

The topography of south-western China is dominated by the eastern extension of the Himalayan Mountains, the Hengduan Shan, which takes the form of a series of north-south ranges deeply incised by three great parallel rivers, the Yangtze (Jinsha Jiang), the Mekong (Lancang Jiang) and the Salween (Nu Jiang). All three originate far to the north on the Tibetan plateau in Qinghai Province, but reach the sea thousands of miles apart, in eastern China, Vietnam and Burma, respectively. In western Yunnan these valleys and dividing ranges are steep and, until quite recently, difficult to access, and have remained as a vast refugium of extraordinarily rich biodiversity. They encompass habitats from subtropical evergreen forests up to snow peaks and glaciers at over 6,000 m. Their remoteness and difficult terrain have served not only to protect their rich biodiversity from destruction and exploitation, but also to make its exploration and description difficult. As is well-known, China is undergoing massive industrial development; natural resources such as timber, minerals, water and hydroelectric power are in huge demand, and even the remotest areas may be threatened. Exploration and cataloguing of the rich diversity of plants and animals is therefore an urgent priority.

Of the three rivers, the Nu Jiang is the most remote and least-visited by westerners. Along its west side, straddling the Burmese border, is the Gaoligong Shan range, some 585 km long and draining westwards into a fourth river in Burma, the Irrawaddy. Its topography and geography have been described in detail by Chaplin (2005). Early plant hunters, such as George Forrest and Frank Kingdon Ward (McLean, 2004; Ward, 1924), explored parts of the Gaoligong Shan and reported its extraordinary richness for rhododendrons and other garden-worthy plants, but

of the early explorers, only the Austrian Heinrich Handel-Mazzetti collected any bryophytes, between 1914 and 1918 (Brotherus, 1929; Nicholson *et al.*, 1930; Winstanley, 1996). Although a bryophyte flora of the wider Hengduan Shan (covering most of the mountains of Yunnan and Sichuan Provinces) has been published (Wu & Wang, 2000), relatively few collections from Gaoligong Shan were available to its authors. However, Chinese higher-plant botanists have long known of the Gaoligong Shan's riches, but as a result of ever-increasing development pressure, Professor Li Heng and her colleagues in the Kunming Institutes of Botany and Zoology took the decision to 'open up' the area to American botanists and zoologists in order to speed up cataloguing the biodiversity and underpin better protection. Generous funding from the US National Science Foundation has paid for a 5-year, Sino-American 10-expedition programme, the Biotic Survey of Gaoligong Shan, of field research and collecting which ended in 2007, resulting in collection of over 19,000 vascular plant specimens, and 7,700 bryophytes. I was fortunate to be invited to join the team, along with Californian bryologist Jim Shevock, and we have collected bryophytes on all the expeditions.

Bryological aims

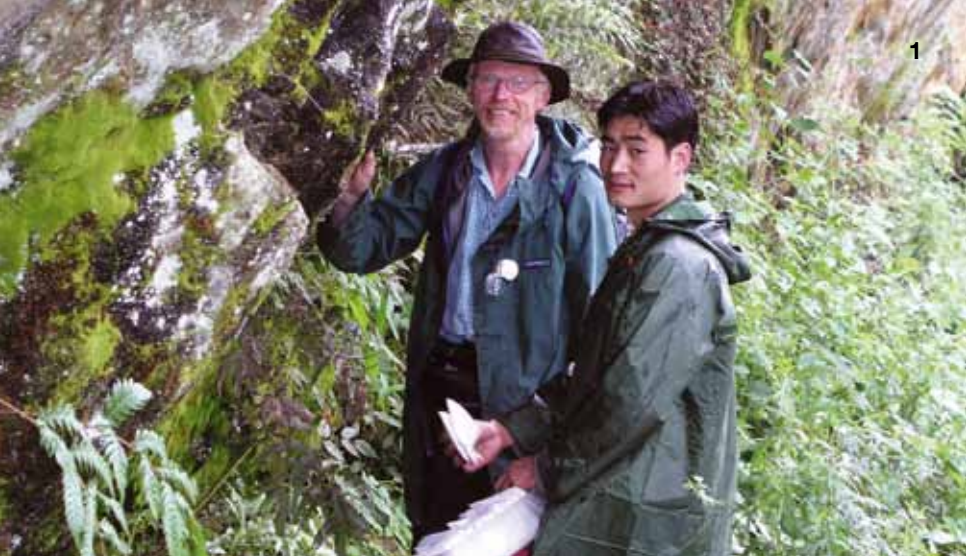
The biota covered by the project included mammals, reptiles, insects (especially beetles), spiders, vascular plants and bryophytes. Quite early on, we discovered a symbiosis between entomologists and bryologists, perhaps due to our slow speed in the field or our shared fascination with tiny organisms. As a result, we frequently teamed up together, although nocturnal collecting was restricted to entomology. Where does one start when asked to catalogue bryophytes in a new, vast and largely unexplored region? The

