



ILLUSTRATION

URBAN NATURE

Science and Technology to Advance City in Nature

To enhance Singapore's liveability while mitigating the impacts of urbanisation and climate change, the City in Nature vision seeks to conserve and extend Singapore's natural capital island-wide, and further integrate nature into the city. Science and technology play a key role in enabling these transformative efforts.

TEXT: REKHA MOHAN AND GERVAIS LEE (NATIONAL PARKS BOARD)



As a result of sustained greening and conservation efforts that have spanned over 60 years, Singapore is one of the greenest cities in the world and home to a rich diversity of flora and fauna despite being a small city-state of 728 km² and one of the most densely populated countries worldwide.

Today, Singapore is advancing into a City in Nature, to further restore nature into the country's urban fabric so as to provide a high-quality living environment for Singaporeans amid increasing urbanisation and climate change. Led by the National Parks Board (NParks), the City in Nature vision builds on Singapore's greening efforts over the past decades, and is also part of a whole-of-nation sustainable development agenda under the Singapore Green Plan 2030.

To achieve this vision, NParks is embarking on a suite of island-wide strategies to

- Conserve and extend Singapore's natural capital
- Intensify nature in gardens and parks
- Restore nature into the urban landscape
- Strengthen connectivity between Singapore's green spaces
- Enhance veterinary care and animal management

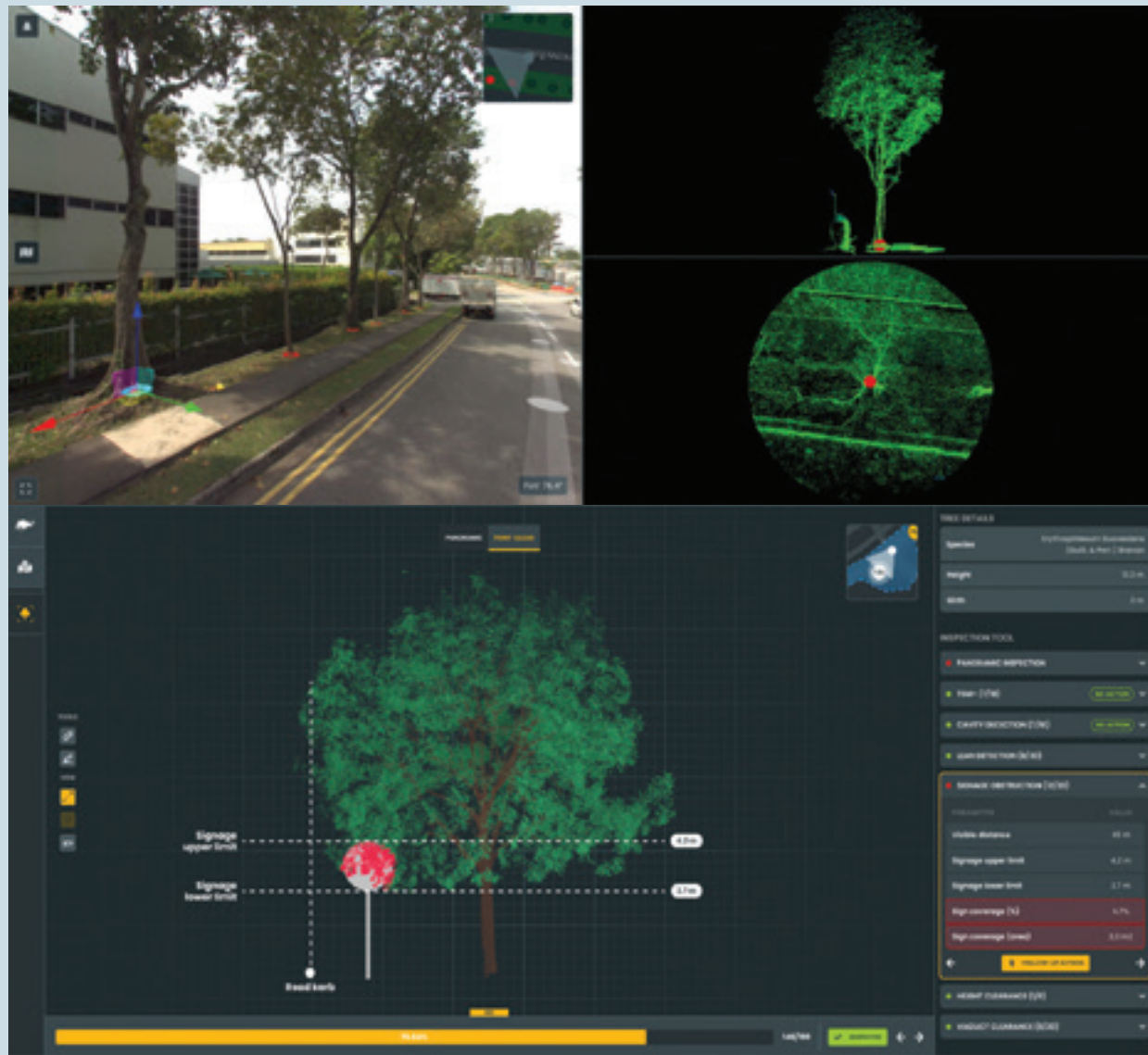
Underpinning these strategies is a strong emphasis on science and technology, to inform and equip the planning, design and management of Singapore's natural capital. This entails advancing research across wide-ranging disciplines—from botany and ecology to the climatological and social dimensions of urban nature—so that NParks can continue to effectively integrate nature into an increasingly complex urban environment and address a greater diversity of challenges and needs.

