NATURE IN SINGAPORE **Supplement 1**: e2022068
Date of Publication: 15 July 2022
DOI: 10.26107/NIS-2022-0068
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Ten lessons from Singapore for the conservation of tropical biodiversity

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Abstract. The exceptional density of plant and animal collectors and collections has made Singapore the world's leading case study of tropical biodiversity under stress. Singapore shows how much native biodiversity can survive under extreme human pressure, but there are also other lessons that can be learned from this small island. Despite two centuries of collection efforts, the biodiversity inventory is very far from complete: a complete list would probably exceed 150,000 species. Invasive species also thrive in Singapore and increasingly dominate outside the nature reserves. Climate change is a threat, but current evidence does not allow us to say, with confidence, how much of one. Many of the other changes that have occurred in Singapore since 1819 are irreversible on a human timescale, so, while conservation should learn from the past it must necessarily look towards the future. Conservation of small populations in small areas of modified habitats needs to be species-focused and pro-active, based on individual action plans for all species identified as vulnerable. No ecosystems in Singapore are anywhere near intact, but there is no evidence yet that species losses are leading to losses of ecosystem functions. Singapore leads as a tropical case study, but the proximity of world-class labs and tropical biodiversity provides an opportunity for leadership in other areas of conservation research and practice. Two final lessons from Singapore are, firstly, the importance for aspiring future conservationists of learning to recognise species of at least one taxonomic group in the field, and, secondly, the big difference that single individuals can make to biodiversity conservation.

Key words. Biodiversity, conservation, deforestation, human impacts, islands, tropics

Recommended citation. Corlett RT (2022) Ten lessons from Singapore for the conservation of tropical biodiversity. Nature in Singapore, Supplement 1: e2022068. DOI: 10.26107/NIS-2022-0068

INTRODUCTION

When Stamford Raffles landed in Singapore in January 1819, the island was nothing special from a biological point of view: just a small (570 km^2) equatorial island, like many others, separated by shallow straits less than 1 km wide from the southern tip of peninsular Southeast Asia. Although Raffles collected plant specimens on his first visit and brought three naturalists with him on his second, at the end of May (Low, 2021; Low et al., 2021), his choice of Singapore was political, not biological. What has made Singapore special since 1819 has been the people, and what has made it special biologically has been the biologists, both visitors and, later, long-term residents (Corlett, 2013). A recent paper on the history of plant taxonomic research in Singapore (Middleton & Turner, 2019) highlights the number and diversity of people who have collected plant specimens in Singapore since William Jack's brief visit in 1819, and the exceptional density of plant collections. Plant collection, description, and publication have had their ups and downs in Singapore but are now certainly on an up. There are no histories this detailed for other groups of organisms, but these groups have undoubtedly seen the same ebb and flow in collection activity, and in most cases, this has resulted in a cumulative density of collections that far exceeds anywhere else in the Southeast Asian region. The same biologists, both visitors and residents, have also made massive contributions to the biological exploration of the whole region, but here I will focus on Singapore and the general lessons that can be learned from it for tropical biodiversity and its conservation in the Anthropocene.

LESSONS

Lesson 1: Even in a tiny equatorial city-state, there is still something to conserve. Two centuries of some of the most intense human impacts in the tropics, including the clearance of more than 98% of the original terrestrial vegetation, a century of uncontrolled hunting, and the destruction of most coastal ecosystems, has resulted in some of the highest national extinction rates in the world. Recent estimates that allow for the loss of species before the intensive collections of the late 19th and 20th centuries are fairly similar for plants (33–38%; Kristensen et al., 2020), birds (33%; Chisholm et al., 2016), and butterflies (46%; Theng et al., 2020). Yet Singapore still supports an amazing diversity of wild species, with the same studies estimating that 1,612 native plant species, 137 native bird species, and 282 native butterfly species are currently present on this small (now c. 730 km^2) island. Conservation is still necessary and worthwhile.

Lesson 2: The inventory is still very far from complete. Despite the exceptionally high number and diversity of collectors and taxonomists who have lived in or visited Singapore since the early 19th century, only the bird and mammal lists are more or less complete. New native species—new records for Singapore and often new to science—continue to be added in all other taxonomic groups (e.g., Ng & Corlett, 2011; Ho et al., 2019). A non-exhaustive literature search by the author found at least 40 records of apparently native species in Singapore, newly published in 2021, spread across the taxonomic spectrum, and at least five species new to science.

How many more species can we expect? The most complete national inventory in the world currently is that of the United Kingdom, which has >70,000 species of animals, plants, fungi, and unicellular organisms recorded in the UK Species Inventory (Natural History Museum, 2022). Other European countries report lists of 50,000–70,000 species, most of which are probably less complete inventories of more diverse biota. It is difficult to extrapolate from the inventories of these much larger, but, on a per-area basis, much less diverse temperate zone countries to Singapore, but comparisons of species totals for well-studied groups suggest that a complete Singapore inventory would exceed 100,000 species, probably exceed 150,000, and possibly exceed 200,000. For most groups of organisms for which there are reasonable collections, such as vascular plants (2,215 in Singapore vs. 1,390 in the UK), reptiles (109 vs. 6), amphibians (27 vs. 7), butterflies (282 vs. 57), and dragon- and damselflies (131 vs. 57), Singapore's recorded diversity considerably exceeds that of the UK, despite much more collecting in the latter. The difference is at least as large for less well-studied groups, such as the ants (>100 vs 52), and there are other diverse groups in Singapore, such as the termites, for which the UK has no native species at all. These differences reflect the near-universal polar-tropical gradient of increasing diversity which has persisted despite much higher extinction rates in Singapore than the UK.