Bryophytes abroad: the Gaoligong Shan mountains of the Sino-Burmese Border

China has certainly had its share of the media spotlight in recent times as it continues develop and modernize, not to mention this summer's Olympic Games. But what of its bryophytes? With ever-increasing pressures on its natural resources and a lack of data on its bryological richness, **David Long** joined a 5-year-long Sino-American project to record the biota of the Gaoligong Shan mountains in the south-west of this mysterious and fascinating country.



Dali pagodas. David Long



only way is to try to collect all species seen, at least once in every locality, and to try to learn to recognize (but not necessarily to put names to) the common species so that we could search for the rarer ones and, hopefully, over the 5 years develop our field expertise. Between trips we could make preliminary identifications and improve our knowledge for the next trip. For our own specialist groups, such as Marchantiales and rheophytes, it gave the chance to make really comprehensive collections.

Thus the predominant aim in the field was to make comprehensive general collections, to prepare five or more sets of duplicates of each (including a duplicate to be gifted to other specialists), to dry these carefully, and to gather accurate locality and ecological data (for example precise geo-referencing with GPS). Back 'home' the collections would be sorted, divided and distributed to participating institutions and specialists, and preliminary, then final identifications made. The final stage, now underway, is specialist taxonomic research followed by publication, both of scientific papers and ultimately a full checklist, as well as other potential studies combining data from the different disciplines. Study of historical collections from Handel-Mazzetti and others will be incorporated in this phase.

In the field

For such a large, international, multi-disciplinary project, logistics of expeditions were hugely challenging, complex and expensive. At times 20 or

more scientists and assistants were involved, not to mention similar numbers of porters and guides when trekking in the mountains. Planning had to be thorough, and for each expedition was discussed and agreed long in advance by the leaders in Kunming (particularly Dao Zhiling) and San Francisco (particularly Principal Investigator Peter Fritsch). Botanical collecting requires a large volume of equipment for pressing and drying specimens, so each expedition needed three large minibuses to transport camping and collecting equipment, people and often food.

Bryophyte collecting is much the same the world over, and we used field packets made from 'rite-in-the-rain' paper, except for samples for DNA research stored in ziplock bags with silica gel. Large conspicuous species were easy and quick to collect, but tiny species such as epiphyllous Lejeuneaceae required careful searching and sorting in the field, in order to collect enough for several duplicates. Mixed collections we tried to avoid. The biggest problem in a high-rainfall monsoon climate was drying, especially when camping. In hotels, forestry stations, etc., with an electrical supply, we used heat drying on early expeditions, but found this too harsh and



and boxes and sealed for shipment.

