

## GIANT PANDA CONSERVATION AND BAMBOO FOREST DESTRUCTION

Julian J.N. Campbell  
School of Biological Sciences  
University of Kentucky  
Lexington, Kentucky 40506, U.S.A.

### ABSTRACT

The mountains around Sichuan contain richer biological diversity than any other temperate region. But in recent centuries, human exploitation has accelerated up from subtropical lowlands, removing most temperate forest. Disturbance is generally excessive for larger mammals of subtropical-warm temperate zones, and now there are threats to those of cool temperate-subalpine zones. The cool temperate zone is wettest, favoring extensive bamboo within the forest. Bamboo is virtually the only food of giant pandas, and this species' range has been reduced by roughly half in the past century. Though much cool zone bamboo remains, patches of larger warm zone bamboos may be needed as well for seasonal use and long-term dynamics. In the past decade at least, decline of giant pandas has been precipitated by periods of bamboo flowering and mortality. Monocarpic life-cycles are a natural feature of bamboos, and flowering may be somewhat synchronous with dry climatic periods. Deforestation has reduced the diversity of alternative bamboos available for emergency use after such events. To resolve the many problems concerned with nature conservation in these mountains - taxonomic, demographic, ecosystematic and socioeconomic - much more interdisciplinary and international cooperation will be needed. There may be hope that recent centralization of planning in China can extend better land-use to the provinces, and that communication problems with western conservationists can be overcome.

### 1. INTRODUCTION

This report summarizes some ecological background, with a botanical emphasis, for the World Wildlife Fund Giant Panda Project. It is an introduction to my field work of 1982 and subsequent literature review [1]. My work was restricted to part of the Wolong Man-And-Biosphere Reserve in Sichuan, China (Figure 1a). I am particularly grateful to G.B. Schaller [2], Z.S. Qin [3], J.C. Hu [4], J. Zhu [5], M.H. Wang [6], Y.C. Yong [7], R.L. Yang [8], J. Seidensticker [9], T.P. Yi [10], W.P. Fang [11], T. Dudley [12] and others for providing further recent details from this reserve and other natural areas around the Sichuan Basin (some unpublished). My full current draft report [1] has three aims: to review all available information on the temperate-subalpine forests of Sichuan and parts of adjacent provinces (Figure 1a); to summarize preliminary results of plant ecological work in the Wolong Reserve; and to discuss future research and conservation plans in the region, with emphasis on its symbolic endangered species, the giant panda (*Ailuropoda melanoleuca*). I hope to work this draft into book format eventually, incorporating details of climatic data, flora and vegetation, bamboo taxonomy and ecology. Bamboo

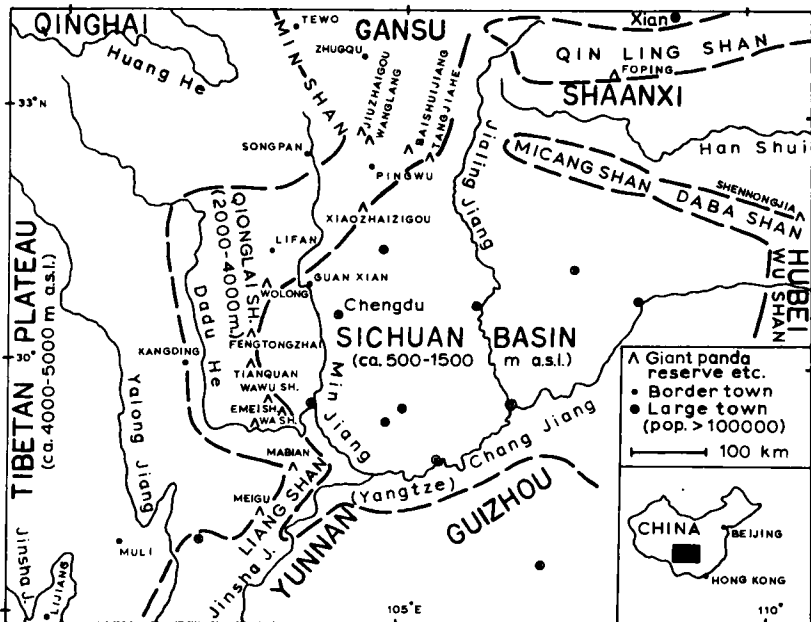


Figure 1a. The Sichuan region referred to in text; general topography and place names (based on [82,87] etc.).

forms over 99% of the normal giant panda diet [2], and its study has been accelerated due to the recent mass-flowering that has led to serious shortages of food. But the taxonomy is still unclear, even at the genus level, while life-cycle periods and environmental relationships of individual species remain virtually unknown.

## 2. NATURAL HISTORY OF THE FORESTS

Botanical exploration of this region by foreigners occurred during 1869-1948, with concentration in 1880-1922 [13,14]. E.H. Wilson [15,16] provided the basic evidence that woody plant diversity here is exceptionally high, and that work was soon followed by similar zoological (e.g. cited in [9]) and anthropological evidence (e.g. [17,18]). Chinese botanists worked intensively after 1920 (e.g. [19-21]), but foreign interaction dwindled. The renewed contact since the 1970's (e.g. [12]) will improve understanding of type collections, species-complexes and evolutionary processes.

