Cross-sectional view of the 'SuperTrees' conservatory.

Gardens By The Bay

Singapore's growth and development resulted in the replacement of more than 80% of its natural environment with cleared and developed space. To transform the city state into a garden nation required the introduction of flora and fauna into man-made urban space with little of the environmental conditions extant that would support the nurture of indigenous species from the original habitats. While careful and informed planning has managed the incorporation of pockets of natural habitats within the Garden City, the necessity to create more green coverage within an intensely developed equatorial metropolis to combat heat sumps required the enlistment of pantropical species introduced from around the world.

The stakes have been raised even higher as Garden City Singapore seeks transition into being a City in a Garden. Drawing upon accumulated botanic and horticultural expertise from four decades of greening Singapore, the National Parks Board, the government agency that evolved from the pioneering Parks and Recreation Department, now spearheads the initiative to cloak the Island of Singapore with a matrix of green spaces, linking the protected nature reserves to the heart of the new Downtown through a series of parks, vertical and rooftop gardens and greenways.

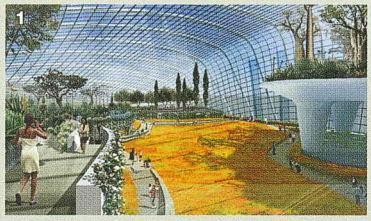
The culmination of this effort is the ambitious Gardens by the Bay project. Following an intensely contested international design competition that attracted 70 entries submitted by 170 firms from 24 countries worldwide, two winning firms worked with the Gardens by the Bay team to produce design master plans for the three waterfront gardens that comprise the 101-hectare Gardens by the Bay. Fringing a brand new reservoir formed by the closure of the bay to the sea when the Marina Barrage was developed, these three gardens, Bay South, Bay Central and Bay East are tasked with meeting a full slate of value propositions. The Gardens will provide the green lung for the evolving new Downtown at Marina Bay. As public spaces, these Gardens will promulgate ownership of a portion of the choicest areas in Singapore for the 'heartlanders' in the housing estates. In a land of perpetual summer, the Gardens at Bay South will create touches of autumn and spring through innovative horticulture. Two cooled conservatories, enveloping cool-dry and cool-moist environments covering two hectares, will allow the introduction of plants into the Singapore landscape from habitats with a Mediterranean type climate, and from cloud forests upon tropical mountains. Eighteen steel 'SuperTrees' rising between 25 to 50 metres in the air, and clad in living skins of epiphytes and tropical lianas, complete the iconic signature of Bay South. Across the fresh water

Bromeliad collection.

Ceiba chodatii at Gardens by the Bay.

the increasing ease of ordering living plants and animals over the Internet. However, more control could be exercised over the two major routes of introduction for potential invaders—the horticultural and pet trades. More work is also needed on the major mechanism by which invasive vertebrates become established in the wild through the deliberate release of animals, either for religious reasons or as unwanted pets. Furthermore, alien introduction is not a simple all-or-nothing process, and there is often a prolonged lag period while population pressure is built up, during which control is still possible.

The third approach, which may often need to be combined with the first two, is the active promotion of native species in urban areas. This is already happening in parks and roadside tree plantings, with a steady expansion in the use of native forest species over the last couple of decades. Whether or not the use of native plants will, by itself, attract additional native animals into urban areas is currently unclear, but, if native seed sources are used, urban plantings can contribute directly to preserving local genetic variation in these species. Other approaches focus on reducing the barriers to native species establishment in urban areas. The best current example of this is the provision of nest boxes in order to mitigate the shortage of natural tree cavities for the re-invading oriental pied hornbills (*Anthracoceros albirostris*). The availability of suitable



(1-3) The cooled conservatories will allow for plants from the Mediterranean type climate and cloud forests.

(4) Construction of the cooled conservatories;
(5) Master plan for the southern and eastern ends of the Gardens.

channel from Bay South, Bay East is developed with rolling terrain and aquatic inlets carved into the bank. Here, trees, shrubs and herbs from the Southeast Asian region hold reign. Land-forming to enhance air and water movement, will also allow microhabitats to develop to increase carrying capacity for local biodiversity. Bay Central links both Bay South and Bay East with pedestrian bridges, creating a waterfront garden promenade that completes a picture-perfect setting for the glass, steel and concrete towers that form the Singapore skyline.

