

## THE IMPACT OF COLD AND FROST ON TERRESTRIAL VEGETATION IN HONG KONG

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Despite its location on the northern edge of the tropics, Hong Kong is subject to periodic influxes of cold air from the north which can reduce temperatures to zero or below on high ground. On one occasion - on 18 January, 1893 - the temperature fell to 0°C at the Royal Observatory (near sea level) and icicles hung from the rigging of ships in Victoria Harbour. The 1819 edition of the Xin'an County gazetteer records an earlier extreme cold event when, on 4 March 1757, there was "frost over one foot thick" (Ng 1983). According to Peterson (1981), there are two different meteorological situations associated with frost in Hong Kong: "advective" cooling, when a cold surge brings strong winds, cloud and often rain; and radiation cooling in calm air under clear skies. On 28 December, 1991, an advective cold surge produced temperatures below 5°C all over the Territory and sub-zero temperatures at high altitude. At Tate's Cairn (576 m) the temperature was at or below zero from 0800h on 28 December until 1000h on 29 December, with an absolute minimum of -2.5°C (Royal Observatory Hong Kong). Hourly temperature readings are not available for Tai Mo Shan but the absolute minimum recorded (at about 850 m) was -4.7°C. Light rain resulted in ice formation on vegetation from about 480 m upwards. From all the available evidence, it seems likely that sub-zero minimum temperatures occurred down to about 400-450 m on Tai Mo Shan and that, over the whole Territory, the "frost line" varied between 250 and 550 metres.

The impact of the cold on plant species was highly selective and varied with altitude. Both the intensity and the longevity of low temperatures presumably increased with altitude but, in the absence of measurements of either parameter, their effects cannot be separated. The data reported here are the results of a survey of cold damage to plants on Tai Mo Shan, the area around Tate's Cairn, and many sites at lower altitude, between 3 and 18 days after the cold event. Caution has been observed in attributing minor damage to the effects of cold because the leaves of many species are already in poor condition in late December. One common effect - the acceleration of senescence and fall in already senescent leaves - has also been ignored as unlikely to be of ecological significance. It has not been possible so soon after the event to assess the extent to which individual plants have been killed. Although many herbaceous species and some woody plants seem unlikely to recover, for others even total leaf loss - particularly at the end of the growth season - is probably no more than a minor setback.

The minimum temperatures recorded at sea-level during the cold event ranged from 2.1°C (Tuen Mun) to 4.9°C (Airport). Very few native plant species were visibly injured in this temperature range. The most conspicuous damage was to the small coastal tree, *Macaranga tanarius*, which is also widely planted inland. Typically the youngest and oldest leaves suffered most but the extent of injury varied greatly and some individuals appeared unscathed. At Mai Po Marshes, newly-expanding leaves of *Avicennia marina* were also killed on some shoots of some individuals, particularly at the seaward margin of the mangrove. Significantly, both *Avicennia* and *Macaranga* are, in Hong Kong, near the northern limits of their vast, tropical ranges.

In contrast to the native flora, chilling injury to exotic species, both cultivated and naturalized, was more widespread. Among the naturalized exotics, the aggressively weedy *Mikania micrantha* suffered significant leaf damage in all parts of the Territory, even where the temperature did not fall below 4-5°C. This species is native to the lowlands of tropical America so this cold sensitivity is not surprising. Other exotic weeds showing consistent chilling injury were also all of tropical origin: *Ageratum conyzoides* (from tropical America), *Catharanthus roseus* (Madagascar) *Ipomoea cairica* (Africa), *Lantana camara* (tropical America), and *Synedrella nodiflora* (tropical America). At higher altitudes, on the Peak and along Route Twisk, the range of species damaged gradually increased, including *Ageratum houstonianum* (tropical America), *Crassocephalum crepidioides* (Africa), *Elephantopus tomentosus* (tropical America) and *Euphorbia hirta* (tropical America).