Our expeditions generally lasted 5 or 6 weeks. As bryologists tend to wander off by themselves in the forest, we were always given an assistant/guide, preferably from a local village. By far our best guide was Fan Xuezhong of the Lissu Minority People who proved an excellent guide and soon became an expert field bryologist even though we shared not a single word in common. Many rare species were spotted by his keen eye. Each expedition focussed on one or several areas we knew to have undisturbed or rich habitats, ranging from the subtropical evergreen broad-leaf forests of the southern hills, along the deep valleys of the Nu Jiang and Dulong Jiang, in the northern temperate mossy *Tsuga/Rhododendron* forest and *Abies/Rhododendron* forest, and, on expeditions in 2005, 2006 and 2007, to the alpine zone in the far north close to Burma and Tibet. The highest elevation reached was just over 4,000 m on Mt Gawa Gapu in 2006, an



moved to fan-drying which, though slower, gave much better specimens. When camping, packets were packed in plastic trays and sent by 'express porter' to the nearest town where an assistant dried them for us. Dry packets were then packed in poly bags

◁ 1. The author and Mr Fan. *Jin-Hyub Paik*
 2. Nu Jiang Valley. *David Long*
 △ 3. Bridge over the Nu Jiang. *David Long*

extremely inaccessible peak reached only along the legendary 'Path of Terror' described by Kingdon Ward (1924).

The Nu Jiang (Salween) valley

The Salween valley and its road gives the only access to much of the Gaoligong Shan. Though much-disturbed and cultivated, except in the steep-sided parts and in side-valleys, and with several large towns, it proved to be of great bryological interest, especially for rheophytes and Marchantiales, many of which like somewhat disturbed sites. The most interesting rheophyte is the moss *Hydrocryphaea wardii* (Neckeraceae) which grows on marble rocks and boulders close to the water. Jim Shevock has now found this in several sites in Fugong and Gongshan counties (Shevock *et al.*, 2006), sometimes growing in extensive sheets. Elsewhere it is known only from a few localities in Assam, Laos and Vietnam. A rheophytic liverwort, *Asterella wallichiana*, is also found in this habitat. Calcareous rocks are rare in Gaoligong Shan, so these same marble rocks above the water level are of interest, are much drier and support species such as *Anomodon viticulosus*, *Didymodon tectorum*, *Grimmia pilifera*, *Herpetineuron toccoeae*, *Syntrichia fragilis*, *Frullania ericoides*, *Reboulia hemisphaerica* and *Mannia californica*, the last new to China. More disturbed roadside cuttings and banks

support several *Marchantia* species, *M. papillata*, *M. paleacea* and *M. subintegra*, the last a local Sino-Himalayan species, and mosses such as *Bryoerythrophyllum inaequalifolium* and *Garckea comosa*.

Forests of the southern Gaoligong Shan

I visited the southern Baoshan, Tengchong and Lushui Counties in 2003 and 2007 where the main ridge rises only to about 3,000 m and is completely forested with subtropical evergreen broadleaf forest, dominated by trees such as Fagaceae, Lauraceae and Theaceae. This forest, where undisturbed, is very rich in subtropical epiphytes such as Neckeraceae and Meteoriaceae, for example *Homaliodendron* spp., *Neckera crenulata*, *Aerobryidium filamentosum*, *Meteoriopsis reclinata*, *M. squarrosa* and *Trachypodopsis serrulata*. Interesting Marchantiales on roadsides included *Asterella cruciata* and *A. multiflora*, both very rare species in China, *Conocephalum japonicum*, *Cyathodium tuberosum*, *Dumortiera hirsuta*, *Plagiochasma cordatum* and *P. pterospermum*. The ‘copper mosses’ *Scopelophila cataractae* and *S. ligulata* were not uncommon on shady rocks. Shady forest banks produced two very striking mosses, *Leucobryum javense* and *Rhodobryum giganteum*.

