

3. Filling information gaps, such as taxonomic inconsistencies and inadequate knowledge of the distribution of woody bamboo species, through both national capacity building and international collaboration.

4. Developing appropriate methods for assessing bamboo resources and the pressures on them and incorporating these methods into NTFP elements of national forest inventories.

5. Assessing the value of existing reserves and reserve networks (especially those in China) for conserving the biological diversity of bamboos.

6. Refining the assessment of available habitat size by including climatic and soil data and applying these approaches for other groups of conservation concern and/or providing NTFPs.

References

Ades, G. 1999. Important discovery of lesser bamboo bat roosting site in Hong Kong. *Porcupine!* 19: 22. (http://www.hku.hk/ecology/porcupine/por19/mammal.htm#mammal3)

Banik, R.L. 1995. In: Rao, V.R., Rao, A.N. (eds) *Bamboo and Rattan Genetic Resources and Use.* INBAR and IPGRI, Beijing and Rome.

BirdLife International. 2000. *Threatened Birds of the World.* Lynx Edicions and BirdLife International, Barcelona and Cambridge.

Biswas, S. 1995. Diversity and genetic resource of Indian bamboos and the strategies for their conservation. In: Rao, V.R., Rao, A.N. (eds). *Bamboo and Rattan Genetic Resources and Use.* Proceedings of the first INBAR Biodiversity, Genetic Resources and Conservation Working Group: 29-34. IPGRI, Rome.

Bystriakova, N., Kapos, V., Lysenko, I. 2002a. *Potential Distribution of Woody Bamboos in Africa and America.* INBAR Working Paper No 43. International Network for Bamboo and Rattan, Beijing.

Bystriakova, N., Dransfield, J., Kapos, V., Lysenko, I. 2002b. *Potential Distribution of Rattans in Asia-Pacific and Africa.* INBAR Working paper No 41. International Network for Bamboo and Rattan, Beijing.

Bystriakova, N., Kapos, V., Lysenko, I., Stapleton, C. 2003. Distribution and conservation status of forest bamboo biodiversity in the Asia-Pacific Region. *Biodiversity and Conservation.* In press.

Clark, L.G. 2001. Diversification and endemism in Andean woody bamboos (Poaceae: Bambusoideae). *Bamboo Science & Culture, J. Amer. Bamboo Soc.* 15: 14-19.

Dransfield, S., Widjaja, E.A. (eds). 1995. *Plant Resources of South-East Asia No 7. Bamboos.* Backhuys Publishers, Leiden.

FAO. 1998. *Asia-Pacific Forestry Towards 2010.* Report of the Asia-Pacific Forestry Sector: Outlook Study. Food and Agriculture Organization of the United Nations, Rome.

FAO. 2001. *Global Forest Resources Assessment 2000: Main Report.* FAO Forestry Paper 140. Food and Agriculture Organization of the United Nations, Rome.

Feng Lu. 2001. *China's Bamboo Product Trade: Performance and Prospects.* INBAR Working Paper No 33. International Network for Bamboo and Rattan, Beijing.

Gillet, H., Walter, K. 1998. *1997 IUCN Red List of Threatened Plants.* IUCN–The World Conservation Union, Gland, Switzerland.

Grass Phylogeny Working Group. 2001. Phylogeny and subfamilial classification of the grasses (Poaceae). *Annals of the Missouri Botanical Garden* 88: 373-457.

Hunter, I.R., Wu Junqi. 2002. *Bamboo Biomass.* INBAR Working Paper No 36. International Network for Bamboo and Rattan, Beijing.

INBAR. 1999. *Socio-economic Issues and Constraints in the Bamboo and Rattan Sectors: INBAR's Assessment.* INBAR Working Paper No 23. International Network for Bamboo and Rattan, Beijing.

Iremonger, S., Ravilious, C., Quinton, T. (eds) 1997. *A Global Overview of Forest Conservation. Including: GIS Files of Forests and Protected Areas, Version 2.* CD-ROM. CIFOR and WCMC, Bogor and Cambridge, UK.

IUCN. 2001. *IUCN Red List Categories and Criteria: Version 3.1.* IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK.

Linnaeus, C. 1753. *Species Plantarum,* ed. 1. Stockholm.

Ohrnberger, D. 1999. *The Bamboos of the World: Annotated Nomenclature and Literature of the Species and the Higher and Lower Taxa.* Elsevier, Amsterdam.

Rao, A.N., Rao, V.R., Williams J.T. (eds). 1998. *Priority Species of Bamboo and Rattan.* IPGRI-APO, Serdang, Malaysia.

Srivastava, U.C. 2001. Conservation of endangered plant genetic resources of economic importance in India. *J. Econ. Taxon. Bot.* 25: 501-508.

Stapleton, C.M.A., Rao, V.R. 1996. Progress and prospects in genetic diversity studies on bamboo and its conservation. In: *Bamboo, People & the Environment* 2: 23-44. Proceedings of the IVth International Bamboo Congress, Bali, May 1995. IDRC, Ottawa.

Subramanian, K.N. 1995. In: Ramanatha Rao, V., Rao, A.N. (eds) *Bamboo and Rattan Genetic Resources and Use.* INBAR and IPGRI, Beijing and Rome.

UNEP-WCMC. 2000. *Global Distribution of Current Forest Cover* (http://www.unep-wcmc.org/forest/global_map.htm). UNEP World Conservation Monitoring Centre, Cambridge.

Vantomme, P., Markkula, A. and Leslie, R.N. (eds) 2002. *Non-wood Forest Products in 15 Countries of Tropical Asia: An Overview.* Food and Agriculture Organization of the United Nations, Rome.