In addition, the development and deployment of technological tools enables NParks to drive greater operational effectiveness and productivity in urban nature management—as greenery and biodiversity become increasingly pervasive in our City in Nature.

Managing Singapore's Urban Trees

Interwoven within Singapore's built environment are an estimated two million urban trees managed by NParks. Under NParks' comprehensive tree management programme, a Geographic Information System-based tree registry system is used to maintain an inventory of Singapore's growing urban tree population, including the trees' individual geolocation and management records.

More recently, a Remote Tree Management System was developed for enhancing accuracy and efficiency in urban tree inventurisation and inspection, where cutting-edge technologies such as mobile laser scanning and panoramic imagery were used to create a comprehensive and representative 3D digital twin of Singapore's urban trees. NParks also leverages other technologies to further its tree management capabilities, such as drones for aerial tree crown inspections, and electronic tilt sensors to monitor the lean of mature trees.



The Remote Tree Management System utilises Light Detection and Ranging (LiDAR) technology to capture dense and accurate point cloud data of trees, which is then processed using machine learning techniques to extract vital information such as tree location, dimensions and branching patterns. This provides representative 3D digital twins of Singapore's urban trees, which can be used for tree inventurisation, virtual inspection and structural modelling, and other applications for tree maintenance, landscape design and city planning.
Image: National Parks Board



A Geographic Information System-based tree registry system is used by field officers for on-site urban tree management.
Image: National Parks Board



Designed for installation on tree trunks, the Tree Tilt Sensor leverages IoT technology to measure tree lean data and transmit alerts to field officers upon detection of tree lean that exceeds a pre-defined threshold. This activates further on-site tree inspection and maintenance.
Image: National Parks Board

Conserving Our Rich Biodiversity

Despite being highly urbanised, Singapore is home to wide-ranging biodiversity residing in terrestrial, coastal and marine habitats. To inform ongoing conservation efforts, NParks leverages a suite of sensor technologies to study and monitor native wildlife populations, such as the use of

- Camera and video traps to survey nocturnal and rare wildlife in Singapore's Nature Reserves and Nature Parks, and to examine the effectiveness of conservation measures
- Satellite tracking to study migratory shorebird movement
- Development of acoustic technologies to survey songbirds and marine megafauna
- New conservation technologies such as the Roadway Animal Detection System and the Forest Fire Detection and Monitoring System, which apply video analytics and machine learning techniques to mitigate vehicular-wildlife collisions and to facilitate early alerts and response to local forest fires respectively.

Camera traps deployed in Singapore's forests enable NParks to monitor the density and distribution of native wildlife populations.
Image: National Parks Board



Satellite tracking technology has revealed that migratory shorebirds wintering in Singapore use both the Central Asian Flyway and the East-Asian Australasian Flyway. This reinforces the significance of Singapore's Sungei Buloh Wetland Reserve as a site of international importance for migratory shorebirds.
Image: National Parks Board



The Roadway Animal Detection System with Advance Warning Signs uses machine learning and a specialised detection system to detect wildlife approaching the road. The system then alerts motorists to slow down through a flashing sign, making road crossings safer for wildlife.
Image: National Parks Board