About thirty temperate-subalpine woody genera are endemic to the broad Sino-Himalayan region centered on Sichuan, or disjunct on mountains further east in Asia or eastern North America. Some seven of these genera (*Tetracentron*, *Cercidiphyllum*, *Euptelea*, *Eucommia*, *Rhoiptelea*, *Bretschneidera*, *Davidia*) are usually placed in monotypic families, whereas no more than three monotypic families occur in other temperate-subalpine regions of comparable extent. The total number of genera (ca. 260) is roughly 50% greater than in most other regions, and the number of species (ca. 1300-1500) is roughly 100% greater (excluding subshrubs; based on [16] etc. [1]). This endemic diversity raises

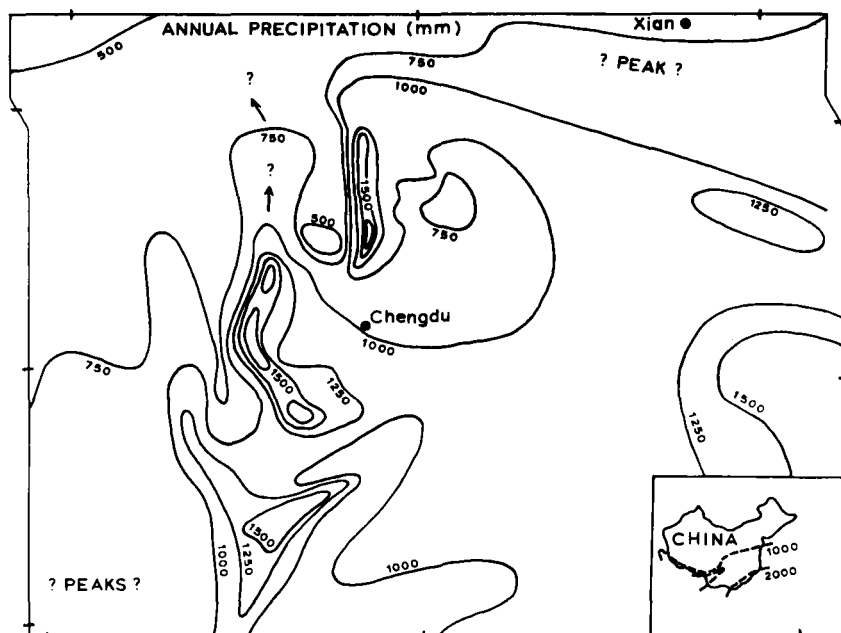


Figure 1b. Annual precipitation, largely based on the most detailed available source [22]. Considerable differences exist on other maps (e.g. [19,44,50,88,89]). Peaks may be underestimated due to absence of stations at high altitude in the most rainy zones.

fundamental questions about the influences of natural and human factors. In particular, can it be attributed to special environmental conditions within the region, or to dispersal barriers that may be overcome by artificial introductions?

Much of the special biotic character here may be attributed to precipitation patterns. Annual totals are not exceptionally high (Figure 1b), but 70-90% falls with little interruption during the 4-6 month warmest season [22-26]. Such temperate monsoonal climate is less pronounced elsewhere in East Asia, except perhaps in a narrow zone along the eastern Himalayas, and on the less extensive mountains along the Pacific coast. Low moisture stress here is probably the major cause of such features as the rarity of trees with ring-porous wood (cf. [27-29]) and the presence of vessel-less *Tetracentron*, the abundance of bamboos and pandas, epiphytes and leeches, etc. However, between the warm disturbed Sichuan Basin and the cold dry Tibetan Plateau, the zone with sufficient annual precipitation for bamboo, at least 900 mm, is only about 100 km wide (Figure 1b,c). This monsoonal precipitation, and other special aspects of climate and physiography (e.g. [30-32]), are linked with the extreme height and youth of these mountains, which form an abrupt transition from subtropical to alpine conditions.

In comparison with climatic factors, dispersal barriers may not be important for endemism of whole genera in this region around Sichuan. Most endemic woody genera do not appear to be relictual from widespread global distributions in the Tertiary era (with *Metasequoia* the major exception), though some probably

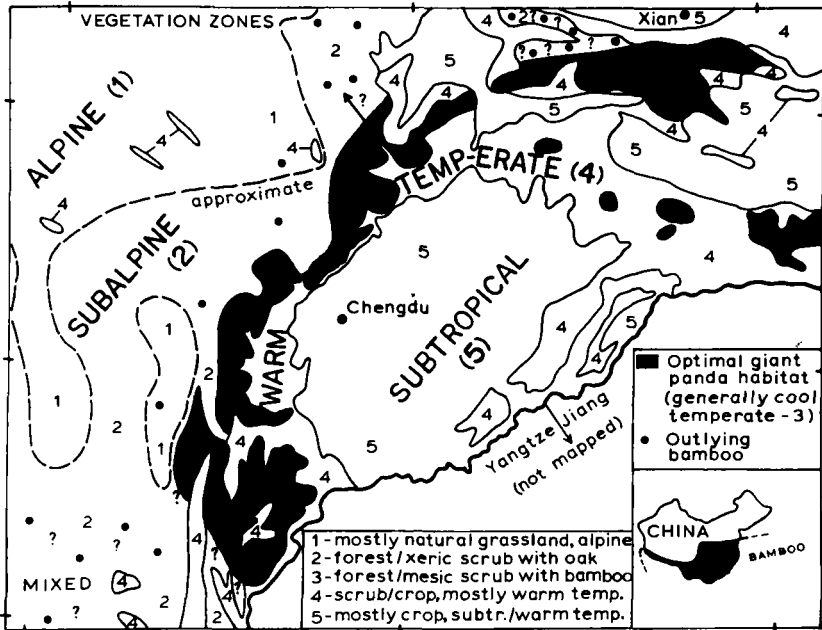


Figure 1c. Major vegetation zones based on recent maps [44,55] and miscellaneous bamboo reports [1]. The mixed scrub-crop zone is largely the difference in limit of cropland in these two major sources, the latter putting it further into montane zones (detailed for Wolong in [1]).