The Gardens by the Bay are conceived to underscore Singapore's commitment to environmental sustainability. In their development, materials are used and systems are developed to ensure maximum efficiency and sustainability in the use of energy and water resources. In developing the cooling strategy for the conservatories, state of the art glazing, water recycling and use of horticultural waste generated during the maintenance of Singapore's parks are critical components. These three gardens sit upon land reclaimed from the sea, and the resultant biodiversity augments the Noah's Ark of fauna and flora that the tropical island nation of Singapore has become. The Gardens by the Bay completes the branding of Singapore as The Tropical City in a Garden. ■ TWK

nesting sites probably limits the numbers of other native species and this could be a fruitful area for research. More generally, the active reintroduction of native species into urban areas is unlikely to be successful unless the reasons for their absence are known and mitigated. The best local example is the oriental magpie robin (*Copsychus saularis*). This native coastal species had become a common garden bird by the 1920s, but was almost eliminated by illegal trapping and, apparently, competition with the expanding myna populations. Reintroduction started in the 1970s and has had varied success, but the magpie robin is certainly more widespread and abundant now than it was 40 years ago.

The Future of Urban Biodiversity

Singapore has a vision for a future in which 'urban' and 'natural' are not automatic opposites. In place of the current situation, where alien-dominated urban habitats surround the last refuges of the native flora and fauna, we hope to see the more tolerant native species spread out from the nature reserves into an increasingly biodiversity-friendly city. A 'City in the Nature Reserve' rather than the other way round. Achieving this vision will require more research and an increasingly active implementation of both our current and our future knowledge of urban ecosystems. ■ RTC

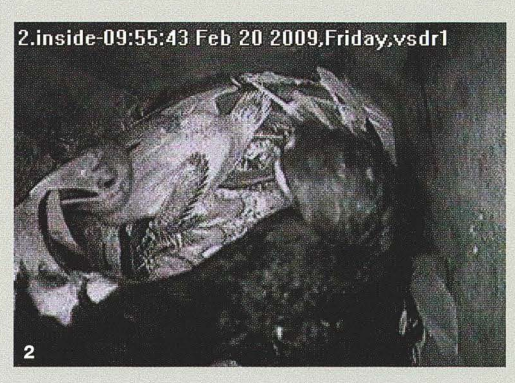
Singapore Hornbill Project

The Singapore Hornbill Project, in collaboration with National Parks Board and Wildlife Reserves Singapore since 2004, seeks to study the oriental pied hornbills (native subspecies: *Anthracoceros albirostris convexus*) in order to better conserve the species. The initial priority of the study was to increase the hornbill population by providing specially designed artificial nest boxes that simulate the increasingly scarce natural tree cavities these birds nest in. Hornbills have successfully bred in these nest boxes, and with each passing season, improvements have been made to their design: they are now equipped with more cameras and electronic sensors to survey behaviour from different angles. The population of less than 15 birds in 2000 has grown to more than 60 individuals in 2010, with at least 12 productive breeding pairs.

In Singapore, the annual nesting cycle of the oriental pied hornbill has been observed to begin in November/December, and lasts until early April to late May. During this time, a breeding pair will enter the courtship and copulation phase—after chasing away their young from the previous season. Subsequently, various potential nesting sites are inspected. Once a suitable nest cavity has been chosen, the female seals the entrance of the cavity and prepares for her nesting confinement. Once sealed in the cavity, the female is entirely dependent on the male partner to provide nesting materials and food for her and the chicks. The average clutch size has been observed to be 3–4 eggs, with an incubation period between 26 to 29 days. The female stays inside the nest for up to 3 months, and during this time she will raise the chicks until they are almost 2 months old and ready to leave the nest. The usual number of fledglings is 1–2 chicks, only occasionally, 3. The discrepancy in the number of fledglings and the number of eggs hatched arises because of infanticide, usually followed by cannibalism. This has been observed to be a relatively common occurrence, in up to 30% of nests in each breeding season. Infanticide occurs usually on the smallest and weakest chick, though infanticide has also been observed to befall larger, stronger chicks.

Nesting commitment exhibited by the breeding pair is characteristic of hornbills, but may be incomplete. Premature female break outs, leading to possible predation or mortality of chicks, have been observed.

With the adaptability of this species to survive and breed in a densely populated country like Singapore, the study of the dietary requirements of this species and the food resources of the habitat can help evaluate the capacity of the garden, greenery and forest in providing food for a sustainable population of hornbills. The management of this species will involve the improvement of the genetic diversity of the population, with genetic studies taking place in tandem with the relocation and exchange of individual hornbills from different populations. ■ NSC/MCR/LHM



(1) A pair of hornbills using an artificial nest box equipped with cameras and electronic sensors; (2–4) Cameras inside the nest box enable the study of parental care and nestling development.

This greater mousedeer (*Tragulus napu*) was photographed during a study to determine the status and distribution of medium size mammals in Pulau Ubin by NUS and NParks researchers.

species conservation plans, pollution control, environmental overlays etc., is increasingly important, especially in view of the 1992 Rio Convention on Biological Diversity which urged bioresource conservation by members. These research areas also have considerable commercial possibilities as such work is now important (often mandatory) for all industrial and other development plans. This trend is apparent in all major western universities and research institutions. In Singapore, the national focal point for biodiversity work is NParks' National Biodiversity Centre, which oversees permits, management and policy matters. Unlike tertiary institutions, NParks' research efforts are directed primarily towards a better management of the species and ecosystems in the protected areas of Singapore.