Dulong Jiang

The other subtropical part of Gaoligong Shan (visited in 2004 and 2007) was the remote Dulong Jiang valley, which lies on the west side of the main range at the northern end, but is part of the Irrawaddy catchment draining into Burma. Until the recent construction of a road, it was very inaccessible and almost unknown to westerners. The forests here are well-preserved except along the river banks, but are very steep. Similarities in the tree species with the forests of Bhutan were noticed, for example species such

as *Pinus bhutanica*, *Exbucklandia populnea* and *Tetracentron sinense* were frequent. The bryophyte flora too seemed different from other parts of Gaoligong Shan, particularly the rich flora of epiphyllous Lejeuneaceae which had been reported before by Chinese bryologists (Zhu & So, 2001). Frequent too was *Pseudospiridentopsis horrida*, in spite of its name a beautiful pleurocarpous moss, usually growing on rocks. The numerous side ravines often had waterfalls where the spectacular *Handeliobryum sikkimense* grew in huge dripping curtains, also *Fissidens grandifrons*, *Hypopterygium flavolimbatum*, *Jubula hutchinsiae* subsp. *javanica* and *Wiesnerella denudata* were not uncommon, unlike a species new to science found in only one place, *Lobatiricardia yunnanensis* (Furuki & Long, 2007). Another surprising find was the leafy liverwort *Pleurozia subinflata*, new to China, growing as an epiphyte on the bank of the Dulong River close to where it enters Burma.

The Qi Qi trail

Before the recent construction of a road into the Dulong valley, the only access was an ancient footpath starting at Gongshan called the Qi Qi (pronounced *Chi Chi*) Trail. The first bryological collector in Gaoligong Shan, Handel-Mazzetti, followed this route in 1916 (Winstanley, 1996) and along it discovered many bryophytes new to science such as *Dicranodontium subporodictyon*, *Plagiochila perserrata*, *Scapania rotundifolia* and *Schistochila macrodonta* (Brotherus, 1929; Nicholson *et al.*, 1930). In 2004 I was able to follow this route from the western (Dulong) end, and in 2007 from the eastern (Gongshan) end and retrace Handel-Mazzetti’s footsteps. This proved highly successful – the route would appear to

▷ 1. *Hydrocryphaea wardii*. 2. *Mannia californica*.
3. *Marchantia papillata*. 4. *Conocephalum japonicum*.
5. *Rhodobryum giganteum*. All photos David Long



- ▷ 1. *Actinothuidium hookeri*. 2. Liverwort heath.
 3. *Scaphophyllum speciosum*
 ▽ 4. The Dulong Road. 5. *Takakia ceratophylla*.
 6. *Abies/Bamboo* forest.
 All photos David Long



have remained completely undisturbed except for the mysterious death of many of the *Abies* trees on the high pass. Not only were some of Handel-Mazzetti's specialities re-found, such as *Schistochlila macrodonta*, but many others too, such as both species of *Takakia* (*T. ceratophylla* and *T. lepidozoides*), wet forest species such as *Acrobolbus ciliatus*, *Actinothuidium hookeri*, *Delavayella serrata*, *Lophocolea sikkimensis*, *Nowellia curvifolia* on logs, *Haplomitrium blumei*, *Herbertus dicranus*, *Hookeria acutifolia*, *Mastigophora woodsii*, *Plagiochila elegans*, *P. semidecurrans*, *Schiffneria hyalina* and the

spectacular *Scaphophyllum speciosum*. On the pass itself was extensive dwarf *Rhododendron* liverwort heath with *Anastrepta orcadensis*, *Anastrophyllum donnianum*, *Lophozia setosa*, *Mylia taylorii* and one of two collections of the undescribed genus *Hamatostrepta*. On wet rocks were extensive sheets of the Himalayan *Andreaea rigida* looking rather like our own *A. nivalis*.

Shibali and the 'Twin Lakes'

Shibali is an old forestry station in Fugong County in the dense evergreen forests between the Nu Jiang and the Burmese border at about