had wider distributions still centered in East Asia (e.g. [33-36]), like the pandas (cf. Figure 1d). However, the large numbers of endemic species within genera of cooler zones may be attributed to recent allopatric speciation due to dispersal barriers between different mountain ranges within the region (e.g. [37-40]). With this subregional endemism, the total number of temperate-subalpine woody species in surveyed areas of a few thousand square km averages only about 30-50% more than the east North American maximum (e.g. Great Smoky Mts., data and sources tabulated in [1]). Similar differences exist in 0.05-0.1 ha plots at Wolong. There may be little or no difference in the number of dominant tree species at such small scales.

There are several available descriptions of forest distribution patterns by early foreign and Chinese botanists (e.g. [15,19,37,41-43]), and there is an important recent synthesis in Chinese [44]. However, quantitative studies are only just beginning (e.g. [1] and cited therein). The general altitudinal zonation of original forests is from subtropical evergreen broadleaf at ca. 500-1250 m, to warm temperate mixed deciduous-evergreen broadleaf at ca. 1250-2000 m, to cool temperate mixed deciduous broadleaf-conifer at ca. 2000-2750 m, to subalpine conifer at ca. 2750-3500 m. Alpine scrub and grassland occur at ca. 3000-5000 m (cf. Figure 1c). There is much interdigitation of these physiognomic formations related to climatic, topographic, edaphic and biotic factors that have some independence from the general thermal zonation [1]. The peak annual precipitation of 1500-2000 mm or more in the cool temperate-subalpine transition (Figure 1b) is probably a major factor controlling some plant distri-

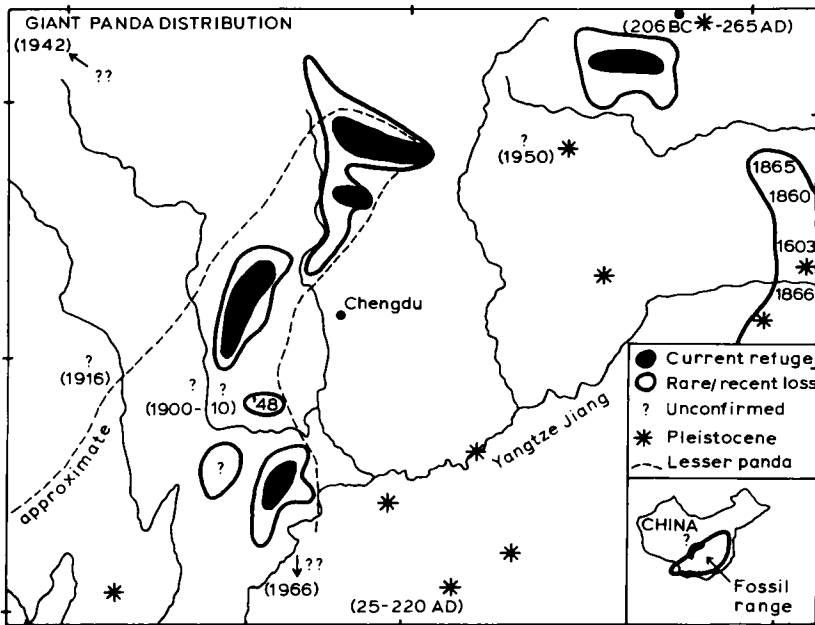


Figure 1d. Panda distribution (based on [5,90,91] etc.).

butions. Bamboo is most widespread in the forests of this zone (Figure 1c). Comparison with forests of eastern North America further emphasizes the special environment of humid East Asian mountains. Endemic Asian tree genera at Wolong are concentrated on warm moist sites, while genera absent from Wolong are concentrated on warm dry sites within the Great Smoky Mountains (detailed in [1]; see also [45]). Another difference is that the mean annual temperatures of formation boundaries are about 2-3 degrees C lower at Wolong, presumably due to a lower incidence of erratic frosts (see also [31,46] etc.).

### 3. DEFORESTATION AND ECOSYSTEM PROBLEMS

Most subtropical forest in the Sichuan region may have been cleared for rice-dominated agriculture about 0-1000 A.D. (e.g. [47-50]). There is virtually none left, though as much as 10% of this zone has scrubby forest and plantation (Figures 1-2). After 1500 A.D., the human population accelerated to double approximately each century (Figure 3 [18]). Warm temperate forest may have been largely removed about 1600-1900 (e.g. [12,40,51]), with spread of rice cultivation, and with introduction of maize in 1820-60 [50,52], which rapidly surpassed buckwheat and wheat in more humid areas. Probably no more than 10% of this forest survives. Cool temperate forest was greatly disturbed after 1870-1920, with increase in logging for export to lowlands, and with introduction of potatoes, which supplemented meagre cultivation of oats and wheat (e.g. [15,49, 53]). Perhaps 20-40% of this forest survives. Subalpine forest was largely undisturbed before the 1920's, except in drier marginal areas, but since then about 1-2% of the original forest area has been removed each year, and little more than half remains today (e.g. [41,44,50,54-56]). The most detailed evidence for the current state of deforestation is the recent map produced by the Chengdu