Much of the research in Singapore has the ultimate aim of helping to conserve the biodiversity of Singapore and Southeast Asia through an understanding of the biology of threatened species (e.g., selected invertebrates, fishes, pangolins, mousedeer, hornbills, monkeys) as well as key patterns and processes (e.g., pollination and seed dispersal). Challenges facing freshwater crab and other endemic species are actively studied by NUS and NParks in attempts to ensure they do not become extinct; the case of the endemic *Johora singaporensis* being a concern, especially since molecular studies have established its important phylogenetic position (Yeo *et al.*, 2006). These include various new monitoring, mitigation and even *ex-situ* breeding initiatives.

The hornbill conservation programme has been very successful, with the oriental pied hornbill (*Anthracoceros albirostris*) returning to Singapore's forests, notably on Pulau Ubin. This collaborative research by NParks, NUS, Wildlife Reserves Singapore (WRS) and independent researchers has yielded striking new information about hornbill breeding biology. Artificial nests permit non-invasive study of diet, laying sequence, care of young and associated cannibalism of some chickens, and the research has expanded to thermal and gaseous physiology within the nest cavity. Genetic analysis is also carried out for the two species of hornbills that have re-colonised Singapore. Other noteworthy programmes by NUS, NTU and NParks have substantially increased conservation knowledge of key species like monitor lizards, colugos (Lim, 2007), pangolins (Lim & Ng, 2007) and mousedeer (Chua *et al.*, 2009). As of 2009, a multi-institutional sea turtle conservation programme was underway, involving the incubation of sea turtle eggs rescued from recreational beaches and the release of hatchlings into the wild. Expertise at NTU has also been utilised to help design a harvest management strategy for the bearded pig in logged-over plantation forests in Malaysia.

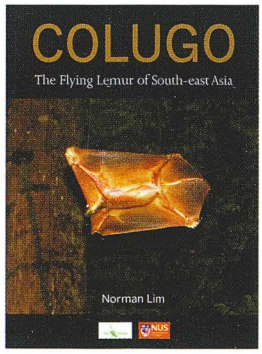
In 2009, NUS, NParks and WRS formally initiated a project to save the banded leaf monkey (*Presbytis femoralis*) from extinction. With a population of less than 40 in 2009, this is the most endangered mammal species in Singapore. Research revealing the number of troops, range, feeding habits, and reproductive rates of this iconic species is essential for developing a conservation plan and is being complemented by collection of tissue samples for genetic analysis.

A recently started project (by NParks, NUS and DHI-NTU Centre) called 'PAM' holds promise to revolutionise monitoring of hard corals. Using novel and easy-to-use equipment, this method is an indirect measure of environmental stress on hard corals, and unlike other methods, detects stress and not mortality.

Organisations such as the Singapore Zoological Gardens and Jurong Bird Park (under the umbrella of WRS) have also taken local and regional conservation issues seriously. WRS' non-profit arm, the WRS Conservation Fund, aims to spur conservation research efforts locally and regionally.

There has been an increasing focus on the practice of conservation, including the identification of areas, habitats and species in need of protection, the design of effective conservation strategies for protected areas and species, and the testing of potential management interventions for the matrix between these areas. One terrestrial example, that of the frogs of Singapore, highlights the need not just for habitat protection, but the management of breeding areas specific to particular endangered species for the best conservation outcomes (Bickford *et al.*, 2010). Other studies by groups of dragonfly and damselfly enthusiasts, together with NParks, PUB and NUS, seek to record species composition and distribution, habitat preferences of key species, larvae identification by matching with emerged adults, as well as to explore the use of DNA fingerprinting to solve taxonomic problems.

The restoration of degraded forests and coral reefs in Singapore has also received attention. As has been



Colugo: The Flying Lemur of Southeast Asia, by Norman Lim.

Maintenance of a healthy grove of the endangered fern, *Dipteris conjugata*, by NParks officers.

discussed, there are projects to help reefs re-grow. The replanted mangroves at Pasir Ris and the landfill island of Pulau Semakau have blossomed into mature patches, showing what can be done with planning and foresight. Shorelines along Pulau Tekong and the Western Catchments are increasingly interwoven with a diversity of mangrove trees on coastal protection structures. Similarly, NParks has worked closely with academic institutions and NGOs to re-plant many fringe areas of the Central Catchment Nature Reserve in an attempt to restore them to their original state. At the time of writing, NParks is planning to link Bukit Timah Nature Reserve to the rest of the Central Catchment using a broad, well-vegetated bridge, the Eco-Link (see page 51). The intention is to allow animals to cross the busy Bukit Timah Expressway which currently separates the two reserves. Movements by seed-dispersing animals and pollinators will also link plant populations.

