CHAPTER 4

Forest Restoration Action Plan

Rachel Tan, Sharon Chan, Adrian Loo & Tan Boxin

Introduction to the Action Plan

The Forest Restoration Action Plan (FRAP), part of the NParks Nature Conservation Masterplan (NCMP), was launched in January 2019. It was formulated to chart the restoration that would be undertaken over the next 10 years to regenerate the secondary forests in the buffer parks surrounding Singapore's nature reserves, as well as disturbed patches within the reserves and core biodiversity areas, including the four nature reserves and Pulau Ubin. This would assist our forests to approximate a mature forest landscape in species and structure over time.

FRAP also seeks to restore ecological processes and functions by enhancing the biodiversity and ecological connectivity in these areas through a science-based approach. It aims to improve the habitats for our native biodiversity as well as strengthen the resilience of our forests to climate change and other anthropogenic pressures. As of April 2023, a total of 398,238 native trees and shrubs have been planted.

Safeguards our core habitats

Under FRAP, NParks is focusing on intensifying our forest restoration efforts across the three Nature Park Networks – Central Nature Park Network, Sungei Buloh Nature Park Network and Labrador Nature Park Network. All three networks serve to protect the nature reserves from the impact of urbanisation and reduce visitorship pressure on the reserves, whilst providing more green spaces for all to enjoy nature-based recreation. They also provide extended habitat and enhanced ecological connectivity for our biodiversity.

The Central Nature Park Network is composed of eight nature parks that buffer the Bukit Timah and Central Catchment Nature Reserves, including Rifle Range Nature Park (66 hectares) which was opened in 2022. Constituting a mere 0.23% of Singapore's land area, Bukit Timah Nature Reserve (163 hectares) alone contains more than 50% of Singapore's native flora and fauna (Chan & Davison, 2019). The primary and mature secondary rainforest habitats provided by our nature reserves are home to many endangered species, and serve as important refugia for rare species that have been rediscovered in recent years through heightened survey efforts (Chong *et al.*, 2018; Ho *et al.*, 2018; Lim *et al.*, 2019). The extended habitats provided by the nature parks are also crucial in supporting the populations of our native species, a point that will be further explored in the 'case studies' section.

The Sungei Buloh Nature Park Network, which buffers Sungei Buloh Wetland Reserve, comprises important core habitats such as the Mandai Mangrove and Mudflat and Kranji Marshes, nature parks and eco-corridors, and nature areas such as Jalan Gemala Marshland and Kranji Reservoir Marshes. Covering over 400 hectares, which is more than triple the size of the Wetland Reserve, this network will safeguard a variety of complementary wetland habitats, including mangroves, mudflats, and freshwater marshes, strengthening the conservation of Singapore's wetland biodiversity. As wetland habitats provide a wide variety of ecosystem services such as serving as a food source and nursery ground for numerous marine organisms, storing carbon, and mitigating coastal erosion, their conservation plays a key role in bolstering Singapore's resilience against the effects of climate change.

The Labrador Nature Park Network is the latest addition that was announced in 2022. This network comprises more than 200 hectares of green spaces and 40 kilometres of trails, park connectors and nature ways, to expand our natural capital and enhance the connectivity between our green spaces. This covers the southern part of Singapore, including Labrador Nature Reserve, West Coast Park, Kent Ridge Park, HortPark, Telok Blangah Hill Park and Mount Faber Park. Labrador Nature Reserve, located at the southern tip of Singapore, is one of the last few coastal hill forests on mainland Singapore with rich biodiversity. Conservation value of such habitat is high as it is getting increasingly rare in Singapore. As part of the Labrador Nature Park Network, new nature parks such as Berlayer Creek Nature Park and Labrador Nature Park will act as a buffer to the 10-hectare coastal hill forest in Labrador Nature Reserve. Together with ongoing habitat enhancement works, this will enhance the ecological connectivity between Labrador Nature Reserve and its surrounding green spaces. This connectivity is carefully planned and guided by NParks Ecological Profiling Exercise.

The science underlying restoration efforts

Decades of rapid urbanisation have taken a heavy toll on Singapore's forests. Primary rainforests, now fragmented across the island, cover only 0.16% of Singapore's land area, while mature secondary forests and young secondary forests make up only 1.37% and 19.64% of land area respectively (Yee *et al.*, 2011). Research has shown that Singapore's secondary forests are regenerating at a very slow pace, with the structure and composition of mature secondary forests contrasting starkly with those of primary forests even after more than a century of recovery (Chua *et al.*, 2013; Goldsmith *et al.*, 2011). Forest succession is likely hindered by the lack of seedling recruitment and the persistence of early successional species. Restoration efforts will therefore go a long way in accelerating forest regeneration and thereby the recovery of biodiversity and ecosystem functioning.