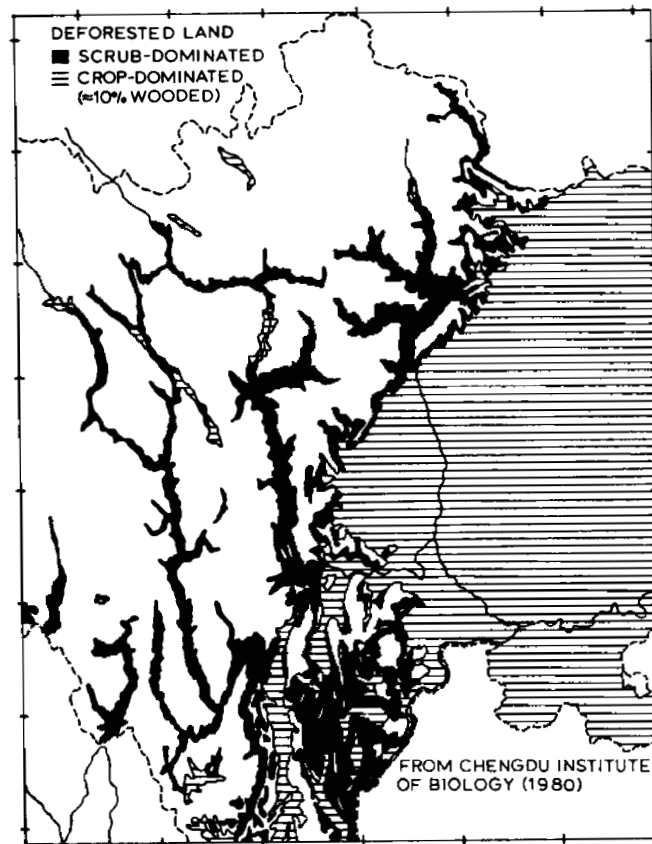
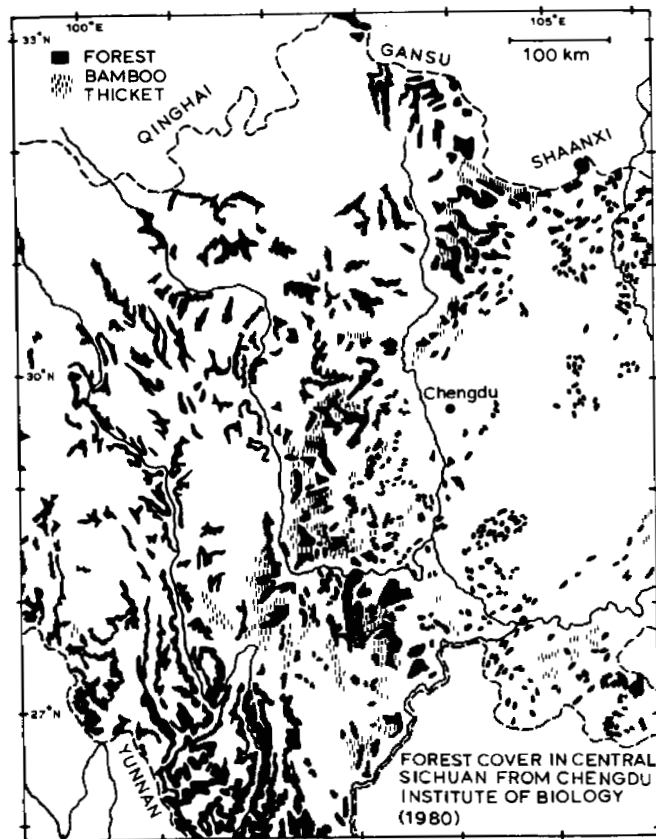


Figure 2. Forested and deforested land in central Sichuan (from [44]). Note that there is some uncertainty about the exact definition of "forest" and the natural state of some subalpine and xeric scrub types, but these have been estimated from general impressions of the literature and detailed comparisons at Wolong (see text and [1]).

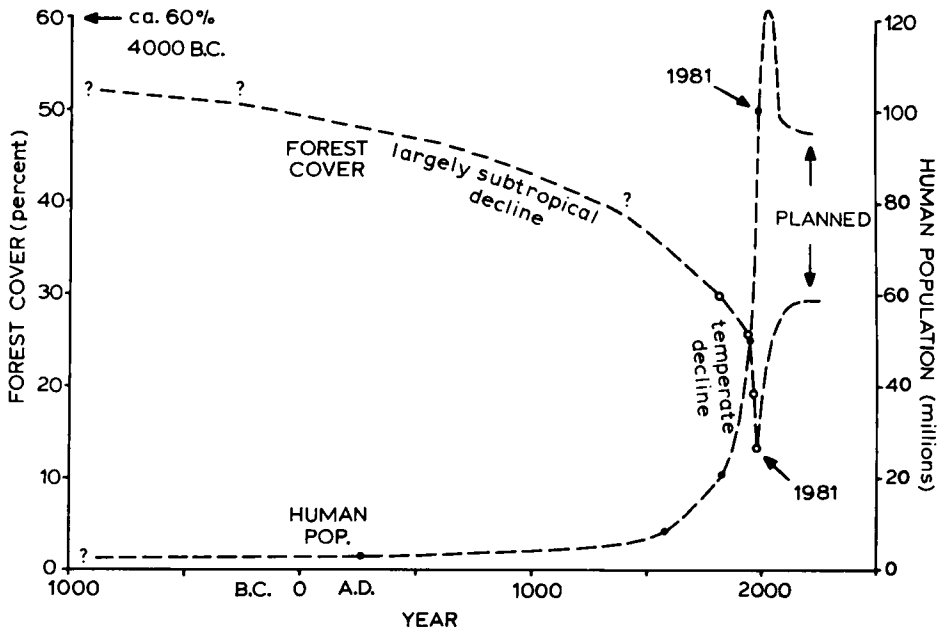


Figure 3. General historical trends of human population and forest cover in Sichuan as suggested by available information (quantitative from [18,50,56] etc., remaining guesswork from miscellaneous sources - see text and [1]).