In 2008, NUS and NParks began a project to explore ways to conserve the native biodiversity in urban areas. The project, funded by the Ministry of National Development Research Fund for the Built Environment involves efforts to increase the use of native landscape plants among professionals in the landscape and horticulture industry through publications, creation of the first native plants database, demonstration landscape plots, developing know-how for propagation of native plants, enabling a gradual build-up of native plant stock for use in landscaping, developing the skills to screen and grow native plants in the urban environment for high survivability, and demonstrating the positive ecological benefits of using native plants in urban landscapes. In land-scarce Singapore, the setting aside of land for nature reserves comes at a huge opportunity cost, so if streets, parks and gardens can act as extensions of nature reserves, there is a more optimal use of land for both conservation and human use.

High-density living environments can have a huge negative impact on the environment, especially in reducing native biodiversity. NUS, NParks and the Urban Redevelopment Authority (URA) have therefore collaborated on urban greenery studies as part of a major research programme on Planning and Development for Sustainable High Density Living spearheaded by the School of Design and Environment at NUS. Also financed by the Ministry of National Development Research Fund for the Built Environment, this project uses six study sites to develop a detailed urban greenery and biodiversity framework that can support land use planning and development in a high-density environment. The baseline information acquired will be used to recommend reviews of building, planning and provision standards which may be failing to address prevailing environmental conditions or specify the environmental and biodiversity levels to be attained.

An example of how research is contributing to practical conservation is the second edition of *The Singapore Red Data Book*, a tripartite collaboration of academia (NUS), government (NParks) and the public (Nature Society [Singapore]). With the support of private industry partners such as SHELL, the *Red Data Book* has become a key document for all government agencies and will evolve as the challenges in Singapore get more acute and complex. Perhaps one of Singapore's biggest possible contributions to conservation biology has been its use as a 'model system' for investigating the impacts of deforestation and urbanisation on tropical biodiversity. These studies have made use of Singapore's exceptionally (for the tropics) well-recorded ecological history, with the ultimate aim of predicting which kinds of species are most vulnerable in order to prioritise conservation efforts.

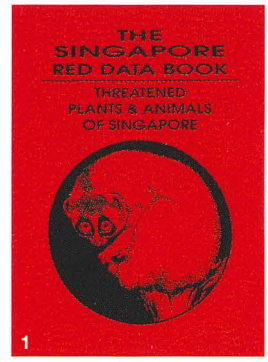
It has also been suggested by some authorities that one reason why biodiversity must be conserved is because it holds great prospects for biomedical research and saving human lives, i.e., people can learn from the survival struggles of 4 billion years of evolution. Already, people have benefited from major drug discoveries from the Madagascan periwinkle and Pacific yew tree. In Singapore, pioneering research by NUS researchers deciphered and cloned the genes responsible for causing blood-clotting in horseshoe crabs (*Carcinoscorpius rotundicauda* and *Tachypleus gigas*)—a major discovery because their blood can detect minute quantities of endotoxins from Gram-negative bacteria which are major disease-causing microbes. Similarly, studies by biologists and engineers from NTU and NUS on algae and blue-green algae (cyanobacteria) have uncovered new insights on the biomedical and environmental significance of these organisms.

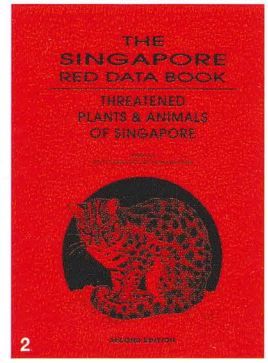
Environmental Science

The world has become a very connected place and scientific disciplines are merging, reorganising and working closely to solve complex problems. This is especially true in the field of environmental science in which the challenges confront not just Singapore but also the region and the world. Problems include the shortage of drinking water, air and water pollution, global climate change and invasive species. Much of the work done by Singapore researchers involves active collaborations with dozens of regional and international organisations, e.g., World Conservation Union, International Maritime Organisation, United Nations Development Programme, United Nations Environment Programme, United Nations Law of the Seas, Food and Agriculture Organisation of the United

NIE scientists have demonstrated the use of ghost crabs (*Ocypode ceratophthalmus*)—shown here feeding on a moon crab (family Matutidae)—as a potential bioindicator of human disturbance on Singapore's beaches.

Coral fragments are used to restore degraded reefs in a research programme by NParks and NUS, supported by private industry.





The (1) first and (2) second editions of *The Singapore Red Data Book* contain an updated list of the nationally threatened flora and fauna.

(1) The clean up of the Singapore River brought life back to its waters, which are now part of the Marina Reservoir; (2) The Active, Beautiful and Clean (ABC) Waterways programme by the PUB enhances the beauty of Singapore's waterways and promotes their use for recreation.