Wen, T.H. 1983. Some ideas about the origin of bamboos. *J. Bamboo Res.* 2(1): 1-10.

Wen, T.H. 1985. Some ideas about the origin of bamboos. *J. Amer. Bamboo Soc.* 6: 104-111.

Williams, J.T. 1998. Bamboo and rattan research. In: Rao, A.N., Rao, V.R., Williams, J.T. (eds). *Priority Species of Bamboo and Rattan:* 3-5. IPGRI-APO, Serdang, Malaysia.

Williams, J.T., Rao, V.R. (eds) 1994. *Priority Species of Bamboo and Rattan.* INBAR Technical Report No 1. INBAR and IBPGR, New Delhi.

Annex I: Priority species of bamboo

Priority bamboos

Twenty taxa of bamboos are accorded high priority for international action:

Bambusa balcooa Roxb.
B. bambos (L.) Voss
B. blumeana J A and J H Schultes
B. polymorpha Munro
B. textilis McClure
B. tulda Roxb.
B. vulgaris Schrad. ex Wendl
Cephalostachyum pergracile Munro
Dendrocalamus asper (Schultes f.) Backer ex Heyne
D. giganteus Wallich ex Munro
D. latiflorus Munro
D. strictus (Roxb.) Nees
Gigantochloa apus J A and J H Schultes
G. levis (Blanco) Merrill
G. pseudoarundinacea (Steud.) Widjaja
Guadua angustifolia Kunth
Melocanna baccifera (Roxb.) Kurz
Ochlanrda Thw. (spp.)
Phyllostachys pubescens [1] Mazel ex H. de Leh (including *P. bambusoides* Sieb. and Zucc and *P. edulis* Makino)
Thyrsostachys siamensis (Kurz) Gamble

Additional species

A further 18 taxa are noted to be important:

Arundinaria spp.
Bambusa atra Lindl.
B. heterostachya (Munro) Holtum
B. nutans Wall. ex Munro
B. oldhamii Munro
B. pervariabilis McClure
Lingnania chungii [2] McClure
Dendrocalamus brandisii (Munro) Kurz
D. hamiltonii Nees
D. hookeri Munro
D. membranaceus Munro
Gigantochloa albociliata [3] (Munro) Kurz
G. atroviolacea Widjaja
G. balui Wong
G. hasskarliana (Kurz) Back. ex Heyne
Oxytenanthera spp. Munro
Phyllostachys glauca McClure
Schizostachyum spp. Nees

Source: Rao et al. 1998

Note: accepted names (as in Ohrnberger, 1999): (1) *Phyllostachys edulis*; (2) *Bambusa chungii*; (3) *Pseudoxytenanthera albociliata*

Annex II: Bamboo species on the *1997 IUCN Red List of Threatened Plants*

Species name as in the IUCN database	Species name as in Ohrnberger 1999	IUCN status
Arundinaria baviensis	*Yushania baviensis*	Rare
Teinostachyum beddomei	*Teinostachyum beddomei*	Indeterminate
Dinochloa dielsiana	*Dinochloa dielsiana*	Indeterminate
Semiarundinaria pantlingii	*Yushania pantlingii*	Rare
Ochlandra ebracteata	*Ochlandra ebracteata*	Rare
Arundinaria densiflora	*Brachystachyum densiflorum*	Indeterminate
Brachystachyum densiflorum	*Brachystachyum densiflorum*	Rare
Phyllostachys assamica	*Phyllostachys manii*	Indeterminate
Ochlandra sivagiriana	*Ochlandra sivagiriana*	Rare
Dinochloa palawanense	*Dinochloa palawanensis*	Indeterminate
Ochlandra setigera	*Ochlandra setigera*	Rare
Arundinaria vicinia	*Fargesia vicina*	Rare
Chimonobambusa quadrangularis	*Chimonobambusa quadrangularis*	Vulnerable
Cephalostachyum capitatum Munro var. *decomposita*	*Cephalostachyum capitatum Munro* var. *decompositum*	Rare
Sasa borealis var. chiisanensis	n/a	Rare
Thamnocalamus tessellatus	*Thamnocalamus tessellatus*	Rare

Source: Gillet and Walter 1998

Annex III: Subtribes and genera of woody bamboos occurring naturally in Asia

Subtribe	Genera
Arundinariinae	*Arundinaria, Acidosasa, Bashania, Ferrocalamus, Gelidocalamus, Indocalamus, Metasasa, Oligostachyum, Pleioblastus, Sasa, Sasaella, Vietnamocalamus, Pseudosasa*
Thamnocalaminae	*Ampelocalamus, Borinda, Chimonocalamus, Drepanostachyum, Fargesia, Himalayacalamus, Thamnocalamus, Yushania*
Racemobambosinae	*Neomicrocalamus, Racemobambos, Vietnamosasa*
Shibataeinae	*Brachystachyum, Chimonobambusa, Hibanobambusa, Indosasa, Phyllostachys, Semiarundinaria, Shibataea, Sinobambusa*
Bambusinae	*Bambusa, Bonia, Dendrocalamus, Dinochloa, Gigantochloa, Holttumochloa, Kinabaluchloa, Klemachloa, Maclurochloa, Melocalamus, Pseudobambusa, Pseudoxytenanthera, Sinocalamus, Soejatmia, Sphaerobambos, Thyrsostachys*
Melocanninae	*Cephalostachyum, Davidsea, Dendrochloa, Melocanna, Neohouzeaua, Ochlandra, Pseudostachyum, Schizostachyum, Teinostachyum*
Hickeliinae	*Hickelia, Nastus, Temburongia*