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Research Paper

Epiphytic strangler trees colonizing extreme habitats of building envelopes in Hong Kong

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ABSTRACT

Trees growing spontaneously on building envelopes, as wall vegetation, denote unique urban ecology. This study investigates the tree flora, substrate, and colonization-development factors on poorly-maintained buildings in Hong Kong. Field surveys gleaned data on species composition, microhabitat, shoot-root dimensions, and biomass structure. The survey sampled 567 trees. They belonged to ten species, distinguished as strong stranglers, moderate stranglers and non-stranglers. Strong stranglers, such as the native *Ficus microcarpa* and *F. virens*, were dominant, with diaspores dispersed mainly by frugivorous birds tapping cultivated and ruderal trees. Most trees had limited crown spread and height, and the larger ones were strong stranglers. The compact tree form, reflecting growth constraints, limited their landscape-scenic contributions. Most surface roots displayed restricted lateral growth contrasted by more vertical extension. Five microhabitats were identified. Two mainly vertical ones accommodated 42.3% of the trees, including wall vertical surface holding the most, and pipe surface. Three mainly horizontal microhabitats, more conducive to seed lodging and tree establishment, held 57.7%, including awning & ledge, roof top & edge taking the second largest share, and window sill & canopy. The stranglers scaled more vertical sites, whereas non-stranglers more horizontal. Root-shoot and root-biomass ratios reflected microhabitat controls. The findings were discussed vis-a-vis pre-adaptation of stranglers to vertical-habitat existence, enabling and restrictive microhabitat traits, plaster degradation as critical pre-condition, leap-frog succession and species paucity, analogy with rocky cliff habitat, and application to building-tree management.

1. Introduction

Vegetation commonly emerges spontaneously on various human constructions, both on ruins and buildings. The large trees clinging on masonry structures of Angkor Wat offer vivid reminders of nature's assiduous and unremitting ability to colonize what has been abandoned by humans (Uchida, Ogawa, Maeda, & Nakagawa, 1999; Caneva et al., 2003, 2015). Such rebirth of nature could happen quickly in the genial humid-tropical conditions. Whereas herbs and sometimes shrubs are dominant on such elevated habitats in temperate latitudes (Bolton, 1985; Galera & Sudnik-Wójcikowska, 2000), sizeable trees can often develop in the tropics (Jim, 1998; Jim, 2013). The occurrence of suitable tree species with adaptations to establish and thrive on artificial structures and substrates constitute the critical prerequisites.

Human settlements show numerous anthropogenic surfaces such as building envelope, wall and paving, which are available for opportunistic colonization by ruderal plant species or synanthropic vegetation (Pyšek et al., 2004; Šilc, 2010), including apophytes which are native species growing in disturbed sites. Such habitats in cities are largely impermeable and harsh, amenable mainly to a small group of herbaceous and non-vascular life forms. Due to deficiency in substrate thickness, volume and quality, and difficulty of securing anchorage, arboreal vegetation can only grow occasionally on vertical surfaces (Lisci & Pacini, 1993a; Lisci & Pacini, 1993b). They can be placed at the polyhemerobic type near the artificial end of the hemeroby scale (Sukopp, 1976), indicating strong human impacts and artificial habitat conditions.

Arboreal vegetation could colonize ruins but usually would not be tolerated on occupied buildings for practical reasons, as the searching tree roots, sheer tree weight and dynamic wind load could damage buildings (Jim & Chen, 2011; Wee, 1992). It is therefore an anomaly to find hundreds of trees growing spontaneously on old buildings in urban Hong Kong. As one of the most compact cities in the world, buildings, roads and impervious hard surface cover most of the built-up areas. The ground level has meager public open spaces at merely 2.9 m^2/person (Jim & Chan, 2016), which is one of the lowest in the world for cities with a similar population. The built-up areas are characterized by exclusion of nature, yet in queer niches on building envelopes, trees manage to find footholds to thrive.

This study explores tree growth on buildings in Hong Kong, focusing

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on strangler figs (Holbrook & Putz, 1996a; Holbrook & Putz, 1996b; Prosperi, Caballe, & Caraglio, 2001) with innate ability to grip the extreme habitats of external walls. The research objectives include: (1) Assessing species composition and biomass structure, including configuration of surficial roots, of arboreal vegetation on buildings; (2) Understanding the intimate association between house trees and key vertical-habitat traits such as building height and substrate properties; and (3) Interpreting underlying factors and processes of colonization of building envelopes by epiphytic strangler figs.

2. Review of vegetation colonization of walls

Vegetation can inhabit walls in human settlements to generate a unique type of secondary habitat filled with synanthropic vegetation. Such vegetation collectively nurtures by spontaneous colonization a rich assemblage of wall flora (Darlington, 1981; Segal, 1969; Woodell, 1979). The walls offer a novel ruderal station for some specialist plants to establish, including natural vegetation dwelling on rocky or cliff sites which are habitat analogs sharing similar environmental conditions (Ceschin, Bartoli, Salerno, Zuccarello, & Caneva, 2016; Yuan, Fang, Fan, Chen, & Wang, 2006). However, individual walls have relatively low alpha diversity and impoverished flora. Their vertical or nearly so posture differentiates them from engineering slopes formed by cutting or filling which are usually below 45 degree. Three main kinds of walls furnish different abiotic conditions for plant life.

