



Hornwort Heaven

The authors, Silvia Pressel, Jeff Duckett and Juan Carlos Villarreal, recount their expedition into the Himalayan foothills of northern India: a thalloid Shangri-La

△ Jeff, Juan Carlos and Silvia admiring a beautiful sunrise over Kachenjunga from the roof top of the Aliment Hotel, Darjeeling. Silvia Pressel/Jeff Duckett

India, and in particular the regions spanning the foothills of the Himalayas, is a global hotspot for hornwort diversity (Villarreal *et al.*, 2010), with more than 30 taxa recorded including more species (9 confirmed) of *Notothylas* than anywhere else in the world as well as many as several endemic taxa, some known only from the type specimens. Complex thalloid liverworts come a close second with over half the world's genera. Most work in these regions has been carried out by Indian bryologists, in particular Drs A.K. Asthana, D.K. Singh and S.C. Srivastava and synthesized in their books on Indian Hornworts (Asthana & Srivastava, 1991) and Notothylaceae (Singh, 2002). We had long been waiting for an opportunity to visit Northern India as part of our collaborative efforts towards a global survey of fungal associations in hornworts and thalloid liverworts and a global hornwort phylogeny. Thus, bursting beside

ourselves with expectation in October 2012 we set off on an expedition to Northern India with the hill stations of Shimla to the West and Darjeeling to the East as our two bases. As this piece will illustrate, our dreams were delivered in both quantity and quality; indeed we had arrived in hornwort heaven. Speaking of the sublime, we also had a quasi divine revelation; thalloid things like the tourist trails.

Shimla and its environs

The hill station of Shimla (or Simla) is the capital of the Indian state of Himachal Pradesh. It lies in the north-western ranges of the Himalayas, some 2400 m above sea level, perched rather precariously on seven steep hill sides stretching 9 km west to east. In 1864 Shimla became the summer capital of British India, providing the perfect escape from the smouldering heat of the lowlands with its subtropical highland climate



△ Figs. 1 and 2, left to right: our ‘lab with a view’, Shimla; rhesus macaques patrol the entrance to Jakhoo Temple, Shimla.
Silvia Pressel/Jeff Duckett

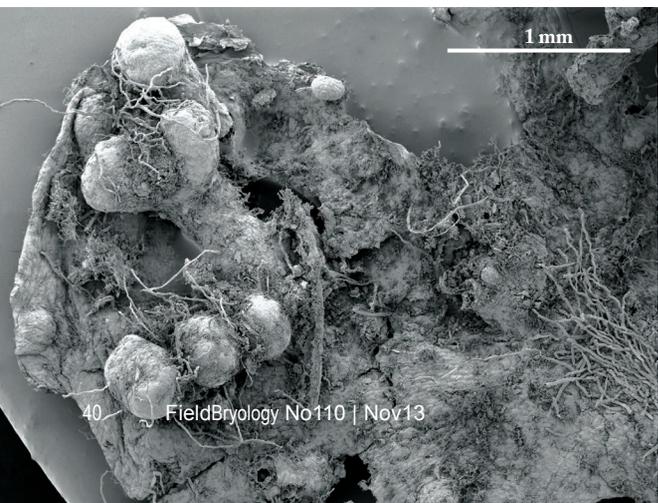
of moderately warm summers and cool winters. To this day hordes of Indian and foreign tourists alike take the spectacular, 8 hour trip on the Kalka-Shimla railway line, once known as the ‘British Jewel of the Orient’, through its 103 tunnels and no fewer than 806 bridges, to find refuge from the often unbearable temperatures of the plains or in search of snow during the winter months.