2,500 m elevation. It proved an outstanding base for 2 weeks in 2005 and a few days in 2007. It lies in a tributary valley (Yamu River) and is reached by an old logging road now used to transport timber from Burma. Around Shibali is beautiful dense evergreen forest of *Castanopsis*, *Lithocarpus*, *Acer*, *Magnolia*, *Lauraceae*, *Sorbus* and other trees, humid bouldery river banks, side ravines, waterfalls, in short a bryological heaven. A few kilometres up the road is the transition to Hemlock/*Rhododendron* forest, which proved to be one of our richest collecting areas of the whole project. Here in 2004 Jim Shevock found an epiphytic member of Neckeraceae which he sent to Johannes Enroth in Helsinki who subsequently described it as *Shevockia inunctocarpa* – a new genus and species, very deservedly honouring Jim's astute bryological collecting (Enroth & Ji, 2006). In 2007 Jim and I returned to try to re-find his plant, and soon did so in three places, growing epiphytically on trunks of *Acer*, *Illicium*, *Sorbus* and an unidentified member of Araliaceae; curiously, it often grew on the underside of leaning trunks. Here Handel-Mazzetti's rare *Schistochila macrodonta* was found again, in abundance, along with other mossy forest species such as *Calycularia crispula*, *Daltonia*, *Delavayella serrata*, *Fissidens anomalus*, *F. polypodioides*, *Geocalyx graveolens* (always on big rotten logs on river banks), *Haplomitrium blumei*, *Hookeria acutifolia*, *Leptodontium viticulosides*, *Mastigophora woodsii*, *Meteoriella*

soluta, *Metzgeria leptoneura* and *Scaphophyllum speciosum*.

Just over an hour's slow drive on the very rough and twisty road from Shibali brought us up to the 'Yaping Pass' at 3,600 m (11,880 feet) and we were able to gaze on range upon range of misty mountains stretching far into Burma on one side, and further north along the Gaoligong Shan on the Chinese side – a breathtaking panorama all round. However, Burma was out of bounds and we headed off south along the ridge on a rough path amongst dwarf *Rhododendron*, juniper and bamboo. On the Chinese side the ground fell





The Gaoligong Shan mountains, China

- ◁ 1. *Asterella cruciata*. David Long
- 2. *Gentiana decorata*. Jin-Hyub Paik
- 3. *Rhododendron dichroanthum*. David Long
- 4. The peak of Mt Gawa Gapu. David Long

high; the trees were curtained with moss.' and 'After several hours, the forest grew thinner, but the trees were gigantic, bigger than anything we had seen previously. It is from these immense conifers that the natives of the Salween fashion their dugouts.' With the help of our guides and climbers we followed Kingdon Ward's path which followed the almost vertical side of a gorge several miles long. The same mossy forest and the gigantic conifers (*Taiwania cryptomerioides*) were there, but time was too short for collecting. After 3 days of mud, slippery rocks and log bridges we finally reached the beautiful alpine lake just below Gawa Gapu where we camped for a week at 3,700 m on a magnificent ridge with trees of *Abies delavayi* and rhododendrons overlooking the lake, with huge screes, cliffs and snow patches above.

I very quickly realized that this mountain was different from the others we had explored – the rock was a soft, calcareous metamorphic schist, and not surprisingly on this rock were many calcicoles like *Athalamia* and *Sauteria*, *Asterella gracilis* (new to China), *Campylophyllum halleri*, *Cirriphyllum cirrosum*, *Distichium capillaceum*, *Paraleptodontium recurvifolium* (new to China), *Preissia quadrata*, *Tortella tortuosa* and *Tritomaria quinquedentata*, not seen in other places. On the screes below the cliffs and amongst the dwarf rhododendrons were the usual mats of *Anastrepta*, *Anastrophyllum*, *Herbertus* and *Mylia taylorii*, and in the wet meadows by the lake were the familiar *Climacium dendroides*, *Drepanocladus cossonii* and *Warnstorfia exannulata*. On the rocks by the lake *Takakia ceratophylla* was found yet again, and on stems of dwarf rhododendrons, *Sphenolobopsis pearsonii*. Amongst the *Abies* trees near our camp, *Actinotuidium hookeri* and *Ptilium*