Lesson 3: Invasive species are a real problem and one which can only get worse. The good news on invasive species in Singapore has been the resistance of primary and old secondary forests to invasion by non-native species of both plants and animals (Lum & Ngo, 2021). However, most other news is more worrying. Outside the resistant tall forests, invasive species are prominent everywhere, often dominant, and usually increasing in dominance. The total numbers of non-native species established in Singapore increase year by year in most major taxa and, as far as I know, no well-established alien has ever died out or been successfully extirpated, although some (e.g., *Lantana camara*) have declined from their peak abundance. There are still a lot more species in the tropics that could potentially invade Singapore and no reason to expect the rates of introduction will decline.

Unlike most of the developed world, Singapore has never had any general policies or programs of action for invasive species, choosing instead to focus control measures on a few species only after they become conspicuous problems, as with the water hyacinth, house crow, and invasive mynas. Although strict controls on the importation of potentially invasive species may be impractical in an economy so dependent on facilitating hassle-free cross-border trade, a focus on early detection, monitoring, and, where possible, immediate extirpation would surely be cheaper in the long run, as well as better for biodiversity. This would not need massive government resources since finding new records of invasive species is best done by an army of enthusiastic amateurs.

Lesson 4: The threat from anthropogenic climate change to Singapore's native biota is somewhere between negligible and disastrous. This may not sound like much of a 'lesson', but it is a useful illustration of the limitations of our current understanding of climate change and its impacts, particularly in the tropics and perhaps particularly in equatorial Southeast Asia. Outside the tropics or on a mountain, an approximation of the future can be seen by looking towards the equator and/or down slope, but this short-cut does not work on an almost flat, equatorial island. Predicting the future here requires the use of models which, although increasingly complex, cannot be verified when extrapolated beyond the range of conditions experienced in the recent past. The latest (CMIP6) climate models do not agree among themselves on the magnitude and, in some cases, even the direction of future changes in physical climatic variables (IPCC, 2021), and there is even less agreement on the likely impacts of the projected 1–2°C of additional warming and $\pm$ 20% change in rainfall on tropical species and ecosystems. This cascade of uncertainties means that our overall predictions of biological effects are probably still little more than guesses. If species in Singapore cannot acclimate or adapt to these changes, then we can fairly confidently predict massive species losses, since the projected 2100 climate is outside the observed ranges of tolerance for most native species. If, in contrast, most species can acclimate and/or adapt to the projected changes, then species losses from climate change will be low. The reality is likely to fall between these extremes, but neither can be ruled out on current evidence.

Lesson 5: There is no going back in conservation. Conservation has, traditionally, focussed on keeping things the way they are and/or restoring things to the way they were (Corlett, 2016). Neither option is possible in Singapore or, indeed, in most of the rest of the world. There are no pristine ecosystems to preserve in Singapore and many of the changes that have occurred in the last 200 years are irreversible on any reasonable timescale. Some nationally extirpated species could, in theory, be reintroduced from populations outside Singapore, but even with maximum ecological restoration the small potential area of habitat limits the number and types of species that could be reintroduced. Tigers are obviously impractical, so culling wild boar and deer 'with the eye of a tiger', will probably be necessary. Some invasive species could potentially be extirpated but, in most cases, introduction, like global extinction, is forever and future ecosystems will inevitably have a significant non-native component. Soils have been massively modified, buried, or removed over most of Singapore and even in the surviving primary forest areas, their chemistry has been changed by pollutants in the rainfall and dust. Soils take centuries or millennia to regenerate. The global changes in the composition of the atmosphere, in climate, and in sea-levels that have affected Singapore will also not be reversed this century, if ever. Conservation in the Anthropocene must learn from the past but look towards the future (Corlett, 2015, 2016).

Lesson 6. Conservation in small areas needs to be species-focussed and pro-active. The continued losses of native species from protected areas, the failure of century-old secondary forests to converge on adjacent primary forest remnants, the inability of most species previously lost to hunting to re-invade, and the unchecked rise of invasive species, all point to the need for a much more interventionist approach to the management of natural areas than has so far been practiced in Singapore. 'Leave it to Nature' is a practical strategy only where you have large, well-connected protected areas or when biodiversity conservation is not an important goal. Pro-active, species-focussed conservation is the norm in the developed world outside the tropics, but no tropical country has previously had the information or resources to do this for a large number of species. This approach requires that species needing conservation management are identified, their needs assessed, individual action plans written for each species, and appropriate actions taken. It is not possible to manage for the unknown majority of species—at least, not directly— but plants, birds, mammals, butterflies and, perhaps, bees and/or ants, would provide an initial list of targets for terrestrial habitats.