Retaining walls hold aft-soil behind the facade to supply moisture and nutrients for plants with roots that can penetrate into it (Jim, 2014). City defence walls embodying a large soil volume in their core are tantamount to retaining walls as a plant habitat (Kolbek, Valachovic, & Misikova, 2015). Traditional masonry retaining walls have numerous joints between individual blocks. For dry walls (no mortar between masonry blocks), roots can penetrate the joints to reach the aft-soil. The intimate association between roots and aft-soil can strengthen plant anchorage to permit diverse species composition and growth forms (Uchida et al., 2015), including trees which are uncommon in temperate latitudes (Altay, Özyiğit, & Yarci, 2010; Caneva, Cutini, Pacini, & Vinci, 2002; Krigas, Lagiou, Hanlidou, & Kokkini, 1999; Świerkosz, 2012) but frequently found in the tropics (Jim, 2013; Jim, 2014). Modern retaining walls increasingly use monolithic reinforced concrete which cannot be penetrated by roots to deprive cities of mural biodiversity and landscape.

Free-standing walls, exposed to the environment, have surface conditions regulated by ambient weather (Darlington, 1981). Usually limited in height, they offer both sides for plant colonization. Stone or brick walls are more receptive to plant growth due to surface roughness and mortared joints. The recessed (with gaps) or ribbon (with protrusions) mortar pointings provide more micro-sites for seed lodging and root gripping by epilithic plants. The smooth surface of flushed pointing is less amenable to plant establishment. Without a soil core, the restricted substrate volume limits plant size and abundance.

Building walls have the external side exposed to the elements. They provide the largest surface areas in a city vis-a-vis other wall types. However, they have not brought large-scale spontaneous greening to cities. Plant colonization tends to occur on older buildings including castles, other fortifications (Caneva, De Marco, Dinelli, & Vinci, 1992; Caneva, De Marco, & Pontrandolfi, 1993; De Neef, Stewart, & Meurk, 2008; Trocha, Oleksyn, Turzanska, Rudawska, & Reich, 2007; Zomlefer & Giannasi, 2005), or archaeological ruins (Caneva et al., 1992; Ceschin et al., 2016). Some studies cover various walls that include old buildings (Altay et al., 2010; Láníková & Lososová, 2009; Simonová, 2008). The archaeological remains or old structures provide weathered or dilapidated habitats which are more receptive to plant growth due to surface roughness, moisture holding capacity and nutrient supply. The building envelope can range from vertical to inclined, and furnish different microhabitat conditions to nurture vegetation.

In the tropics, young occupied buildings with degraded envelope due to poor maintenance can be colonized by plants (Jim & Chen, 2011; Wee, 1992). Some strangler-fig trees (genus *Ficus*) manage to survive especially on old buildings in the tropics. Regular maintenance of the building envelope is inimical to plant establishment. The urge to remove wall vegetation, especially strangler figs to avoid structural damages, has suppressed their presence in cities (Wee, 1992). Masonry building walls can foster plant growth. Outside the tropics, plants may colonize horizontal surfaces of buildings such as roofs, terraces and stairs (Galera & Sudnik-Wójcikowska, 2000; Hruška, 1987). This confined growth habit indicates that extra-tropical species lack the adaptive capability to grip vertical surfaces.

3. Study area and methods

Three densely-developed districts in the core city area of Hong Kong were chosen for field studies. They include the oldest Central-Western (CW) developed since the 1840s, Yau-Tsim-Mong (YM) since the 1860s, and relatively young Kwun Tong (KT) since the 1960s. They cover respectively 12.6 km^2, 7.0 km^2 and 11.3 km^2, holding 240,600, 339,400 and 643,600 population in 2016 (Census and Statistics Department, 2017). Most buildings in these districts are private, respectively containing 3248, 3051 and 946 high-rise blocks, including some built before the 1960s (over half a century old). Due to negligence and lack of public awareness, many ageing buildings are poorly maintained (Ho, 1993; Hui, Wong, & Wan, 2008), providing opportunities for vegetation growth that may include trees.

A reconnaissance of the sampled sites provided the foundation to develop a field record form to glean systematic data on trees, habitats and environs. It was pilot tested and refined before gleaning live data. An electronic hypsometer (LaserAce, MDL Laser Systems, York, UK) measured from the street level tree height, crown and root spread, and elevation of tree base. Habitat conditions were assessed by building condition, attachment position, attachment surface orientation, surface paint condition, plaster condition, and surface moisture status. Species identification was based on Hong Kong Herbarium and South China Botanical Garden (2007, 2008, 2009, 2011). Field work was conducted in summer when the trees displayed optimal growth.

Some numerical indices were developed to assess tree dimensions, tree form, biomass, root spread, root geometry, root cover, substrate suitability, and tree performance. They were computed using the detailed numerical field data divided. The computation methods and formulae are explained in the footnotes of Tables 1–6. Statistical analysis was conducted by IBM SPSS version 24, and other calculations by MS EXCEL 2016.

4. Results

4.1. Tree species composition and abundance

The buildings accommodate 567 trees belonging to 10 species, divided into three groups according to strangler habit (Table 1). The strong stranglers include native *Ficus microcarpa* and *F. virens*, and exotic *F. benjamina*. Based on local and other tropical studies, they demonstrate vigorous ability to strangle host trees and secure footholds on old stone walls and buildings (Jim, 2014; Jim & Chen, 2011; Wee, 1992). The moderate stranglers, including *F. subpisocarpa, F. religiosa* and *F. rumphii,* produce few aerial or adventitious roots and grip host trees mainly by normal roots (Galil, 1984). The six strangler species fall under genus *Ficus* under moraceae (Mulberry family). The remaining four species, *F. variegata, Bombax ceiba, Brousonnetia papyrifera* and *Citrus grandis*, are non-stranglers; their existence on buildings is likely accidental.

Strong stranglers dominate the building trees, especially *F. microcarpa* taking 58.9% and *F. virens* 27.3% (Table 1; Fig. 1). These two species are favored by common availability of seed sources due to popular planting in urban parks and roadsides, and common ruderal