We arrived in Shimla after a long car ride from Chandigarh airport on 1st October 2012 and spent eight days in this stunning location at what is the optimum season, between the summer monsoon and the winter, for thalloid bryophytes. Having somewhat taken over and transformed the roof terrace of our hotel into a ‘lab with a view’ (Fig. 1), the attempts of feral monkeys to steal just about everything notwithstanding, we set off to explore. A

stroll along the Mall, the main street in Shimla, on day one gave us a taste of things to come, with its stunning combination of hornwort and thalloid liverwort taxa covering the brick walls and soil banks along the way. These had a strong ‘Mediterranean feel’ to them, with numerous species of, *Asterella*, *Cryptomitrium*, *Cyathodium*, *Fossombronia*, *Mannia*, *Marchantia*, *Pallavicinia*, *Plagiochasma*, *Riccia* and *Targionia*, jostling for space whilst slightly less crowded earth banks were dominated by the three hornwort genera *Anthoceros*, *Folioceros* and *Phaeoceros*.

Many more interesting plants were awaiting us by the Jakhoo Temple, dedicated to Hanuman, the Monkey Lord; its giant statue (the world’s tallest) towering over the town below from the top of Jakhoo Hill – at 2454 m the highest point in Shimla. Quite fittingly, troops of monkeys (rhesus macaques) patrol the temple entrance

▽ Figs. 5 and 6, left to right: scanning electron micrographs showing the distinctive tubers of *Phaeoceros himalayensis*; *Cyathodium tuberosum* with its rather impressive marginal hairy tubers. Silvia Pressel/Jeff Duckett





△ Figs. 3 and 4, left to right: *Sewardiella tuberifera* and *Anthoceros erectus*, Jakhoo Temple, Shimla. Silvia Pressel/Jeff Duckett

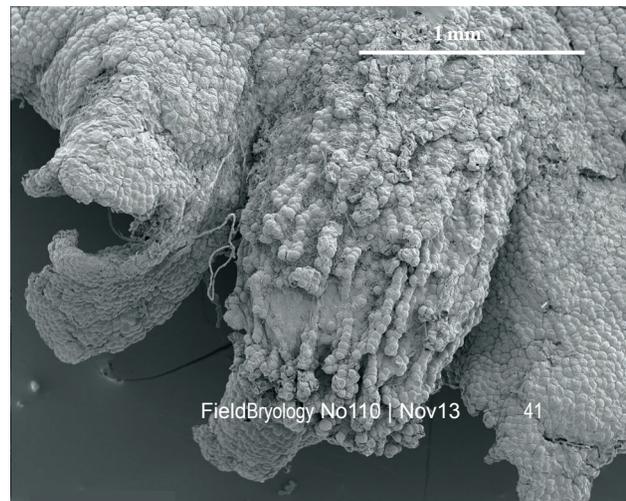
and its grounds (Fig. 2) and any ‘removable’ item belonging to tourists and devotees is fair game to them, as we very soon found out. Indeed it was here that we learned an invaluable lesson: if bryologising whilst surrounded by monkeys REMOVE YOUR GLASSES BEFORE THE MONKEYS DO IT FOR YOU. Jeff’s glasses disappeared before any of us had time to blink, however after some negotiations involving the exchange of copious amounts of peanuts and a small amount of money – provided by a most strategically-placed and considerate ‘passerby’ – Jeff was able to regain control of his visual aid just in time to spot a lovely colony of the endemic *Sewardiella tuberifera* (Petalophyllaceae) on an earth bank nearby (Fig. 3). We were particularly happy with this find as *Sewardiella* is the only thalloid liverwort genus yet to be sequenced.

As we followed the meandering road, lined by *Cedrus deodara* forest, that leads away from

the temple, we were delighted to see large populations of *Anthoceros erectus* (Fig. 4) a dioicous species with diminutive male thalli and, for the first time, *Phaeoceros himalayensis*, with its characteristic large tubers covering and extending from the ventral side of the thalli (Fig. 5). No less impressive was the extensive thalloid liverwort assemblage, including: *Athalamia hyalina* and the Indian look- a-like for *Pellia*, *Calycularia crispa*, in addition to all the taxa seen in the morning. However, our favourite for the afternoon, beautiful hornworts aside, was the highly photogenic *Cyathodium tuberosum*, its hairy marginal tubers clearly visible with the naked eye (Fig. 6).