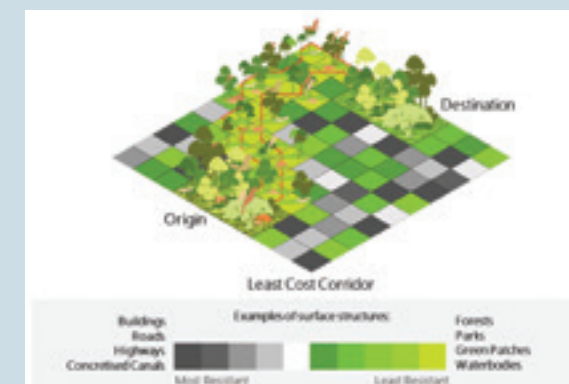
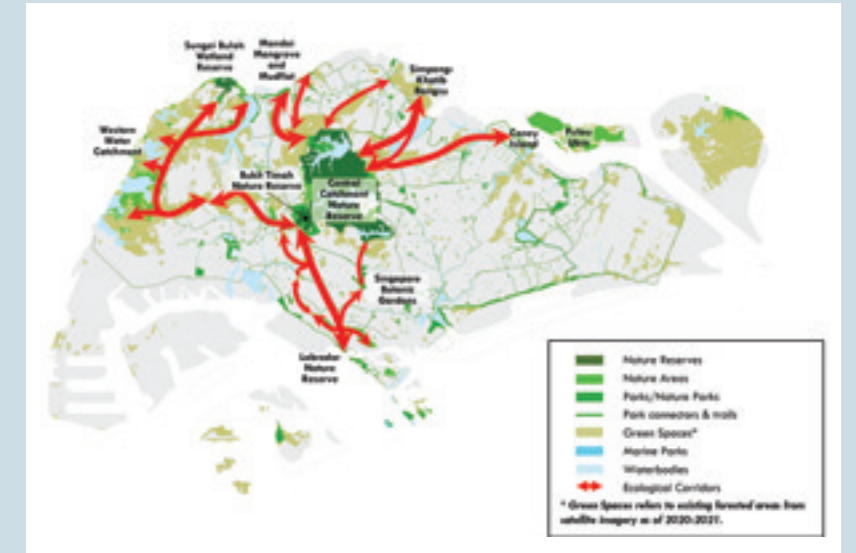
Integrating Nature Conservation and Land Use Planning

To develop a comprehensive picture of Singapore's island-wide ecosystem and ecological connectivity, NParks led an island-wide Ecological Profiling Exercise (EPE). The EPE utilised a combination of least-resistance pathway and agent-based modelling tools to understand the role of specific sites in providing refugia and ecological connectivity for native biodiversity.

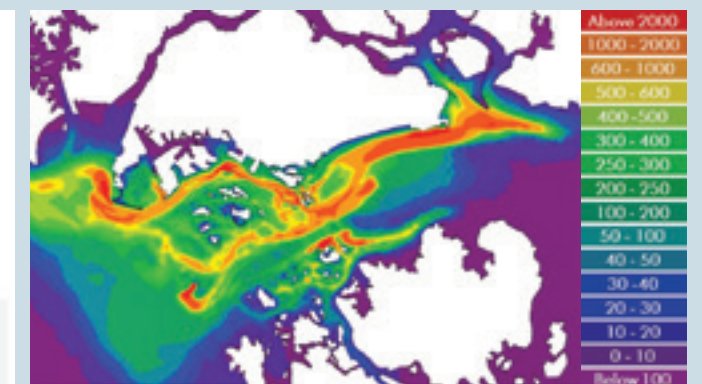
Completed in 2022 in tandem with the Urban Redevelopment Authority's Long Term Plan Review, the EPE facilitated the identification and safeguarding of key ecological corridors between core habitats by establishing plans for Nature Park Networks and Nature Corridors in Singapore's land use plans.

By adopting a holistic and science-based approach, the EPE empowers urban planners to include ecological considerations upfront in the land use planning process, to better balance development with nature conservation.

Map of terrestrial ecological connectivity identified through NParks' Ecological Profiling Exercise.
Image: National Parks Board



Least-resistance pathway modelling for terrestrial habitats identifies the surface structures (e.g., roads, forests, buildings) between core habitats and assigns a numerical value to each structure, with a lower value indicating greater conduciveness for an animal to cross. The least-resistance movement pathway is then established based on the route comprising pixels of the lowest value.
Image: National Parks Board



Agent-based spatial modelling for coastal and marine habitats simulates the movement of large numbers of individual organisms to understand their dispersal pattern, such as coral larvae dispersal following a mass spawning event (map shows predicted cumulative densities of coral larvae within Singapore's coastal waters following a mass coral spawning event in 2013).
Image: National Parks Board

Combatting Illegal Wildlife Trade

On the global front, the use of science and technology has bolstered NParks' efforts to tackle illegal wildlife trade, together with international partners under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

The Centre for Wildlife Forensics was launched by NParks as Singapore's first national facility for wildlife forensics, and has also been recognised as a CITES-registered laboratory. Through collaboration with international experts, the Centre has developed genomic capabilities to sample and identify large volumes of wildlife seizures (e.g., pangolin scales, elephant ivory), to support investigation and enforcement efforts. The Centre also leverages various detection and diagnostic technologies to investigate cases of illegal wildlife trade, including vision-based and AI-assisted tools to identify CITES-listed timber specimens and illegally traded shark and ray species.