Reconciling rapid growth with care for the environment. Also in the 1970s, Lee Kuan Yew set up the Anti-Pollution Unit, which imposed strict rules on polluting industries. The decision—unpopular at the time—has given Singapore the gift of good air quality alongside rapid industrial growth.

The country has spent more than $10 billion on major environmental infrastructure works over the past 30 years. In the words of Prime Minister Lee Hsien Loong: "Singapore has practised sustainable development even before the term was coined. We pursue growth in order to have the means to improve our lives. We also safeguard our living and natural environment, because we do not want our material well-being to come at the expense of our public health or overall quality of life."

Overcoming its scarcity of space, limited water supplies and no natural resources, Singapore houses over five million people in one of the world's best urban environments, thanks to imaginative city design, careful planning and judicious land use.

From Garden City to City in a Garden. A long-term, integrated approach to land-use planning was key in realising the Garden City vision. Despite Singapore's limited land area of 700 sq km, one-tenth of the land was set aside for parks and other green spaces. The country's four nature reserves, covering more than 4.5% of Singapore's land area, are protected by law. They represent key indigenous ecosystems and help conserve our natural heritage. The Sungei Buloh Wetland Reserve, for instance, is on the East Asian-Australasian Flyway and is an important stopover for migratory birds coming from as far as Siberia.

Much of Singapore's original forest cover and native species were lost before independence in 1965. Since the British first established a presence here in the early 1800s, more than 99% of the estimated 540 sq km of original vegetation has been cleared. Singapore has also lost about half of its animal species in the last 200 years. However, what remains is rich.

Rich biodiversity. The country is home to over 2,000 native plant species, 98 reptiles, over 350 birds, more than 280 butterflies, and nearly 120 dragonflies. The 164-ha Bukit Timah Nature Reserve (BTNR), for example, has more tree species than in the entire North American continent.

Despite being one of the busiest ports in the world, Singapore's waters host around 260 species of hard corals (over 30% of the global total of 800 hard coral species), and more than half of the seagrass species found in the Indo-Pacific region.

New species continue to turn up. An ambitious wildlife survey in 2007 identified 35 plant and animal species never before recorded in Singapore, and another seven thought to have been extinct, including spiders, plants and a turtle. That same year, Belgian entomologist, Patrick Grootaert, discovered over 150 new species of long-legged flies, of the family Dolichopodidae, in Singapore.

Return of the hornbill. Among the native species being rediscovered, the oriental pied hornbill is a spectacular case in point. This bird, a native species of Singapore and the region, had been extinct in Singapore for many decades. But in 1995, bird watchers began spotting it again.

The birds had flown into Singapore from neighbouring forested countries, and were given a bit of help to make Singapore a permanent home. Nesting boxes set up in the wild to overcome a shortage of natural nesting cavities proved a hit, and the majestic bird has bred in Singapore every year since 1997.

National Development Minister Mah Bow Tan said: "Success stories like this inspire us to remain committed in our biodiversity conservation efforts, so that our future generations can continue to appreciate the wonders of nature."

Praise from the United Nations. Indeed, Singapore's greening efforts have received international recognition. The Secretariat of the United Nations' Convention on Biological Diversity, for example, has hailed the republic as a living testimony that sound urbanisation and ecologically managed cities can exist.

Interview

Minister for National Development Mah Bow Tan:

Biodiversity plays an important role in sustainable living. Our rainforests protect our water catchment areas by preventing soil erosion and filtering rainwater. Mangroves and coral reefs serve as nurseries and shelters for marine organisms.

Biodiversity also helps us connect with nature and our natural heritage. With rapid urbanisation and development, if we are not mindful of biodiversity conservation, our city will degenerate into a cold, concrete jungle and our quality of life will suffer. Despite our rapid economic development, Singapore is a haven for biodiversity, with over 2,000 species of native plants, 98 reptile species, over 350 of birds, more than 280 of butterflies, and nearly 120 dragonfly species.

Despite being one of the busiest ports in the world, our waters harbour around 260 species of hard coral—a third of the global total, and more than half of the seagrass species found in the Indo-Pacific region.

We are still discovering new species and we are also rediscovering native ones. The oriental pied hornbill is a case in point. This beautiful bird had been extinct from Singapore for many decades but flew in from neighbouring countries and has begun breeding here again since 1997, with help from nesting boxes that we set up in the wild to overcome a shortage of natural nesting cavities. Success stories like this inspire us to remain committed in our biodiversity conservation efforts, so that our future generations can continue to appreciate the wonders of nature.

To remain at the leading edge as a distinctive global city, we are now evolving our Garden City towards a City in a Garden, where our homes, workplaces and schools are nestled within one beautiful tropical garden. Singaporeans can expect bold and exciting changes as we advance towards this vision.