away steeply into two large cirques, one with a single lake and the other with two almost identical lakes which we nicknamed the 'Twin Lakes'. We spent several days in this area, exploring the boulder screes, cliffs, liverwort heath amongst the dwarf shrubs, streams, flushes and wet meadows around the lakes. My botanical colleagues Simon Crutchley and Jin-Hyub Paik concentrated on the rich herb meadows while the entomologists hunted for beetles amongst the boulders. I truly had a bryological feast, and could easily have spent a week or more there. The liverwort heath was highly reminiscent of some mountain corries in north-west Scotland, with species such as *Anastrepta orcadensis*, *Anastrophyllum joergensenii*, *A. donnianum*, *A. alpinum*, *Bazzania pearsonii* and *Pleurozia purpurea*, but also with additional species unknown in Europe: *Apotreubia nana*, *Microdendron sinense*, several large *Scapania* species and *Takakia ceratophylla*. On the acidic boulders the black *Apomarsupella revoluta* was common, along with the rare *Miehea indica* and whitish cushions of *Paraleucobryum enerve* while the diminutive *Apomarsupella verrucosa* grew just

like a *Gymnomitrium* on rock walls and sides of boulders. Around the lakes the flushes were rich in liverworts, with several *Jungermannia* species such as *J. cheniana* and *J. conchata*, abundant *Gottschelia patoniae* constituting a big extension of range from Nepal and Sikkim, a new species *Gottschelia grollei* (Long & Váňa, 2007) and *Moerckia blyttii*. The new genus *Hamatostrepta* was also found here, and from GPS readings it transpired I had collected it just inside Burma, along with several bryophytes inadvertently found new to Burma such as *Anastrophyllum alpinum*, *Bazzania pearsonii*, *Horikawaella subacuta*, *Plagiochila carringtonii*, *Pleurozia purpurea*, *Racomitrium joseph-hookeri* and *Takakia ceratophylla*.

The 'Path of Terror' and Mt Gawa Gapu

On his return from the Dulong Valley in 1916, Handel-Mazzetti had traversed the southern slope of the highest peak in Gaoligong Shan which he called the Gomba La, now called Mount Gawa Gapu, 5,128 m high. He reported alpine lakes and magnificent meadows, but also

very steep and difficult terrain. Later, in 1922, Frank Kingdon Ward traversed the same route on his westward journey from China to Burma (Ward, 1924). On several occasions we had asked our Chinese colleagues to organize an expedition to Gawa Gapu, but they always refused on the grounds that the route was too dangerous. Only by enlisting two professional American climbers, Andy Polloczek and Barbara Andrews, to ensure our safety, was permission granted and the Gawa Gapu expedition in autumn 2006 became the greatest and most exciting challenge of the project. On 15 August 2006 we set off from Gongshan on this journey, driving up to the Lissu village of Sijitong where over 40 porters were waiting to carry our camping and collecting gear and food. We set off at lunchtime, following the steep-sided Nianwaluo He valley north-westwards.

Kingdon Ward described the start of this journey along the same route which he called the 'Path of Terror'. 'The path climbed giddily. We balanced on crazy logs or descended the face of the cliff, clinging for dear life to roots and rocks. Everywhere the rank undergrowth surged waist-

crista-castrensis were conspicuous. Later in the week, heavy rain hampered our field work and we did not cover as much ground as hoped, but the vicinity of the camp kept us busy. Another consequence was that the tributary streams were in spate for our descent adding to the excitement of the journey, but all returned to Gongshan without mishap.

The future

The pressures of economic development in China are such that the future of the rich biodiversity of the Gaoligong Shan is hard to predict. It is very much the hope that the results and publications from our explorations can be used by our Chinese colleagues to bring about stronger protection for this wonderful mountain range. The first signs of the tourist industry are appearing in the area, and routes such as the Qi Qi trail are likely to come back into use by trekkers. With appropriate management, this could help future conservation. In the short term, we have an urgent agenda to identify our collections and to publish the results to raise international awareness of the region. With this in mind, a range of international bryological collaborators are already working on families such as Jungermanniaceae, Mniaceae, Frullaniaceae, Pottiaceae and Sphagnaceae, and a steady stream of new taxa are emerging.

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