Institute of Biology [44], as redrawn in a simplified form here (Figure 2). The definition of "forest" in that source is unclear, but it probably excludes vegetation that has had less than ca. 20-30 years to recover from clearance, in contrast to some other sources (cf. [55-56], discussed in [1,57]).

Recent deforestation has been concentrated in the Min Jiang watershed and in adjacent Gansu Province to the north. Logged land appears to have had negligible management for timber production, being largely converted, after fuel-wood collection and burning, to pasture and marginal crops (see also [57]). Most current reserves are in relatively inaccessible mountains (Figure 1a), where logging for export was delayed until after the 1950's [1-12]. These areas did not receive full official protection until the 1970's, except perhaps Wanglang. Only in the Da Liang Shan reserves to the southwest does extensive warm temperate forest survive. In the Min Shan to the northwest, there may be no warm temperate forest left, due to the combination of human disturbance and drier climate at lower altitudes.

The history of disturbance in the Wolong Reserve area can be tentatively traced from miscellaneous records. There was probably no significant export of timber before 1442 A.D., when the Wassu Principality was established here by the lowland administration [58]. However lamaist Giarong tribal people lived here and cultivated a little bottomland. In about 1775, the administration extended power over other tribal areas further north and west, and a trade route through Wolong became frequently used (perhaps initially for gold [15]). In the Muping

Principality to the southwest, logging for export and cultivation of maize began in 1820-60, with some stimulus by Catholic missionaries [52]. (The first giant panda obtained by a foreigner was here, by David; now this area is the Fengtong-zhai Reserve - Figure 1a.) In the central Pitiao He valley of the Wolong Reserve, the first foreign reports, early in this century [15,58-60], indicated that export had begun about 1900 on a small scale and in marginal zones. Large-scale industrial export could not have begun until the road was built, in the 1940's or 1950's [21]. A "timber industry area" was set up at the center of the reserve in 1965-75, but some management for conservation also began in 1963-65, and in about 1976 logging was officially halted due to concerns for giant panda survival [4-6]. In 1982, I saw no evidence of continued logging for export, except perhaps for a short final burst in marginal areas before a tightening of regulations at that time. However, timber-poaching by local people was obviously continuing, and massive tree-planting efforts since the 1970's were failing in many areas, largely due to grazing by domestic goats. While most subalpine forest remained, the degree of clearance in temperate zones was similar to the provincial average indicated above.

Forest ecology in the Sichuan region first developed as an organized discipline during the 1930's when logging had accelerated (e.g. [19,41-43]). There were several forest surveys then and some studies of tree growth. But ambitious reforestation and conservation programs formulated in the 1950's encountered difficulties due to political turmoil and lack of ecosystem planning (e.g. [57, 61]). Recently, there has been a resurgence of activity, with slopes over 10 degrees officially designated for forests and a goal to double cover in the next century (e.g. [62]). But there is no evidence that the general precipitous decline has been reserved yet. Broad problems that demand urgent attention by ecologists are hydrological degradation of ecosystems due to disturbance, including increased runoff and erosion together with reduced vegetation humidity and regeneration (e.g. [57,63]), and effects of disturbance on individual species, especially endangered ones. At the ecosystem level, much more interdisciplinary organization is required, but since the 1970's scientists and administrators have at least expressed clear ecological concern. For example, the Xinhua news agency reported in 1979 that "Logging, clearing of forests for cultivation, expansion of pastures and forest fires have so seriously upset the ecosystem balance in the Min Jiang basin in Sichuan that ecologists claim the Chengdu plain, home of at least 80 million people, faces desertification within a few decades, and the Yangtze could become a second Huang He" ([56] cited in [57]). At the individual species level, for example, the bamboos deserve much more taxonomic and ecological work, since they are dominant in the remaining forest understory, they interact with forest dynamics by temporary suppression of tree seedlings, and they provide food for many animals, including pandas [1].

#### 4. GIANT PANDA-BAMBOO FOREST INTERACTION

There are about 1000 (-2000?) giant pandas today, concentrated in remaining cool temperate-subalpine forest. Most bamboo in their range is not included in official reserves (Figures 1-2). Much bamboo inside and outside of reserves is excessively disturbed or isolated from true giant panda refuges. Some bamboo may remain after logging, increasing in density at sites where soil erosion is not too severe. But the widespread encroachment of farmland, beginning with wood-foraging by people and grazing by livestock, tends to eliminate bamboo eventually along with other forest plants. Moreover, giant pandas appear to prefer bamboo in association with large trees, which they use for scent-marking and resting sites [2]. Also, their restriction to small isolated areas must increase susceptibility to environmental fluctuations and problems of inbreeding.