Other bryophyte localities, posing as tourist haunts in the immediate environs of Shimla, that all provided exciting finds included the Viceregal Lodge (Rashtrapati Niwas), now the Indian Institute of Advanced Study, built

▽ Figs. 7 and 8, left to right: *Notothylas* cf. *indica*, one of the many *Notothylas* spp., scanning electron micrographs showing a highly ornamented involucre. Silvia Pressel/Jeff Duckett





△Figs. 9 and 10, top to bottom: a possible candidate for *Anthoceros macounii*, Hatu Peak, Narkanda; hornwort-covered bank just outside Jaypee University, Shimla. Silvia Pressel/Jeff Duckett

as a home for Lord Dufferin, Viceroy of India from 1884-1888 on top of Observatory Hill, one of the seven hills that Shimla is built upon. In the shadow of this imposing if not rather a over-embellished Scottish baronial building, among the flower beds and on the earth banks of its sprawling gardens, we finally came across our first *Notothylas* species (Figs. 7 & 8). Our further discovery that Indian buses are never full and, despite hyper-overcrowding, the very slim conductor will always collect your fare, was made on excursions to the nearby Glen, so called because of its resemblance to the same in Scotland, and the Chadwick Falls (67m high), 6km west of Shimla. Finds here included more

Phaeoceros, *Anthoceros* and *Notothylas* species (including *P. carolinianus*, *P. laevis*, *A. bharadwajii* and *N. levieri*) covering the earth banks along the path leading to the falls whilst just below these *Calycularia*, *Marchantia paleacea*, *Dumortiera* and more prosaically *Conocephalum conicum* made an appearance. Whilst the *Conocephalum* looked exactly like its European counterpart the *Dumortiera* thalli were highly papillate and clearly referable to *D. hirsuta* subsp. *nepalensis* in contrast to the largely smooth thalli in British material (subsp. *hirsuta*). Despite their very different appearance, a recent molecular study has shown that the two are closely related (Forrest *et al.*, 2011). Our current studies of *Dumortiera* (Pressel & Duckett, unpublished) have revealed that the papillae are caducous and function as gemmae in a genus where asexual propagules were not thought to occur (Paton, 1999). Further afield we visited the village of Kurfi (16 km from Shimla, 2510 m above sea level). Avoiding the distraction of yak rides (strictly for tourists with nothing better to do), we spent hours examining more hornwort-covered banks and explaining to children on pony trekking excursions what we were doing. Our longest excursion was a drive to Narkanda, 65km from Shimla and 8km beyond Narkanda, up a rather precipitous road through pine and spruce forests to the Hatu Peak (3300m) with open alpine turf and cliffs just above the trees and offering a spectacular view across almost the entire Himalayan range. Here we found yet more hornworts including a candidate for *Anthoceros macounii* (Fig. 9) a long way outside its known world range and for the first time *Herbertus* and *Lophocolea minor* smothered in gemmae compared to their more sporadic occurrence on British *L. heterophylla* (Paton, 1999).

During the first leg of the expedition we did manage half a day off from field work when



△Figs. 11 and 12, left to right: Jeff is too busy looking for bryophytes to notice a toy train in full steam; searching for bryophytes in one of the many tea plantations of Darjeeling. Silvia Pressel/Jeff Duckett

Silvia and Jeff gave seminars (on bryophyte fungal symbioses and stomata) to students, all immaculately dressed in blue and white uniforms, at the Jaypee University of Information Technology at Wanknaghat, 22km downhill from Shimla. They were warmly welcomed by the vice-chancellor Prof. Ravi Prakash and Dr Chauhan head of Department of Biotechnology and Bioinformatics, but afterwards reverted to type being unable to resist the hornwort-covered banks just outside the campus (Fig. 10).

