Understanding the Effects of: Climate Change on Tropical Urban Biodiversity

Text by Richard Corlett
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The recent explosion of interest in tropical urban ecology has been triggered by the realisation that most of Earth's 7 billion people now live in urban areas (the 50 percent mark was reached in 2008) and that this percentage is increasing most rapidly in the tropics. Indeed, most global population growth over the next few decades—an extra 2 billion by 2050!—will occur in tropical cities. Arguably this is a good thing, since high-density cities can be less environmentally damaging than spreading the same number of people over a larger area. Urban ecology, it is hoped, will help us avoid some of the problems associated with urbanisation outside the tropics and allow us create healthier, more attractive, and more sustainable cities, while reducing adverse impacts on wild species and natural habitats. Making nature more visible and more accessible to urban residents may also contribute to the greater environmental awareness that will be needed to overcome the multiple environmental crises now confronting the tropics. Moreover, many urban ecologists believe that studies in the novel environments of urban areas can lead to new insights into ecology and conservation biology.

This new respectability for urban ecology—once the Cinderella branch of the discipline—has coincided with the realisation that urban biodiversity and urban ecosystems are on the front line of the fight against climate change. Cities are a continually changing habitat for wild species at the best of times, with roads widened, buildings replaced, topography remodeled, and open spaces infilled by new construction, but they now face a threat that was rarely even mentioned in books and articles written a mere decade ago. It looks inevitable that global climate change will affect all of the world's cities over the next few decades, with all of them getting warmer and most also experiencing less predictable changes in rainfall and other aspects of climate. Coastal cities—and most big tropical cities are coastal—are also threatened by rising sea levels.

In larger cities, this impact of global climate change will be on top of local changes arising from urbanisation itself: the so-called "urban heat island effect". This is the result of a variety of factors, including waste heat from buildings and vehicles, dark surfaces that absorb heat from the sun, the reduction of evaporative cooling from vegetation and soil, and streets lined by tall buildings that trap heat. As a result, tropical urban areas are almost always warmer than their rural surroundings, with the difference generally greatest on still evenings. For example, in Singapore, high-density urban areas can be as much as four degrees centigrade warmer than rural areas several hours after sunset. Conversely, green areas, such as large urban parks, can be several degrees cooler than their surroundings. The impacts of the urban heat island effect on biodiversity have not been studied in the tropics, but it is well documented in European cities that high-density urban areas favour plant and animal species from warmer climates. Indeed, the association between plant distributions and temperature is so strong that spontaneous (i.e., not planted) flora can be used to map the heat island in these cities.

Singapore has warmed about 0.25 degrees centigrade per decade over the last 50 years, as a result of both local and global effects, and the National Climate Change Secretariat is expecting an additional 2.7 to 4.2 degrees centigrade of warming by the end of this century. These predictions, which are similar to those for other tropical cities, are based on the IPCC's moderate "A1B scenario" for global greenhouse gas emissions. However, this scenario is looking overly optimistic at present, with actual emissions rising much faster than expected. It is probably impossible to predict greenhouse gas emissions more than a decade or so ahead with any reliability, but a much more rapid warming is certainly possible, with a rise of three to four degrees centigrade in temperature by mid century, unless a global agreement on reducing emissions is reached soon. Although the rainfall predic-

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tions from different climate models vary too much to be useful, the frequency and length of dry periods have been increasing in Singapore since the 1960s, with the two longest periods since records began occurring in 2005 (40 days) and 2009 (42 days). The "haze" from regional fires may also be intensifying droughts in Southeast Asia by suppressing rainfall.

A five-degrees-centigrade rise in temperature would give London a climate like the south of France today and New York a climate like South Carolina. Thus, if residents of these cities want to know what their future climate and ecosystems will be like, they just need to look south. In contrast, the expected temperature rise of three to four degrees centigrade in equatorial Singapore would give it a climate that exists nowhere on Earth today and, moreover, has not for several million years. There are hotter places than Singapore, certainly, but none that combine heat with year-round rainfall and constant high humidity. The absence of a modern analogue for Singapore's future climate makes it very difficult to predict the impact on biodiversity (or, indeed, on people), but several general trends are likely.