Another obstacle to natural regeneration is the dominance of exotic plant species in abandoned-land forests, defined by Yee *et al.* (2016) as forests regenerated on land formerly used for plantations or village settlements (kampungs) that were vacated with the mature trees left on site. As many of the nature parks in Singapore fall into this category, their forested areas are mostly dominated by exotic species such as Rubber (*Hevea brasiliensis*), African Tulip (*Spathodea campanulata*), Albizia (*Falcataria moluccana*), Oil Palm (*Elaeis guineensis*), fruit trees, and ornamental plants, and tend to have compacted and degraded soils (Yee *et al.*, 2016). While some regeneration is underway given their proximity to the nature reserves, they still lack the abundance and diversity of native species needed for succession to take place. These forests may hence require intervention to help them mature into native-dominated secondary forests (Shono *et al.*, 2006, 2007a; 2007b).

Forest restoration methods

FRAP utilises a science-based approach where forest restoration strategies are selected based on existing site conditions and known land-use history. Some sites may only require passive restoration (Assisted Natural Regeneration), but in many cases, active restoration methods such as Framework Species Method and Maximal Species Diversity Method are needed (Elliot *et al.*, 2013).

Species planted are carefully chosen, taking into consideration the habitat type and specific location they are planted in. As far as possible, the selected species occur naturally in that locality or match the habitat and profile of those naturally occurring in the surrounding nature reserves. Many of the trees and shrubs planted are also propagated from native germplasm from our forests. The

Native Plant Centre supplies 1–3 metre tall saplings grown from seeds collected from our forests, some of which were collected in bulk during masting events. Many of the species propagated by the Native Plant Centre are endangered, such as Banjutan (*Hopea ferruginea*) and Singapore Kopsia (*Kopsia singapurensis*) which are included under NParks' Species Recovery Programme. These endangered species are planted under FRAP in our bid to not only restore the forests but also ensure the long-term survival of these species.

Assisted Natural Regeneration

This method is suitable in areas where seed sources are available nearby and dispersal is not limited, and natural regeneration is already underway. No tree planting is conducted under this method. Instead, weeds like the fast-growing climbers such as the Zanzibar Yam (*Dioscorea sansibarensis*) and Mile-a-Minute (*Mikania micrantha*), and the aggressive ground-covering fern Resam (*Dicranopteris linearis*) that suppress the natural regeneration and succession of native species are removed. Non-native trees that compete with our native tree species are also removed, such as Rubber, Albizia, and African Tulip. The removal of exotic trees is done sensitively and phased over time so as not to adversely affect the habitats provided by some of these species.

Framework Species Method

A framework of light-tolerant, fast-growing, nitrogen-fixing, and fruit-bearing species are introduced, typically early to mid-successional species. By fixing nitrogen in the soil and attracting pollinators and seed dispersers, these species help improve the soil condition and enable more native species to be naturally dispersed from the nature reserves into the regenerating forests. Having fast growth rates and spreading crowns, framework species also allow canopy cover to be established and, hence, weeds to be shaded out quickly in restored sites. This method is often used in areas which have a low density of natural recruitment, but which are relatively close to available seed sources and experienced low to intermediate disturbance in the past. Examples of framework species include nitrogen-fixing trees such as Petai (*Parkia speciosa*) and the Greater Grasshopper Tree (*Archidendron clyperia*), fruit-bearing trees such as the Common Sterculia (*Sterculia parviflora*) and Kumpang (*Horsfieldia polyspherula*), and pollinator-attracting trees such as the Pulai Penipu Paya (*Alstonia angustifolia*).

Maximal Species Diversity Method

This technique involves the planting of a wide range of species, mainly later successional species that are not easily dispersed or are rare in occurrence. This may involve multiple plantings to first plant earlier successional species before introducing species from later successional stages, or may involve the one-off planting of climax forest species in sites with canopy cover already established. This method is chosen for areas which are more remote from the nearest seed source, and have undergone intense degradation or had a long history of disturbance. Some examples of primary rainforest climax species are Dipterocarps (*Shorea* spp., *Hopea* spp., *Dipterocarpus* spp.) and Kempas (*Koompassia malaccensis*).