Darjeeling and its environs

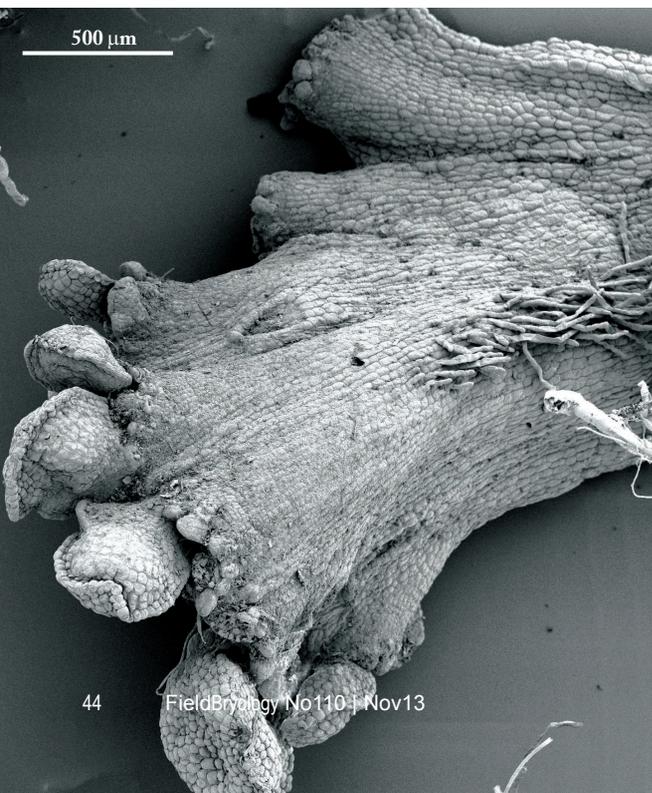
Surrounded by tea plantations Darjeeling, a sprawling provincial town and tourist mecca in West Bengal in the Eastern Himalayas at 2000-2100m has a unique blend of Nepalese, Tibetan and Bengali cultures, including food, and is the epicentre of a hoped-for country known as Gorkhaland. Sherpa Tenzing Norgay's memory is much revered with a road named after him (and which it turned out to be a good place for hornworts) and many shops still display the 1951 newspaper announcing the conquest of Everest with the headline of Edmund Hillary's immortal words "we knocked the b*****d off". We had similar emotions, but without the vernacular, every time we found different hornworts in the certain knowledge that more people have now climbed Everest than are ever likely to see what we were seeing.

Though at much the same altitude, Darjeeling,

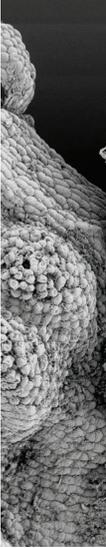
with an annual rainfall of 3090mm, is much wetter than Shimla (annual rainfall 1575mm) and has a distinctly damper, mistier and ethereal ambience with the added dimension of steam from the 'toy trains' (Fig. 11). The Darjeeling Himalayan railway, hugging the contours of the hills throughout its length and including the middle of the main road for significant stretches and with no major bridges or tunnels, far from being a distraction from bryology, proved to be a hornwort honeypot. At every stop, long and frequent, every bank, siding and the famous Batasia loop, where the track makes a complete circle to go under itself, produced at least 3 different hornworts.

After a somewhat harrowing journey from Shimla, involving an overnight stay in the completely forgettable city of Chandigarh, an 8 hour taxi journey with an off piste detour because of a landslide, not to mention changing accommodation in pouring rain and darkness along unpaved streets (the one we had booked turned out to be semi derelict) we established our base camp in the Aliment Hotel. Not only did the Nepalese owners have an invaluable knowledge of the places we might wish to visit, they also gave us 'a lab with an even better view than in Shimla' – a panorama of Kachenjunga, the world's third highest mountain (8598m), and no feral monkeys.