There are about 10-15 bamboo species in the whole giant panda range, excluding subtropical-warm temperate species that are rarely available due to disturbance. There is much difference in species composition between the four major mountain ranges, and there is a general increase of diversity in warmer zones with a shift from Arundinariinae to Phyllostachyidinae (ongoing taxonomic synthesis by [1,10,64,65] etc.). At Wolong in 1982, above-ground bamboo biomass averaged about 5-10 tonnes/hectare (dry) at 2200-3000 m, where stands of *Arundinaria fangiana*, *Yushania chungii* and *Fargesia* aff. *spathacea* covered 30-90% of the ground. Away from this optimum, biomass declined abruptly to the upper bamboo limit at ca. 3400 m. It declined more gradually to 1 tonne/hectare or less at 1000-1500 m and below, though individual clumps of some larger species here may have at least 10 times more biomass per square m than the most widespread species higher up. Annual above-ground production of non-flowering bamboo at Wolong (data pooled with X.T. Zhang, Z.S. Qin et al.) averaged about 15-25% of biomass, as generally reported in other bamboo studies (cited in [1]). The annual population turnover of fully grown culms was a similar percentage of standing density. There was no significant difference between culm recruitment and mortality in all non-flowering plots combined, but there was much small-scale variation in the ratio of these rates (at ca. 1-2 square m) that had little relation to major gradients of forest composition or basal area [1]. This variation needs to be analyzed in relation to processes of clump expansion and decline.

At current giant panda densities of about 0.1-1 per square km of bamboo in the cool temperate-subalpine transition, their exclusive diet of bamboo culms and leaves amounts to only 0.1-2.0% of above-ground production [1-4]. But at certain seasons, especially in the spring, they often migrate to lower temperate zones and feed on the thicker young culm shoots of different bamboo species [1-9]. At Wolong in 1981-82, there was a definite shift by some adults from eating leafy culms of *Arundinaria* at 2600-3000 m in the winter, to eating culm shoots of *Fargesia* at 2200-2600 m in April-June. About 10-20% of these shoots were taken, and, after this production diminished and the shoots approached full height, the animals returned to the higher bamboo. In other reserves, seasonal descent may be as low as 800-1000 m, but at Wolong there is too much disturbance. This change in behavior may be an important requirement after the relatively poor winter diet and during the usual mating season of April-May [2]. In addition to having relatively high protein and available carbohydrate content (dry weight), these shoots have relatively low silica content, while silica tends to increase in old leaves remaining on plants until replaced in summer (see also [66] etc.). High silica content may reduce digestibility of old leafy material, though a different problem with young shoots is the high water content, which requires large bulk feeding rates [2]. Many other animals eat these shoots sometimes, and insect larvae destroyed about as many as giant pandas did at Wolong. The size and protein content of shoots is still higher in some species of warm temperate-subtropical zones. Moreover, in these warm zones some species produce shoots in August-October and others in April-May, whereas in cool zones shoots are mainly produced in April-June (or with a few to August in dwarf subalpine *A. fangiana* etc. [1-3,10,64]). But human activity has destroyed much of this lower bamboo or made it unavailable. If bamboo shoots are important for reproduction, one might speculate that the autumn oestrus behavior observed in some giant pandas is relictual from a time when they roamed into warmer zones, and eat large late-season shoots [67].

Most bamboos of the Sichuan region appear to be gregariously monocarpic [1-10]. Mass-flowering over many square km is generally followed by mortality and regeneration by seed, which may require about 10-15 years before biomass is recovered. At least 138 giant pandas starved due to mortality of *Fargesia* *spathacea* during 1975-76 in the southern Min Shan (Wanglang and Baishuijiang

Reserves etc., Figure 1a). Another major decline is currently feared due to flowering of Arundinaria fangiana during 1983 further south, including Wolong (and perhaps A. fargesii further east?), unless massive emergency measures are implemented.

Based on available records, mass-flowering by each species may last up to 10 years, sometimes with geographic or altitudinal shift across the range. Typical intervals between these events appear to vary from about 30 to 120 years, often with negligible flowering between. It is generally believed that intervals are fairly consistent within a bamboo species, but in this region no species' history has been clearly traced for more than two mass-flowerings. Different species have sometimes flowered together. Some 95% of all available records (counting individual herbarium specimens etc.) have been concentrated in 55% of the time since records began: during 1885-92, 1914-22, 1930-43, 1949-52, 1955-65 and 1973-83 [1]. In 1885-92, 1930-43 and 1973-83, more species were involved and a wider area was covered. These flowering periods have largely coincided with relatively dry climatic periods, which are reported to have cycles of roughly 20, 40 and 80 years in China [68-71]. (The only exception is the Phyllostachys flowering of 1955-65.) Such climatic cycles may have solar relationships (see also [72]). It is arguable that dry periods would be favorable times for sexual reproduction to occur in bamboos. As well as seed dispersal to moister microsites, and perhaps seed dormancy for a year or more, shorter juvenile stands might have lower moisture requirements [1]. (It might even be worth asking whether local climatic changes caused by deforestation have influenced flowering.) Other important environmental factors, such as fire, may be associated with dry periods in some areas (cited in [1]). A more tenuous hypothesis proposed by some Chinese researchers is that earthquakes are related to flowering or mortality, perhaps involving dry conditions as well [6,73]. There has been some striking coincidence with earthquakes (see also [32]), but no rigorous analysis.

