1

The Survival of Singapore's Last Freshwater Swamp Forest

Swamp Thing

Text by Geoffrey Davison and Cai Yixiong
Images by Cai Yixiong

The extraordinary fact of Nee Soon's survival, with possibly 700 species of native plants (over one-third of all the native flora) and one-third to two-thirds of other major groups (including birds, mammals, dragonflies, reptiles, fishes, freshwater crabs, and prawns), is both despite and because it is embedded within a city of more than five million people, virtually surrounded by three reservoirs, and just metres away from a major expressway.

Freshwater Swamp Forest

Freshwater swamp forest is forest that is periodically inundated and therefore wet underfoot for part of the year. In the tropics, huge and spectacular areas of freshwater swamp forest occur in the Amazon Basin, with many adaptations amongst the trees, fishes, and even freshwater dolphins taking advantage of thousands of square kilometres of seasonally available deep water. In Southeast Asia, the areas are smaller, but have still been significant in the recent past, along the alluvial floodplains of major rivers such as the Kinabatangan in Sabah; Mahakam and Kapuas in Kalimantan; and Indragiri in Sumatra. A key point is that flooding is not due solely to rainfall, though rainfall is an ultimate contributor to flooding. Furthermore, the ground is not characterised by peat (which in Southeast Asia develops where rainfall is the sole source of flooding), so the soils are mostly mineral and show loss on combustion of less than 65 percent of their mass.

Singapore once had extensive freshwater swamp forests, though only two areas were ever known in much detail: Jurong, in the vicinity of the current Jurong Lake District, and Mandai, including Nee Soon and what is now Upper Seletar and Lower Seletar reservoirs. Now, only Nee Soon remains, within the Central Catchment Nature Reserve. Even that has been disturbed to a certain extent. The Nee Soon freshwater swamp forest is special because (a) it is the last remaining example in Singapore and (b) it supports by far the highest proportion of nationally threatened plant and animal species in Singapore.

The extraordinary fact of Nee Soon's survival, with possibly 700 species of native plants (over one-third of all the native flora) and one-third to two-thirds of other major groups (including birds, mammals, dragonflies, reptiles, amphibians, fishes, freshwater crabs, and prawns), is both despite and because it is embedded within a city of more than five million people, virtually surrounded by three reservoirs, and just metres away from a major expressway.

Water is Key

Hydrological changes have been identified as important elements affecting the sustainability of Nee Soon. There are contradictory hearsay reports of increased flooding over the years, but also of decreased flooding over the same period. Strangely, both opinions point to the same evidence to support their case, such as erosion notches along the banks of streams. What is not in doubt is that dramatic changes have occurred within the past 200, and even the past 50, years. Cash crops such as gambier and pepper came in during the 1830s. They were followed by vegetable farms, tapioca, and fruit orchards in the 1870s, then by more commercial pineapple plantations and rubber in the early twentieth century. All forest downstream has since been removed, the reservoirs have since been impounded, and downstream areas that were rubber and coconut plantations up to the early 1980s are now residential. Although so many species of plants and animals occur there, the population size of each species is inevitably tiny. The entire system is therefore fragile and vulnerable to future change including climate change beyond our control.

Rainfall may provide the bulk source of fresh water, but if it is not the only source of flooding, what are the others? There must also be percolation laterally through the soil, but it will be gradual and limited by the soil structure and topography. Rainfall percolation and groundwater strongly influence the depth of the water table, which in most areas is below ground but sometimes rises above the ground surface, that is to say, it floods. Surface water flows out of Nee Soon in small streams, but what if there is backflow? In the past, a high tide on the coast downstream coinciding with heavy rainfall inland would have backed up water in the stream system, again leading to transient floods; but now there is a reservoir in between. Eventually, water must leave the system either via the streams or by evapotranspiration from the forest plants back to the atmosphere.

The objective of the current research in Nee Soon is to break down the components of the systems to analyse the effect of each part. Once this is better understood, there is a chance of manipulating conditions and preventing extremes that might threaten the freshwater swamp forest, its plants, and its animals. Within about 500 hectares of Nee Soon, there are eight sub-catchments. In each sub-catchment, the same hydrological processes occur: rainfall, horizontal groundwater percolation, fluctuations of the water table, outflow, backflow, and evapotranspiration. Each of the eight sub-catchments is of different size and slope, differing in tree composition, stream size and length, distance from streamhead, and outflow point.