Needing to recover from the journey we began our exploration of Darjeeling with a 'gentle' car-



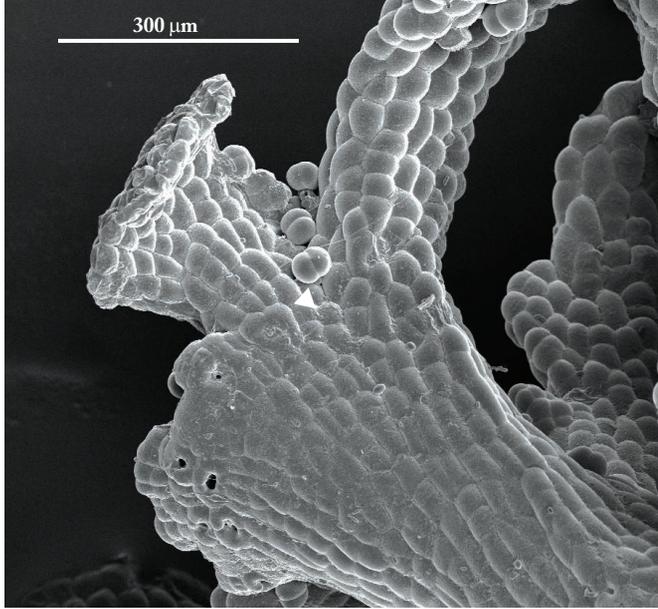
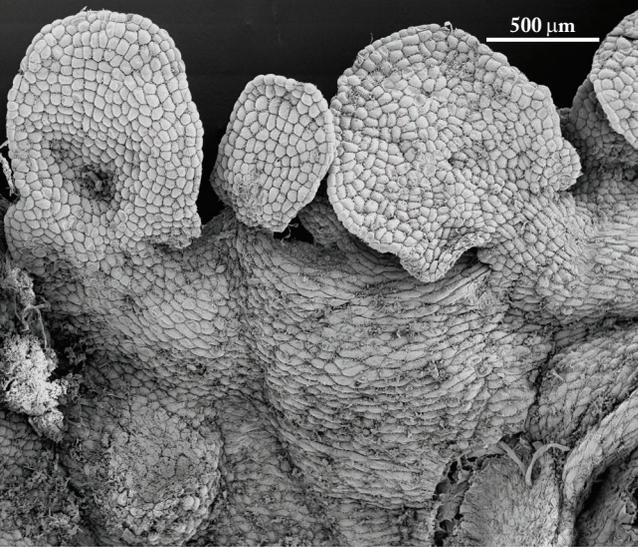
<Figs. 13, 14 and 15, top to bottom: gemma extraganza in Lloyd's Botanical Garden, Darjeeling; *Conocephalum supradecompositum* (13) and *Anthoceros angustus* (14) vying for supremacy in the gemma stakes; scanning electron micrograph beautifully showing the gemmae in *A. angustus*. Silvia Pressel/Jeff Duckett



free day in the world famous Lloyd's Botanical Garden where we were immediately brought to our knees by a very different, but no less diverse hornwort and thalloid assemblage from that in Shimla, and a gemma extraganza. Vying for supremacy in the gemma stakes the rockery beds contained extensive colonies of *Conocephalum supradecompositum* (Fig. 13) and *Anthoceros angustus* (Figs. 14 & 15), the latter soon to be immortalized as the first hornwort to have its genome sequenced.

Only slightly more adventurous, on the next day we visited tea plantations (Fig. 12) and the Victoria Falls and, despite lots more *Anthoceros*, *Phaeoceros*, *Notothylas* and *Folioceros*, we were disappointed not to see *Megaceros tjobodensis*, the only hornwort genus to have eluded us so far. We did not have long to wait. This lacuna was filled the following morning with a trip to the nearby viewpoint of Tiger Hill (2590m). Unlike the hundreds of tourists who go there at 4.30am to see the sunrise over Kachenjunga (we'd already done that from the lab) we went at 9am to find the place deserted apart from *Haplomitrium dentatum* on the banks and the *Megaceros* in a stream. Our taxi then took us downhill to the lowest point of the trip altitudinally, the Teesta River at 220m, with our first taste of momos and more *Megaceros* along the way. Here we found yet further *Notothylas* samples on mud banks exposed after recent flooding (Fig. 18).