The major alternative hypothesis for bamboo flowering proposed in western literature, by Janzen [74], assumes that a long time is required to accumulate enough nutrients for seed-consuming animals to be satiated after mass-flowering, which is then followed by their starvation. Also, rather than environmental cues, a physiological 'clock' under genetic control is supposed to initiate flowering. This hypothesis may indeed apply to many subtropical-warm temperate bamboos (such as Phyllostachys), for which there is considerable evidence of such animal interaction and precise timing of flowering. However, cool temperate-subalpine species may have somewhat different interactions. The lifespans of cool zone species tend to be longer than those of warm zones, on average, and some appear to be much longer than the time required to accumulate enough resources for their observed seed production, as estimated from the few available data (e.g. [1,74-76]). Moreover, the smaller average seed production and seed size of cool zone bamboos may reduce attraction for some consumers. Also, long climatic cycles to which bamboos might respond are reported to be more pronounced in cooler zones (e.g. [68,70]). Finally, it is conceivable that bamboo stands are so extensive within humid montane forests that mortality of mature plants is required for sexual reproduction from seed to avoid parental competition. Monocarpy is clearly a genetic trait associated with the woody rhizomatous habit in bamboos [65], which together with complete culm growth in one season produces particularly uniform competitive cover [1]. The timing of flowering must also have some genetic control, but the major unanswered question is still: to what extent is genetic control modified by environmental periodicity, either directly or through evolution? It is worth noting that some climatic periodicity appears to have been related to solar cycles for at least 680 million years, though its clarity may have fluctuated [72]. Available data may not be enough for firm support of any particular hypothesis, but it

is useful to pursue more thorough synthesis of existing flowering data in herbaria and obscure literature, in addition to setting up long-term monitoring programs. Analysis should not be biased by the most striking coincidences.

In summary, the ability of giant pandas to survive such natural fluctuations must have been greatly reduced by human disturbance. It is probably not true that their wider fossil range in the whole Quaternary era (Figure 1d) was largely due to the absence of human disturbance, considering the large shifts in climate that have occurred. However, some human effects may have begun as early as the late Pleistocene [77]. Certainly, spread of pasture and cropland during the past 2000-3000 years has eliminated the species at lower altitude in the Sichuan region and on isolated outlying mountains, perhaps as far east as the maritime Jiangxi-Fujian region [5]. From evidence summarized above, the accelerated logging of the past 100 years has destroyed at least half of the remaining bamboo-forest habitat within the recent historical range (Figures 1-2). Increasing human pressures at low altitude, including capture [78-80], combined with flowering of the few bamboo species at high altitude, has created a dangerous situation, especially since 1930. If enough bamboo forest were undisturbed in the warm temperate zone, then during regeneration higher up giant pandas could descend to survive on the different bamboo species here, mainly Sinarundinaria, Phyllostachys, Chimonobambusa, etc., near refuges currently threatened [1-10]. If late-season shoots enhance reproduction (see above) and growth, then a greater supply of the larger Bambusa and Sinocalamus of the subtropical zone might also be desirable. The mortality of most giant pandas in parts of the southern Min Shan during the 1970's was clearly aggravated by scarcity of alternative bamboos at the relatively dry and disturbed lower altitudes. Current flowering of other species to the south and east may not create such serious problems, since more alternative bamboos are available. But giant pandas may be wary of foraging too close to dense human settlements. There are no recent reports of mass-flowering in the most southern (Liang Shan etc.) and eastern (Wu Shan etc.) outposts of extensive bamboo forest around the Sichuan Basin [1-12]. However, giant pandas have already been eliminated from most of this forest, presumably due to disturbance in combination with previous flowering. They are now unable to migrate back, unaided, from their northwestern refuges across the lowlands.

## 5. RESEARCH AND CONSERVATION PRIORITIES

I suggest the following general priorities for continued botanical research applied to conservation in this region. Interdisciplinary and international cooperation should be strengthened through better exchange of ideas and materials. The problems of hydrological degradation, in particular, need urgent study with new ecosystem approaches. Straightforward research on taxonomy and distribution is being completed, and there is much potential for a shift to ecological emphasis. Taxonomic studies on bamboos should be promptly linked with giant panda conservation, which has much real and symbolic importance as an endangered species problem in these forests. There should be more synthesis of existing data on bamboos, as well as intensified monitoring in relation to animal consumers and forest dynamics in general. Basic study of forest-climate relationships is an essential starting point for ecological study, but available climatic data from the most humid mountains are much too scanty for serious research on vegetation patterns (cf. Figure 1b). Details of fluctuations from year to year should be made available as well as mean values. Broad surveys of vegetation composition should be intensified on the ground in conjunction with aerial photography and LANDSAT imagery. Multivariate analysis of environmental relationships should be initiated.

In the current giant panda crisis, zoologists are trying to feed or rescue starving animals for security and breeding, but there are no clear plans for return to the wild. Reliance on artificial propagation would be precarious at best, considering the continuing difficulties in zoos. Botanists should be determining the species and genetic relationships of bamboos that flower, pooling old records of flowering and climate, and studying life-cycle mechanisms, so that times and places of further outbreaks can be predicted, together with periods needed for recovery. But, to date, problems of administration and communication have hindered the interdisciplinary cooperation needed for this. I was not even allowed to remove bamboo samples to the local herbarium for study, or to see meteorological data collected in our research camp. As the crisis abates, and more long-term plans for reserve management are developed, it will then be important to intensify study of vegetative growth, rhizome, culm and leaf dynamics, water and nutrient relations, the biochemistry of consumption by pandas, etc.