Urban areas are already warmer and drier than any natural habitat, so the increasing contrast between future urban climates and the past environments in which Singapore's native plants and animals evolved will further reduce the suitability of urban habitats for native species. Currently most native species in urban areas—including widely planted native trees such as the sea apple and yellow flame—are from exposed coastal habitats, where micro-climatic extremes are common. Other urban natives come from the rainforest canopy, which is also an exposed habitat, although temperatures there are moderated by the continuous supply of water brought up from the soil below and transpired from the leaves of canopy trees. The ultimate heat tolerances of species in neither group are known, but it

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seems unlikely that plants and animals adapted for millions of years to temperatures below 34 to 35 degrees centigrade will thrive much above this range. Droughts are also a potential threat, although many species native to Singapore are also found in parts of the region that already experience a regular dry season of one to two months.

While most native species are expected to do poorly, many aliens are likely to do better. Most alien species in Singapore, including both planted ornamentals and free-living weeds and animals, come from drier, more seasonal climates and are able to tolerate a several-month dry season with maximum temperatures often well above those that currently occur in Singapore. The house crow and common myna, for example, are native to parts of India where annual maximum temperatures exceed 40 degrees centigrade. Aliens already outnumber native species in most tropical cities, but the effects of climate change are likely to exacerbate this trend. While alien species are by no means all bad news—imagine Singapore without Central American rain trees and carpet grass—the resources (space, light, food, nesting sites, etc.) used by aliens are not available to native species. Moreover, the same climatic trends are expected in many tropical cities, leading to increasing homogenisation of their flora and fauna.

While Londoners may view the prospect of a Mediterranean climatic future with equanimity, any increase in temperature is bad news for Singapore and other tropical cities. What can be done to reduce this threat? A global agreement on cutting greenhouse gas emissions would be the best answer, but that is beyond the control of individual cities and indeed countries. The one element that can be modified locally is the urban heat island effect, and reducing that could go some way towards mitigating the impact of a global rise in temperature, at least for a few decades. This is partly a problem in architecture, engineering, and urban planning, but the urban ecologist can also make a contribution. Numerous studies have now shown the mitigating effects of urban vegetation on the heat island effect, from local to city scale. The mechanisms of this "oasis effect" include the shading of windows, walls, and roofs, and the evaporative cooling of leaf surfaces by water brought up from the soil.

Predicting the impacts of urban greening on local climate is a complex task, since there are many confounding factors, but modeling studies suggest that the changes in the amount of greenery must be dramatic to have a significant cooling effect on a citywide scale. A reduction of temperature by a degree centigrade or so seems to be the most that is usually practical, although much larger effects are possible in localised areas. Greening can also be combined with engineering measures, such as increasing the average albedo (reflectivity) of unshaded surfaces so less heat is absorbed, to give larger overall reductions. Trees are more effective than turf grasses, because of their shading effect, and maximising tree cover is the simplest way to reduce temperatures at the pedestrian level. Achieving this in existing tropical cities will require not only replacing grass and shrubs with trees, but also replacing some existing impervious surfaces by vegetation. Replacing buildings by vegetation would reduce local temperatures even more, but at the expense of displacing people to the urban fringe and increasing overall city size. Green roofs, roof gardens, and vertical greening can also contribute to urban cooling, although their impact is mostly through reducing energy consumption by buildings.

An engineering approach to urban greening will not necessarily benefit native biodiversity, but a win-win scenario for people and wild species may be possible if a diversity of native plant species is planted wherever practical and if efforts are made to produce the multi-layered structural complexity that most native animals prefer. Dense plantings will also maximise the cooling effect, although they may increase humidity, which is good for native species but may reduce human comfort to some extent. These general prescriptions will need to be combined with measures that target desired native species individually. These might include planting larval and adult food plants for butterflies and moths, providing artificial nest-boxes for birds that would naturally make use of old and dying trees, and the supplementary feeding of species that suffer from competition with invasive aliens.