Lesson 7. There is not much evidence for the 'rivet popper' theory of biodiversity. If, as Ehrlich & Ehrlich (1981) argued, species in an ecosystem are like the rivets in an aircraft, we may see no change when a few species (or rivets) are lost but, at some point, the continuing loss of species will result in a catastrophic loss of function. There is no sign of this yet in Singapore. Bukit Timah Nature Reserve is, apparently, still flying despite loss of 30–50% of the 'rivets' (Ho et al., 2019; Lum & Ngo, 2021). We may not, however, be looking at the most sensitive functions. Alternatively, it may be that, with a hyperdiverse biota, most species have potential substitutes. But it would be dangerous to accept this argument without much better evidence. Where pairs of similar species that coexist in nature have been studied in detail, they invariably differ in significant ways.

Lesson 8. Singapore could be doing more for tropical biodiversity. The unique proximity of world-class labs and tropical habitats, embedded in a region that forms a large-scale natural laboratory, provides the opportunity to move beyond local case studies and to tackle some of the big, urgent, questions in tropical biology. Singapore is too small to allow for the independent spatial replication needed for robust large-scale ecological experiments but there are still opportunities for high-impact studies of plant- and animal-thermal tolerances, canopy physiology, and ecological restoration methods, to give just three examples. Case studies are important, and this island has provided many of these, but Singapore could also lead research and conservation practice in other areas.

Lesson 9. Learning to recognise species in the field is still the best basis for becoming a conservationist… but you also need to know how to use the new tools. Virtually all of the leading conservation biologists of the last two generations started with an obsession—often as a teenager, but also frequently developed as an undergraduate—with a specific group of taxa. Being a general 'greenie' is not enough: it appears that you need to believe that ants, or frogs, or birds, or mosses, or butterflies, or stick insects are worth thousands of hours of extra work for which knowledge is the only reward. Only this, it seems, allow one to see 'Nature' not as an undifferentiated mass, however valuable, but as individuals, populations, and species in a struggle for existence in the face of both natural and human pressures. The importance of learning to recognise species in at least one group of organisms still seems to be true today, despite advances in technology, but it is no longer enough. A budding conservationist now also needs GIS (Geographic Information Systems), modelling, and molecular skills, and should at least be aware of new developments in artificial intelligence and robotics, which are beginning to impact both research and practice in conservation. Add to this an ability to communicate science effectively and you have the next generation of conservation leaders.

Lesson 10. One person can make a big difference. Singapore did not have to be a center for biological research, and this has always been a tiny part of what the island did. Stamford Raffles, with his broad biological interests, got it off to a good start (Low, 2021; Low et al., 2021), but the flame has been kept alight—and re-lit when it has gone out—by a succession of individuals who went far beyond what they were being paid for. My personal list includes Nathaniel Cantley, Henry Nicholas Ridley, Richard Eric Holttum, Navjot Sodhi, Peter K.L. Ng, and Hugh T.W. Tan, but more could certainly be added. These people were important not only because of their own research output, but also for both inspiring and facilitating the research of others, and for then ensuring that the results reached the people who can make use of them.

DISCUSSION

Can these lessons be scaled up to tropical Asia and to the tropics as a whole? I think so, for most of them, although in some cases 'multiplying' will be more practical than scaling up as such. Ultimately, all conservation is local and many of these lessons can be applied to any 1,000 km^2 of the human-dominated tropics. Wild species persist in even the least promising of landscapes and the species we see are just the tip of the biodiversity iceberg. Although some losses are predictable, there is also a large element of chance, so it is always worth protecting—and managing—another fragment of habitat. Bukit Timah was logged and isolated in the 19th century, hunted until at least 1940, fought over in February 1942, and is now heavily overused for recreation, but it is still important for conservation (Lum & Ngo, 2021). Multiply Bukit Timah 100 times, or 1,000, or 10,000, and the impact on global tropical biodiversity would be massive.

Multiplying the people will be more challenging but not, I think, impossible. My own experience in tropical Asia and elsewhere in the tropics suggests that enthusiasm for nature is universal, but that the tools for converting this enthusiasm into expertise—nature societies, guidebooks, local natural history journals, sympathetic government authorities, experienced mentors etc.—are more patchily distributed. Where these are all present together, as in several parts of the Neotropics, in India, and increasingly throughout Southeast Asia, the results can be spectacular.

ACKNOWLEDGEMENTS

I spent nine years at NUS, in two separate periods, so the list of people I ought to acknowledge is longer than this essay. I will therefore only mention Hugh Tan, my oldest friend in Asia, Chong Kwek Yan, who invited me to contribute to this special issue, and Peter Ng, who provided useful suggestions and two important new publications.

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Editor's note: The initial version of this paper contained an error in the Recommended Citation. It was reuploaded with a corrected Recommended Citation on the 13th of March 2023.