Works are underway at the Gardens by the Bay in the heart of Marina Bay, the new Downtown. These gardens will be for all Singaporeans to enjoy, and will redefine the urban greenery experience for everyone. We will expand our park connector network, which will increase the connectivity of our recreational spaces, and open new avenues for Singaporeans to enjoy activities such as cycling and jogging.

Our blue and green spaces will be seamlessly integrated, as we landscape our waterbodies to create active, beautiful and clean waters. There will be more skyrise greenery, covering our built environment with a lush, vertical green mantle. We will create an environment where biodiversity can thrive, and where our natural heritage can be safeguarded.

Spreading the Green Mantle

There has been no let up in the effort to sustain the flora and fauna we have left, and indeed, to resurrect some from the dead.

Government agencies such as the National Parks Board and the PUB, as well as scientists at tertiary institutions here, have been instrumental in research, public education, reforestation and clean-up projects in Singapore's green and blue spots. Their work ranges from studies to document the biodiversity of intertidal life at Labrador Park, to the clean-up efforts in the mangroves of Sungei Buloh Wetland Reserve.

NParks launched the National Biodiversity Strategy and Action Plan in 2009, reaffirming the Government's commitment to conserving the country's natural heritage. Apart from championing a wide-range of conservation projects, the plan also aims to give voice to biodiversity issues in policy and decision-making.

Thirteen hawksbill turtles, some of which were fitted with tracking devices, were released in waters off Pulau Subar Laut for a project to protect endangered turtles.

Raffles Museum of Biodiversity Research. At the Raffles Museum of Biodiversity Research, National University of Singapore, people can learn about the region's plants and animals through an extremely comprehensive collection of preserved specimens, or attend talks given frequently by experts.

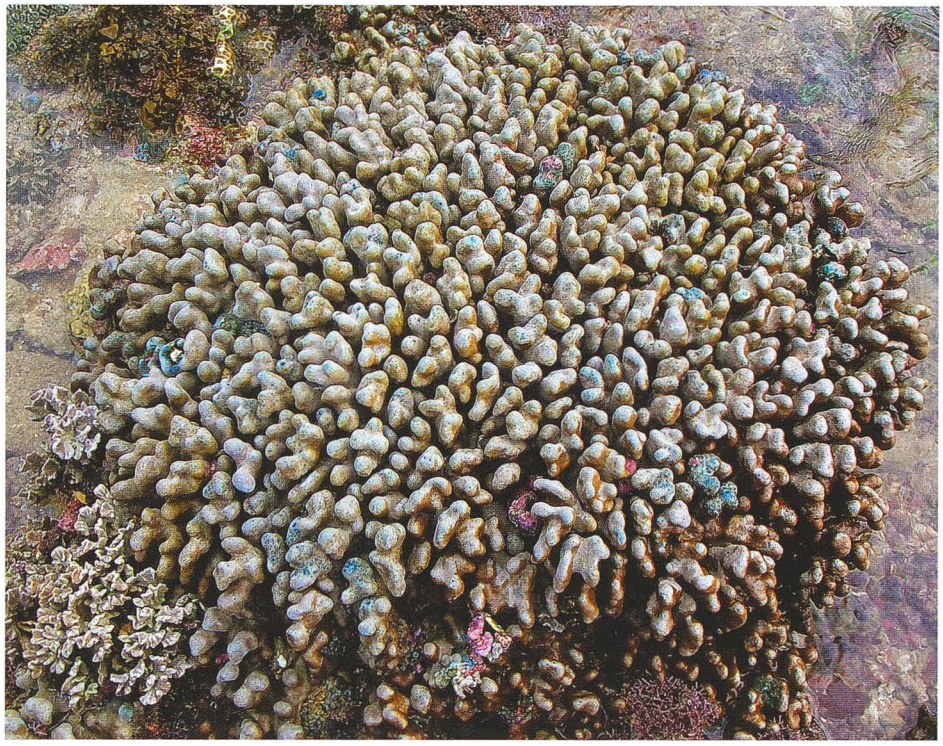
Volunteer groups have also grown in size and strength, getting their voices heard on anything from saving land from redevelopment to preventing poaching of key species.

Role of civil society. The Nature Society (Singapore), for example, organises activities such as guided nature walks, bird and butterfly watching and slide shows, conducts conservation projects and surveys, and works with schools and community groups to promote nature appreciation.

Ecology lecturer, N. Sivasothi, among the first to blog about green issues in Singapore, helped to bring to public attention Pulau Ubin's Chek Jawa, which started the effort to save the wetlands from reclamation in 2001. Another person to lead the green effort here is WildSingapore founder Ria Tan, who has spent hours each day updating her website with news and pictures from Singapore's best green websites. Such volunteers have shown that they are capable of fast and significant action.