Above about 250 m on Route Twisk, the first damage to native, non-coastal species was visible. It is not known how low the temperature fell here but the available evidence suggests it did not get down to zero. Two fig species, *Ficus hispida* and *F. fistulosa*, the treelet, *Aralia chinensis*, and a

fern, *Blechnum orientale*, seem to be the most cold-sensitive. Interestingly, the figs and the *Blechnum* are also found throughout lowland Southeast Asia. Widespread, but still highly selective, damage to native species started about 450 m (just above the estimated "frost line"). Only common species are listed here. Between 450 m and 550 m, partial or complete leaf death occurred in the four species mentioned above, plus *Aporosa chinensis*, *Breynia fruticosa*, *Bridelia tomentosa*, *Bischofia trifoliata* (planted here, though native), *Embelia laeta*, *E. ribes*, *Helicteres angustifolia*, *Inula cappa*, *Melastoma candidum*, *Melastoma sanguineum*, *Psychotria rubra* and *Saurauia tristyla*. Similar, but usually less pronounced, injuries were observed in many of the same species near the summits of Tate's Cairn and Kowloon Peak.

With increasing altitude, the degree of damage increased in the above-listed species (where they could be found) and more species showed signs of frost damage. By 700 m, *Antirhea chinensis*, *Chrysanthemum indicum*, *Ficus hirta*, *Glochidion* spp., *Psychotria serpens*, *Rhodomyrtus tomentosa*, and *Schefflera octophylla* were also severely injured, with the extent of injury apparently unaffected by exposure, aspect or the presence of a tree canopy. Among the exotics, *Lantana camara* and *Mikania micrantha* looked completely dead. In contrast, many other native species showed little or no visible injury at 700 m. Common frost-resistant woody species included *Ardisia crenata*, *Camellia* spp., *Euonymus chinensis*, *Eurya* spp., *Ilex* spp., *Ilea chinensis*, *Ligustrum lucidum*, *Lonicera* sp., *Machilus* spp., *Milletia nitida*, *Phoenix hanceana*, *Pittosporum glabratum*, *Rhaphiolepis indica*, *Sarcandra glabra*, *Ternstroemia gymnanthera*, *Viburnum odoratissimum*, *Zanthoxylum scandens*, and all the Fagaceae.

Towards the summit of Tai Mo Shan (957 m), most of the more sensitive species are absent and signs of frost injury began to appear in some of the species that were undamaged at lower altitudes, including *Machilus* cf. *thunbergii* (but not the other *Machilus* species), *Rapanea nerifolia*, *Rubus reflexus* and *Melastoma dodecandrum*. However, even in the highest and most exposed positions, many species were completely unaffected and some (e.g. *Eurya chinensis* and *Pittosporum glabratum*) were in flower.

The pattern of frost damage among plant taxa is not random. All the more frost-sensitive woody species are members of genera in which the majority of species occur in the tropical lowlands, south of Hong Kong. All the most frost-tolerant woody species, in contrast, are in genera with extensive extra-tropical distributions and which are typically rare or absent in tropical lowlands. The neatness of this pattern is somewhat obscured when species of intermediate tolerance are looked at, but it is striking none the less. Such a pattern would be no surprise to a horticulturalist but it is important to remember that these are all native species, in which one might have expected the biogeographical heritage to have been obscured by evolutionary adaptation to local environmental conditions. This is thus an example of "phylogenetic inertia", where ancestry has apparently limited the response of a taxon to directional selection.

The great frost of January, 1893 produced similar but more severe effects on the vegetation of Hong Kong Island. The greater degree of damage may, in part, have been the result of the longer period of cold, with at least four days of frost at higher altitudes. Unfortunately, there were no records of temperatures or vegetation damage from the area which is now the New Territories, where even lower temperatures must have occurred. Above 250 m on the Island, *Bischofia trifoliata*, *Blechnum orientale*, *Ficus hispida*, *Melastoma candidum* and *Rhodomyrtus tomentosus* were killed outright and many other species suffered leaf damage (Skertchly 1893). More than eighty species of exotics were also injured.

One interesting question that arises from these observations is the extent to which such events - or rarer, even colder, extremes - have excluded cold-sensitive taxa from the local flora. The complete absence of the lowland tropical families Dipterocarpaceae and Myristicaceae is an obvious example. Hong Kong's mean climatic parameters are little different from those of areas supporting Malayan-style tropical rain forest in southwest Yunnan at similar latitudes. The severity and frequency of extreme cold periods is the simplest explanation for the differences in flora and vegetation.

All plant names follow Anon (1978), except *Crassocephalum crepidioides* (Benth.) S. Moore, *Mikania micrantha* HBK, and *Zanthoxylum scandens* Bl.

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