Community involvement

Community involvement also constitutes a key thrust of FRAP. Stakeholders such as the Friends of the Parks communities, NParks volunteers, schools, corporate organisations, and other members of the community have been contributing to the restoration of our forests by planting trees, collecting seeds and saplings from our forests, propagating them in our community nurseries, conducting invasive species management, and even carrying out research and monitoring of our forest restoration plots.

In 2019, around 2,400 volunteers from over 60 schools and organisations participated in 80 forest restoration activities conducted under the Forest Restoration Action Plan. For instance, about 100 volunteers from Bukit Timah Community Club, WWF Singapore, Kindred, Friends of Bukit Timah Forest, and other community organisations came together to weed *Dioscorea sansibarensis* at the Rifle Range Nature Park in September 2019 (Fig. 1).

Figs. 1. (A) NParks staff briefing the volunteers. (B) Participants, including Adviser Sim Ann and Chairman of the Friends of Bukit Timah Forest, Joseph Koh, with their large haul of weeds. (Photo credit: Cheryl Chia)

Case studies

Thomson Nature Park

Thomson Nature Park is a 50-hectare buffer park bordering the eastern side of the Central Catchment Nature Reserve. As the site of a former Hainan Village, Thomson Nature Park is also rich in cultural heritage. After the village was vacated in the late 1980s, remnant vegetation reclaimed the abandoned land, including fig trees and cash crops such as rambutan, jackfruit, durian and starfruit, and have since served as important food sources for the forest inhabitants there. Over time, the secondary forest at Thomson Nature Park has regenerated, facilitated by its proximity to the Central Catchment Nature Reserve.

Unsurprisingly, Thomson Nature Park is home to a rich diversity of fauna, including many rare and locally endangered animals such as the Malayan Porcupine (*Hystrix brachyura*), Sunda Pangolin (*Manis javanica*), Straw-headed Bulbul (*Pycnonotus zeylanicus*), and Blue-rumped Parrot (*Psittinus cyanurus*). The freshwater streams in the nature park also provide habitat for a range of native aquatic species including the Malayan Box Terrapin (*Cuona amboinensis*). In particular, Thomson Nature Park serves as a key conservation site for the critically endangered Raffles' Banded Langur (*Presbytis femoralis femoralis*).

To further assist the recovery of forest structure and composition, as well as improve the rainforest habitat for these native animals, NParks has been carrying out sensitive habitat enhancement since 2016. Exotic plant species are gradually being removed, and many fruit-bearing species are being planted under the Framework Species Method to strengthen the network of dispersal from seed sources in the nature reserve to the nature park. As of April 2023, 1,579 trees and more than 2,700 shrubs from nearly 200 species were planted in partnership with the community.

In November 2019, nearly 200 students from the Jane Goodall Institute (Singapore) (JGIS) Roots & Shoots programme planted 80 trees along the Ruins and Figs Trail, thereby adopting a forest restoration plot and launching a new programme called 'Plant for Hope' (Fig. 2A). The students have since been returning to the plot to carry out invasive species management and monitor the survival and growth rates of the planted trees (Fig. 2B & 2C). In October 2020, a second round of planting was conducted to further enhance the site.

Figs. 2. (A) Dr Jane Goodall with NParks staff after the launch of the Roots & Shoots' "Plant for Hope" programme on 27 November 2019. (B) Students from the Roots & Shoots schools plot and measure all the saplings planted and any other naturally introduced saplings in the plot. (C) JGIS volunteers maintain the plot by weeding Mile-a-Minute and grasses. (Photo credit: Tan Beng Chiak)

Habitat restoration efforts at Thomson Nature Park encompass the following strategies:

- Removal of invasive species followed by replanting – Oil palms, rubber trees, and other non-native plant species are removed in phases to make way for native species to be planted.
- Planting of Raffles' Banded Langur food plants – From January 2019 to April 2023, more than 800 trees comprising nearly 40 species were planted to increase habitat resources for the Raffles' Banded Langur.
- Planting of keystone species – Keystone species such as figs, which produce fruit all year round, are planted to provide a constant supply of food for animals in the nature park.
- Stream restoration – Ferns and riverine plants are planted by stream banks to prevent erosion and to improve the health of the stream for aquatic species.
- Planting to enhance ecological connectivity – Trees with spreading canopies are planted along the edge of the nature park to improve connectivity for arboreal animals which regularly cross between the nature reserve and nature park in search for food and mates.