During the May 2010 accident, when 2,500 tonnes of crude oil leaked into the ocean off Changi Beach and East Coast Park, Tan was among the environmentalists and members of the public who leapt into action to document the damage and help save the creatures affected by the spill.

Pulau Semakau landfill. Several projects have received international acclaim for leading the conservation movement, including the Pulau Semakau landfill—the 350-ha island and wildlife haven with rich mangrove swamps, forests and coral beds, and none of the stench or piles of garbage seen in other landfills.



Blue corals are sometimes mistaken for hard corals. They are, in fact, more closely related to soft corals, sea fans and sea pens.

Bengalia, three *Phumosia*, two *Hemipyrellia*, two *Hypopygiopsis*, two *Catapicephala*, two *Caiusa*, and many more. The larvae of yellow blow flies (*Bengalia* spp.) feed in TERMITES' nests. The adults often hover over marching columns of ANTS and snatch eggs, pupae or food from them. ■ WLK/PG

Bluebottle flies See BLOW FLIES.

Blue corals *Heliopora coerulea*
Octocorals (see ANTHOZOANS) belonging to the order Helioporacea. They are a major component of reef environments. Sometimes mistaken for HARD CORALS, blue corals are one of the two octocorals known to produce a hard skeleton. The skeleton is blue, caused by the deposition of iron salts in the calcium carbonate skeleton. Blue corals, however, actually appear brown most of the time, due to the colouration of the thin layer of soft tissue covering the skeleton. The blue skeleton is only visible when a part of the coral is broken off and exposed. Blue corals have the longest geological history among extant corals; their fossil records can be traced to more than 100 million years ago. In Singapore, they are fairly common on rocky shores and reefs. The colonies, which can be more than 1 m wide, are usually boulder-shaped with thick, knobbly finger-like projections. ■ RY/LAC/STM

Blue dragon See NUDIBRANCHS.

Blue-green algae See CYANOBACTERIA.

Blue pansy See BRUSH-FOOTED BUTTERFLIES.

Blue pea See FABACEAE.

Bobtail squids See SEPIOLID SQUIDS.

Bodhi tree *Ficus religiosa*
Somewhat deciduous, large strangler fig (see FIGS) in the MORACEAE family, up to 25 m tall, with a short, fluted trunk, some aerial roots and a large crown. All parts of the plant produce white latex when damaged. The spirally arranged, long-stalked leaves have a distinctive, heart-shaped leaf blade that has a long, narrow drip tip. The tiny flowers develop inside a 1.3–1.7 cm wide structure called a syconium which turns purple when ripe. This species is native to India, but while most exotic figs fail to ripen in Singapore because they lack their species-specific wasp pollinators, the bodhi tree is so widely planted in Southeast Asia that its pollinator has spread with it. Many BIRDS (e.g., BARBETS, BULBULS, oriental pied hornbill (see HORNBILLS), Javan myna (see MYNAS), pink-necked green pigeon (see PIGEONS)) eat the ripe syconia and spread the seeds. Seedlings grow in many urban sites—on buildings, walls, gravestones, and in drains or cracks in the road. Together with the Malayan banyan (*F. microcarpa*) and Benjamin fig (*F. benjamina*), it is one of the the most widespread figs in urban Singapore, but unlike the other two species very few seedlings grow up into adults. This species was introduced to be planted in temples as it is considered sacred to Buddhists and Hindus in Singapore and the rest of the world. The bodhi tree is the tree under which Siddharta Gautama (the Buddha) is believed to have achieved enlightenment. ■ HTWT

Boletes Order Boletales
The majority of the CLUB FUNGI termed boletes have fleshy fruiting bodies that have tubes and pores beneath their caps. Spores are produced

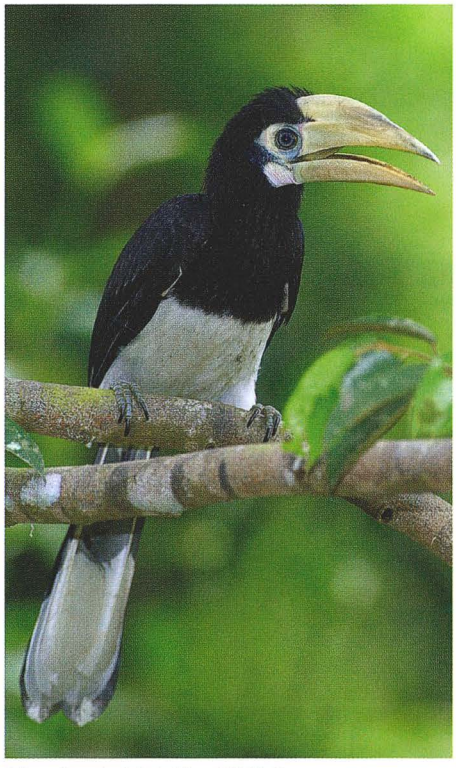
A fruiting body of *Boletus* sp. showing the pores on the under surface of the cap.