Fin Finder is Asia's first mobile application that employs machine learning and artificial intelligence to identify shark and ray species from photos of their fins. Developed through a partnership between NParks, Microsoft and Conservation International, the app helps support worldwide enforcement efforts against illegally traded shark and ray species.
Image: You Wai Hong, Bloom Association

Safeguarding Singapore's Biosecurity

Maintaining high levels of biosecurity is key to NParks' work in safeguarding animal and public health. To strengthen Singapore's biosecurity while reducing stress for pets relocating to Singapore, NParks' Animal & Veterinary Service introduced the use of radio frequency smart collar tags to allow pets imported from lower-risk countries to be quarantined at home and to be monitored closely without separation from their owners.

Remote surveillance and sensor technologies (e.g., drones, closed-circuit television cameras) have also been piloted to strengthen the inspection of imported animal consignments. In addition, NParks has been refining its capabilities in the use of environmental Deoxyribonucleic Acid (eDNA) as a non-invasive approach for the early detection and management of diseases (e.g., in fish and turtles), based on environmental samples such as air or water.

Closed-circuit television cameras with live transmission enable NParks to conduct remote and real-time inspection of imported pig consignments.
Image: National Parks Board



NParks has implemented smart collar tags for animals that are eligible for home quarantine. This also allows animals with pre-existing medical conditions or special medical needs to serve post-arrival quarantine at home. Singapore is one of the first countries to employ the use of such technologies for pet home quarantine.
Image: National Parks Board

Nature for Health and Well-Being

Multi-disciplinary research on the wellness benefits of urban nature has enabled NParks to advance the implementation of landscapes and programming for enhanced public health and well-being. Since 2016, NParks has been incorporating therapeutic gardens into various parks across Singapore, leveraging evidence-based design principles to bring about health and wellness benefits for seniors and other users.

Studies have also indicated that NParks' national horticultural programmes (e.g., community and allotment gardening, therapeutic horticulture, home gardening) contribute towards liveability outcomes such as improved mental well-being and social cohesion, across the general population and for specific community segments. Arising from recent research on how landscape characteristics affect brain activity patterns, NParks has also rolled out design guidelines for contemplative landscapes, which promote the wider implementation of landscapes that enhance mental well-being across Singapore.

Bishan-Ang Mo Kio Park Therapeutic Garden.
Image: National Parks Board



In-situ collection of brain activity data from a participant exposed to a landscape with high contemplative quality. This comprehensive outdoor experimental study employed a multi-modal electroencephalography (EEG) and Functional Near-Infrared Spectroscopy (fNIRS) system for objective assessment of the well-being impacts of green space exposure.
Image: National Parks Board



Research studies conducted in Singapore have found seniors reporting better mental health outcomes after receiving therapeutic horticulture interventions.
Image: National Parks Board

Nature-Based Solutions for Climate Change

NParks is actively driving research to deepen the science behind safeguarding Singapore's natural capital amid climate change, and to advance the implementation of nature-based solutions. Research efforts under NParks' Marine Climate Change Science programme will inform evidence-based strategies to enhance the ecological resilience of Singapore's coastal and marine ecosystems towards climate change impacts (e.g., sea level rise, increasing sea surface temperatures, extreme storm events).

By harnessing multi-disciplinary expertise across government agencies and the research community, the programme will also examine ecological engineering solutions to further protect Singapore's coasts, and blue carbon capture and storage by local habitats. Similarly, NParks is leading parallel research efforts to understand how terrestrial urban greenery and inland blue spaces can be further leveraged as nature-based solutions for climate adaptation.



The Marine Climate Change Science programme will investigate the effectiveness of nature-based solutions such as mangroves, and strategies to strengthen their ecological resilience amid projected climate change.
Image: National Parks Board




The naturalised waterway at Bishan-Ang Mo Kio Park serves as a nature-based solution to build resilience against inland flooding, while providing additional benefits as a biodiversity habitat and recreation area.
Image: National Parks Board

Long-Term Monitoring

NParks' Long-Term Socio-Ecological Research programme consolidates research activities that leverage dedicated long-term study sites, repeated studies, and integrated and interdisciplinary efforts. This allows the programme to examine the long-term impact of Singapore's City in Nature efforts and generate scientific insights to enhance existing strategies.

Efforts under the programme will, for instance, enable monitoring of key ecological processes in Singapore's forests and green spaces. At the same time, the programme will study the values, beliefs, and norms of Singaporeans towards nature, and how Singapore's City in Nature efforts can influence physical, mental, and social well-being outcomes.

The programme also includes a Long-Term Forest Ecological Monitoring plot network in the Central Catchment Nature Reserve, where monitoring studies will improve our understanding of historical changes in Singapore's forests, and inform future efforts to support forest ecosystem resilience. 



Tree and vegetation survey in a Long-Term Forest Ecological Monitoring plot within the Central Catchment Nature Reserve.
Image: Teo Jinying



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