But without waiting for details of biological research, there are certain clear directions in which conservation action should move. The fundamental problem of continued human population expansion and exploitation in remaining natural habitats can only be solved by close understandings between conservation scientists and administrators, lowland people with their demand for wood, and indigenous people of the mountains. Conservation programs should be linked with better education, farming and forestry. Current management of the giant panda crisis should be followed up by construction of more enclosures with bamboo for holding rescued animals. Replanting and protection of bamboo should be integrated with general multiple-use reforestation programs. Captive animals should eventually be reintroduced to areas of suitable habitat where the species has been eliminated, though in some such areas better control of the human population would be required first, as well as better survey of natural potential. For example, the Shennongjia Forest District of western Hubei (Figure 1a) has become heavily logged only in the past 10 years, with agricultural encroachment now threatening [12]. Bamboo forests here and elsewhere on the eastern side of the Sichuan Basin (e.g. [81]) have the same genera or species as the more extensive western areas. In more accessible eastern areas with small islands of bamboo forest, careful reintroduction and management of giant pandas could generate much tourism.

These problems are severe tests for China's new ecological policies, and western organizations would offer more support if possible. However, problems of foreign ebullience and Chinese reticence must first be overcome. Recent inter-actions such as the World Wildlife Fund project and the Sino-American botanical exchange (e.g. [12]) have provided some important data and also exposed serious deficiencies. A more thorough ecological approach is now needed. Recalling the momentous Qinghai-Xizang symposium of 1980 [40], there should now be no delay in organizing a more practical meeting of scientists and administrators concerned with geo-ecological problems of these mountains around Sichuan, assuming provincial interests can be accommodated. The region shares many problems with the Himalayas, in particular, and more work should be shared, both at the degraded ecosystem level and at the endangered species level (e.g. the lesser/red panda which is more opportunistic but also largely depends on bamboo for food [9]). The recent designation of the Wolong Reserve as part of the Man-And-Biosphere (UNESCO) system [82,83] provides an important opportunity for deepening the ecological work here, and for linking up with MAB projects in the Himalayas [84]. But there is no sign that such cooperation is being planned. Insightful leadership from Beijing and foreign capitols is needed. Politicians could use such projects to reaffirm cultural ties, with some focus on wild pandas being a potent symbol. Considering China's great recent advances in population control, development of alternatives to wood as

a resource, and conservation-reforestation planning, an 'open-door' policy for these mountains need not result in excessively negative exposure (cf. [57]). However, I suspect that only when the current giant panda crisis abates, and local biologists complete their inventories, will close foreign inspection be invited.

With all the global ramifications of such endeavors, outsiders must not overlook the sensitive issues of indigenous Sino-Himalayan peoples. The recent spread of the Chipko movement from west-central Himalayas has reawakened local resistance there to over-exploitation of montane forests by outside interests [85]. At the opposite extreme of the Sino-Himalayan region, in the upper Min Jiang valley of Sichuan, the Qiang people (among others) may still retain fervent conservation beliefs despite their gradual cultural decline over the past 2000 years [17-18]. At least in 1941, after the modern acceleration of timber-export from their surrounding forests had begun, C.M. Hu [18] reported this New Year's Day song:

"The greatest are Heaven and Earth,  
Next to them is the Sacred Forest,  
Wild beasts beating stones on the cliff,  
Fir trees and birch trees,  
Grasses flourishing, lakes deep,  
Mountains high, the land big,  
Remember, remember."

Can the traditional concerns of these people now be integrated with centralized conservation planning? Montane minority peoples in general are increasing in population more than lowland (Han) people in China, since they are exempt from the 'one child only' policy, and there is presumably a desire to raise many children in such marginal socioeconomic environments [56]. These people must be assured of a secure economic base, education, and participation in conservation planning, if their desperation is to be dissipated and some natural harmony restored.

The ultimate conservation problem is to persuade people interested in expansion and exploitation, from greed, fear or ignorance, that their demands are detrimental to the natural heritage, that this is undesirable, and that broad-minded research and planning can be used to change desperation into good fortune for all. For success, fundamental discussion of ideology is required. The 'conservation for development' slogan resulting from the recent IUCN-UNEP-WWF World Conservation Strategy [86] may reflect a common ideology based on human need (or greed?). Indeed, in China, which has been just as destructive of nature in the past as the west, conservation and population planning is now largely motivated from government by threats of economic disaster. Certainly, there is much economic argument to conserve forest resources for future use, to develop alternatives, and to limit population. But when alternatives are developed further and some relaxation of the crisis comes, might not that argument fade in a country like China, which has been accustomed for so long to living at marginal economic conditions? It might not take much more concrete and steel, biogas and hydroelectricity, dams and irrigation ditches, etc., to reduce a purely economic argument for forests. But the addition of aesthetic, or even altruistic, arguments, together with their economic spinoff in tourism, offers more fundamental hope for conservation. Such arguments have only recently been officially promulgated in the People's Republic, evolving in part from the traditional aesthetics of gardening (e.g. [9,57,62]). Until this time, most people in Sichuan probably did not even know that the giant panda was endemic to the region and endangered. Suddenly, the species has become a widespread symbol of new conservation policies. Probably this symbolism will help, but I suspect that lowland Chinese people will have to dig much deeper into their

collective unconscious to create a new golden age of forest conservation (cf. [51]). If they can do this, it will surely be the greatest human ecological drama of all time, since the richest and currently most threatened temperate forests will be secure. Yet further south, the tropical tragedy will almost certainly continue to get worse.

#### ACKNOWLEDGEMENTS

In addition to the many people who have contributed information and ideas, especially those referred to above, World Wildlife Fund-International provided the initial opportunity and contract to work in Sichuan, under the special guidance of Mark Halle. I am extremely grateful for this chance.

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