Syconia on leafy branches of a bodhi tree (*Ficus religiosa*).

Hook-tip moths Family Drepanidae
The common name of this family of MOTHS refers to the shape of the forewings of some species that have a hook-shaped tip. The wings often contain silvery markings and are held outstretched close to the resting surface. They are mostly nocturnal and have short bodies with abdominal hearing organs for detecting echolocating INSECT-EATING BATS. The larvae are peculiar as they often have the end of their bodies and sometimes heads raised at rest. At least eight species can be found in Singapore. *Tridrepana fulvata* is a typical bright yellow moth with a hook-shaped tip on the forewing (wingspan 27 mm). Its larvae food plant includes *Nephelium* (see SAPINDACEAE). The wings of some species such as *Drapetodes mitaria* and *D. interlineata* lack hooked tips (wingspan 26 mm). ■ MC

Hoppers See TRUE BUGS.

Hornbills Family Bucerotidae
Large BIRDS with a prominent bill, with some species having a projection or casque above the bill. Hornbills are mainly frugivorous but also hunt small animals to supplement their diet, especially during the breeding season. Their flight is powerful, and they produce loud wing beats as air rushes through the base of the flight feathers, unimpeded by the lack of underwing coverts (small feathers that cover the underside of the flight feathers). They are capable of flying long distances. Hornbills nest in tree cavities of large trees. When ready to lay eggs, the female enters the cavity and seals the entrance with clay and droppings, leaving only a small vertical slit, through which the male feeds her and the chicks, until they are ready to leave the nest. Sometimes the female breaks the seal when the eggs hatch, re-seals the cavity and assists the male to feed the young. Hornbills are highly endangered as their forest habitats continue to dwindle and poaching continues. One species has re-invaded Singapore after an absence of a century. The oriental pied hornbill (*Anthracoceros albirostris*) is a relatively small species (68–70 cm) and inhabits coastal and mangrove forests. They move in small parties and are rather noisy. A large breeding population of more than 60 individuals has become established on Pulau Ubin. Small numbers have also been seen in Changi and Pasir Ris. The rhinoceros hornbill (*Buceros rhinoceros*, 91–122 cm) has been nationally extinct since the late 1800s, but escapees from the caged bird trade are occasionally sighted in various parts of Singapore. See also page 141. ■ WLK



A juvenile oriental pied hornbill (*Anthracoceros albirostris*), from a highly successful breeding population on Pulau Ubin.

The extremely well-camouflaged Malayan horned frog (*Megophrys nasuta*) is more often heard than seen. Its call is a loud 'honk'.

Horned frogs *Megophrys* spp.
FROGS belonging to the family Megophryidae. Horned frogs are mottled grey to brown with a pointed snout and horn-like skin flaps over the eyes. These enable the frogs to blend almost perfectly among leaf litter on the forest floor, concealed from both predators and prey. The Malayan horned frog (*Megophrys nasuta*), also known as the horned toad, is locally endangered and confined to the BTNR and CCNR. It grows to a snout-vent length of 16 cm, and is an ambush predator of INSECTS and other small animals. ■ MC/KL

Horned powderpost beetles
Family Bostrichidae
Also known as auger beetles. These INSECTS are usually cylindrical, with rasp-like teeth on the front of the thorax. They usually measure between 2–24 mm. The head is often concealed when viewed from above, as it is bent downward and obscured by the thorax. Horned powderpost beetles, especially the larvae, bore into wood to feed and can quickly reduce it into a fine powder, hence their common name. In Singapore, *Sinoxylon* sp. has been recorded. ■ MC

Horned toad See HORNED FROGS.

Hornets See TRUE WASPS.

Horn shells Family Potamididae
Snails found mainly in mangroves and estuaries. Some horn shells are called mud creepers and look very similar to the CREEPER SHELLS (family Cerithiidae). Their operculum is thin and circular with multiple concentric rings. The animals have a highly protrusible proboscis which is used to pick up detritus. Horn shells transfer sperm packets to females by muscular and ciliary action. In Singapore, nine species have been recorded. The largest is the telescope mud creeper or telescope snail (*Telescopium telescopium*), which can attain a shell length of more than 10 cm. The obtuse horn shell (*Cerithidea obtusa*), known locally as chut-chut, and the quadrate horn shell (*C. quadrata*) are often collected for food in the region. They are commonly found on tree trunks in mangroves. The mud creeper (*Terebralia palustris*), rarely encountered on the main island, can be seen on some of the offshore islands where it appears to prefer more disturbed mangroves facing the open sea. Singapore was designated the type locality for the species. The girdled horn shell (*C. cingulata*) often shares the same intertidal