Modellers of Past and Future Times

The key activity of current research by the National Parks Board, Tropical Marine Science Institute of the National University of Singapore, and Public Utilities Board, together with help from Earth Observatory Singapore and the University of Queensland, has been the analysis of the factors described above. Through numerical modelling, it is becoming possible to analyse what would happen to the entire freshwater swamp system if one component were changed. For example, imagine if rain simply ended tomorrow, followed by permanent drought. Anyone can say that the water table would drop, but we can now model exactly how fast it would drop, and by how much, at each sub-catchment within the area. In principle, we can model the effects of any given drought, whether it lasts 2 days, 20 days, or 200 days. Imagine if the vegetation were totally removed within one sub-catchment, leaving bare ground. Evapotranspiration from plants would be eliminated and replaced by solely physical evaporation from a plane ground surface. Imagine if rainfall and evapotranspiration continue, but if a flood were to be created by pumping water artificially into one of the streams. In principle, the physicists and computer modellers will be able to do their magic and again tell us how the system would respond.

1. Clear water running beneath a shady canopy is typical of freshwater swamp forest.
2. Amongst the tree ferns and pandans along the stream banks, pale knee-shaped roots of trees poke up from the waterlogged ground.
3. Two out of Singapore's three endemic freshwater crabs (pictured is the *Parathelphusa reticulata* or Swamp Forest Crab) are found in Nee Soon, and they are totally protected by law.
4. The Green Tree Snail (*Amphidromus atricallosus temasek*) is an arboreal species endemic to Singapore, found in humid forests.
5. One of the important crustaceans in Nee Soon is the Malayan Shrimp (*Caridina malayensis*).


4


5

Current hydrology, though, depends on the past. We now know that agricultural changes have led to erosion (on slopes) and sedimentation (in valleys and streams), and these processes are continuing. A soil core dating from the present back to approximately the year 1775 (which is 45 years before Singapore was founded) has been analysed for its pollen content, showing a fairly steady proportion of lowland forest tree pollen over the past 50 years, but wild and uncertain fluctuations before that have yet to be understood.

There seem to have been periods with significant grass input. But when forest has been present, trees have been main drivers of the evapotranspiration. A digital terrain model of the ground surface, subtracted from a digital surface model of the forest canopy, gives the vegetation height. When combined with the leaf area index, this can approximate the measurement of evapotranspiration in each of the eight sub-catchments. Within the forest, there are certain tree species favouring wetter conditions, others favouring drier ground, and some that don't really care where they grow. Once all of these features have been properly appreciated—which is not yet—we will be in a position to analyse what the impact would be if any bit of the whole system were to be perturbed, for example, by a drought. Already it appears that the two opinions—one, that the system is becoming wetter and the other, that it is becoming drier—may both be correct. Middle stretches of the streams have possibly accumulated more sediment, slowing water flow and making flooding in mid sections more likely, whereas downstream stretches may be less liable to backflow, making flooding less likely. So far the project has measured more than 1,650 stream profiles, about every five metres along every branch and trickle, and at selected points the bottom and surface flow water rates have been measured. Piezometers in streams allow 24/7 data collection on water depths. The research team collects data on pH, dissolved oxygen, salinity, turbidity, total dissolved solids, temperature, and conductivity.

Along the streams, the aquatic fauna is being sampled at more than 60 points, with repeats to look at consistency. Like the plants in the forest, the stream animals show clear differences: some are limited to the upstream sections, some are found everywhere, and some (mostly unwanted invasives) occur downstream or outskirt. Amongst the fishes, for example, 4 species have been found at all sites, 10 species have been found at more than 10 sites, 9 species are restricted to the stream outlet, and 1 fish is restricted to a single mid-stream locality. For 6 of the fishes, Nee Soon is their only known locality in Singapore. Based on the combination of hydrology and faunal surveys, we will soon be in a position to say if a particular branch of the stream were to dry up or to flood, exactly which fishes (and frogs, and dragonflies, and caddisflies, and water beetles, and aquatic snails), and roughly how many of them, would be affected.

Why Bother?

Biologists have known for decades that Nee Soon is a vital area for conservation in Singapore. That fact alone has not been enough to suggest and design conservation measures other than the default option of locking up the system using a hands-off approach. With a better understanding of the system's freshwater dynamics, we should soon be able to design long-term monitoring protocols and steps to conserve the biodiversity within Nee Soon freshwater swamp forest that are tailored to particular species, particular parts of the catchment, and particular event probabilities. Then land and water managers will be in a much stronger position to ensure the sustainability of this tiny but important fragment of Singapore's natural heritage. CG