If global and regional temperatures rise by more than one to two degrees centigrade, however, reducing the urban heat island effect is unlikely to be enough and urban temperatures will also increase. As temperatures rise, or if droughts become prevalent, a complete reliance on native species may no longer be possible. In this situation, there is a clear hierarchy of preferences, placed in descending order. First, wherever possible, native species grown from local seed sources are preferred, with native coastal species most likely to cope with the extra heat and drought. The second preference would be to plant better-adapted genotypes (natural varieties) of native species, imported from warmer and drier parts of their natural ranges. Finally, if the use of non-native species is necessary, those from neighbouring regions of tropical Asia should be prioritised over those from further afield, since these neighbours are more likely to provide resources

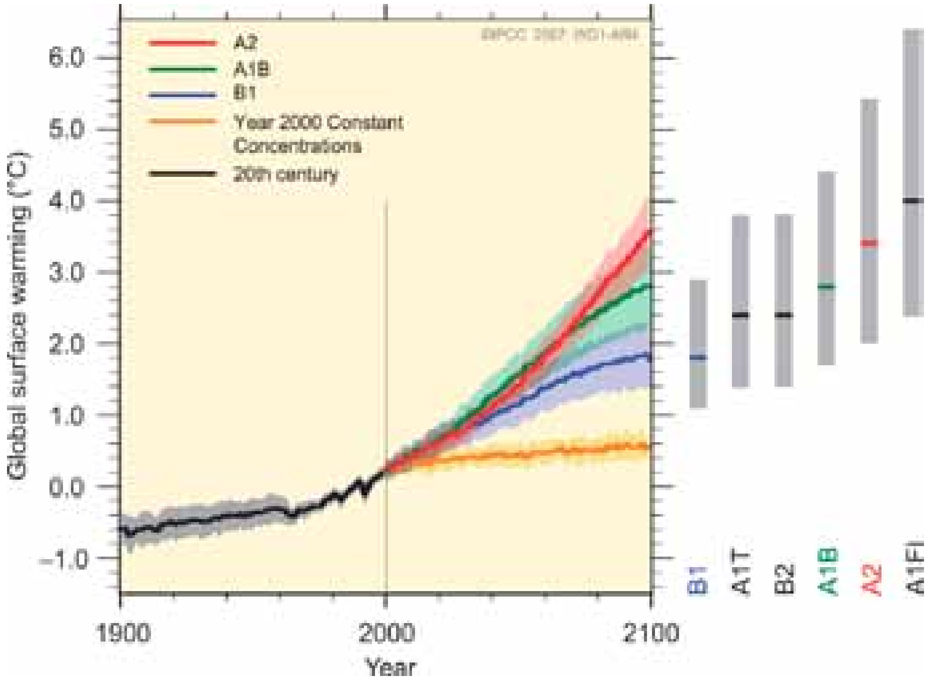

FIG. 1. Predictions of global warming over the remainder of the twenty-first century depend on which greenhouse gas emissions scenario (B1, A1B, A2, etc.) and climate model are used. This graph, taken from the 2007 IPCC Fourth Assessment Report, shows how the predictions for global average temperature by 2100 (the grey bars on the right) vary depending on the combination of assumptions. Most studies use the moderate A1B emissions scenario, but global emissions are currently far exceeding this.
(Source: IPCC Fourth Assessment Report 2007).

(such as nectar, fruits, and leaves) that can be used by surviving native animals.

With further increases in tropical urban temperatures—of three, four, or more degrees centigrade—current prejudices against aliens will likely give way entirely to concerns for human health and comfort. Plants will still play a role, but they will be selected from the global species pool for their desirable properties and, very likely, be genetically modified to enhance these. In addition to manipulating heat and drought tolerances, increasing the leaf area index (the number of leaves above a given point on the ground) and the albedo (the proportion of sunlight reflected rather than absorbed) should enhance their effectiveness in mitigating urban warming. Urban animals too are likely to be chosen for functional reasons—colour, song, pest control, and so forth—and may need modification. A fully domesticated nature will not be ideal, but it may be the best we can do in a difficult situation.

Finally, the focus in this essay has been on the impacts of climate change on cities, but cities are also the major sources of greenhouse gases, so the impact of cities on the global climate should not be forgotten. Urban trees directly remove carbon dioxide from the atmosphere, storing it in their wood, but the vegetation density achievable under urban conditions is insufficient for this to significantly reduce overall urban emissions. Fortunately, high density living brings opportunities for energy efficiency in building design and transport systems that are unavailable in rural areas, and increasing efficiency is a major focus of research in Singapore and other tropical cities. A global agreement to reduce carbon emissions would force greater efficiency on all the world's cities, but common sense suggests that we need to start now, since urban redevelopment is slow and retrofitting expensive. People and biodiversity are often in conflict in the tropics, but in relation to climate change they are on the same side. Save our climate! CG

Further Reading:

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