Our only other significant excursion away from Darjeeling was a two day trip to the village of Lava and the Neora National Park on the Bhutan border. This proved good for hornworts



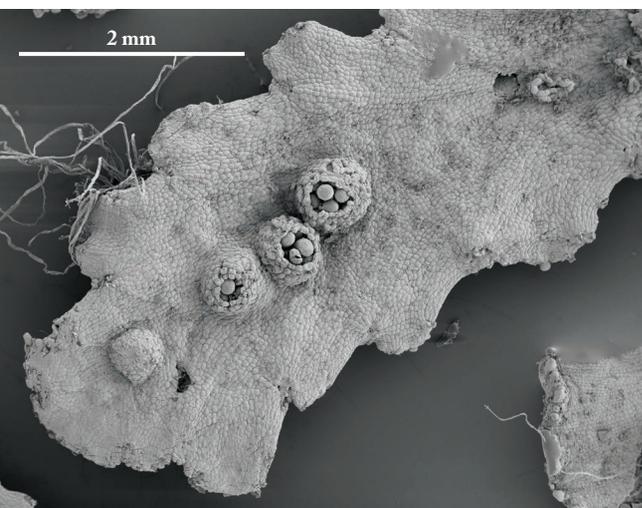
and in particular our finding the rarely collected species *Folioceros assamicus* (Figs. 16 & 17) and lots of *Herbertus*, but disappointing for thalloid liverworts. We were however, pleased to see a second *Haplomitrium* species *H. indicum* (Fig. 19) and quantities of the early divergent polytrichalean species *Lyellia crispa* (Bell & Hyvönen, 2010).

Aside from the above excursions we spent the rest of our time ambling around the backroads and sights of Darjeeling including the Bhutai Busty monastery, the Makahi Temple, St Andrew's Church and St Paul's School all of which yielded several hornworts, including a lovely colony of *Notothylas cf. levieri* (Fig. 20) greeting devotees on their way to Makahi Temple, but with pride of place going to Nightingale Shrubbery Park where we located, much to the consternation of nearby courting couples, another rarely collected species *Folioceros kashyapi* (Figs. 21 & 22). One evening we shared with Dr Ashish Kumar Asthana and his wife, the equally distinguished Indian bryologist Dr Geeta Asthana, and were able to establish a framework for close collaboration including sharing morphological and molecular data and joint publications on diverse aspects of Indian hornwort biology.

We simply can't wait to for a further Indian adventure with the Western Ghats, the hill station of Mussoorie and the glaciers beyond at the top of our list. This expedition fulfilled our wildest bryological expectations on top of



△Figs. 16-19, clockwise from top: scanning electron micrographs of *Folioceros assamicus* showing dimorphic gemmae, large and thalloid (16) and small 1-2 celled (arrowed, 17); admiring *Notothylas* by the Teesta river; *Haplomitrium indicum*, Lava village. Silvia Pressel/Jeff Duckett



<Figs. 20-22, top to bottom: *Notothylas cf. levieri*; *Folioceros kashyapi* with its lovely marginal gemmae and its orange antheridia; a view of the thallus with antheridia under the SEM. Silvia Pressel/Jeff Duckett

trip, remained in perfect health throughout even after consuming the carnivore versions of all of these, albeit with great trepidation.

Acknowledgements

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which Silvia was able to continue her love affair with steam trains and try a lot of new vegetarian dishes (channa bhaturi = Tibetan bread, paper dhosas, momos, Himalayan noodles, pakoras, diverse thalli and tukpas to mention but a few) and Juan Carlos, unlike on his previous Indian