The 3-kilometre-long Old Upper Thomson Road separates the Central Catchment Nature Reserve from Thomson Nature Park as well as forest patches in Upper Thomson, Lentor, and Tagore, making the road a focal stretch for ecological connectivity to be enhanced. To facilitate the movement of the Raffles' Banded Langur and other arboreal animals, rope bridges have been installed along the road at locations where the langurs have been observed to habitually cross. Culverts are also being maintained to promote the crossing of terrestrial animals. By increasing connectivity for arboreal and terrestrial mammals that are important seed dispersers, such as the

Long-tailed Macaque (*Macaca fascicularis*), Lesser Mousedeer (*Tragulus kanchil*), and Malayan Colugo (*Galeopterus variegatus*), these efforts are important in aiding the natural regeneration of the forest. A similar approach has been implemented at Rifle Range Nature Park.

Chestnut Nature Park

Previously the site of a kampung, Chestnut Nature Park had part of its forest cleared during the early 1900s to make way for agricultural activities. As the villagers eventually moved out and the kampungs were demolished, pockets of open space were left to be taken over by nature once again. Fast-growing exotic species such as Albizia and African Tulip soon started to dominate, along with other non-native fruit trees and oil palms.

Forest restoration efforts at Chestnut Nature Park have been concentrated on sensitively removing the non-native species in phases to ensure that habitat resources are maintained, while carrying out replanting with native trees to aid regeneration of the young secondary forest. A combination of the Framework Species Method and Maximal Species Diversity Method is used, due to the variation in site conditions of the different plots. In open plots without pre-existing canopy cover, fast-growing native tree species that can tolerate full sun conditions, such as Jelutong (*Dyera costulata*), are typically chosen to enable quick establishment of the canopy cover. Canopy closure deters the growth of sunlight-loving weeds which can smother native trees and hinder their growth. Fruit-bearing trees such Santol (*Sandoricum koetjape*), Salam (*Syzygium polyanthum*), and Rambai (*Baccaurea motleyana*) are chosen to attract frugivorous birds and bats, which assist natural regeneration by bringing in other seeds from nearby seed sources. Keystone species which fruit all year round, such as various species of fig trees, are planted as well. In sites where non-native trees have been selectively retained, mid- to late-successional species that require moderate light conditions and humidity are grown under the shade of the non-native trees. Examples of such species are Sepetir (*Sindora wallichii*), Gaharu (*Aquilaria malaccensis*), Tempinis (*Streblus elongatus*), and nitrogen-fixing legumes such as Kempas (*Koompassia malaccensis*). Enrichment planting of these species is also carried out in the understorey layer of less diverse secondary forest sites, to help overcome the limited natural dispersal range of seeds from primary forest patches.

From January 2019 to April 2023, more than 2,759 native trees from 70 species were planted in Chestnut Nature Park. NParks has been working closely with the Friends of Chestnut Nature Park and the National University of Singapore (NUS) Ridge View Residential College (RVRC) on forest restoration programmes, including tree planting, weeding, and growth monitoring at Chestnut Nature Park (Fig. 3 & 4).

Figs. 3. (Top left and bottom left) The Chestnut Point restoration site in August 2018 before the commencement of forest restoration efforts. (Top right and bottom right) The Chestnut Point restoration site in February 2020, after 101 trees were planted in September 2018. (Photo credit: RVRC (bottom left and right))

Figs. 4. (A) Dr Chua Siew Chin and her RVRC students after a weeding session at Chestnut Nature Park to remove non-native climbers such as *Mikania micrantha*. (B) RVRC students after a tree planting event at Chestnut Nature Park. (Photo credit: RVRC)

Rail Corridor

Since 2018, the central and southern stretches of the Rail Corridor have been rewilded and planted up with more than 4,931 native trees. Similar to the restoration undertaken at Chestnut Nature Park, a phased approach is used to progressively remove exotic species such as Albizia and African Tulip along the Rail Corridor, and replace them with native tree species. Most of the trees planted initially were fast-growing species in order to quickly provide shade, but increasingly, a greater number of slower-growing forest species and native fruit trees are being planted to provide a lush green belt for biodiversity to thrive. Following the Maximal Species Diversity Method, a wide range of mid- to late-successional species are chosen, including the Shore Laurel (*Neolitsea cassia*), Derum (*Cratoxylum maingayi*), Cheng Tng Tree (*Scaphium macropodum*), Keruing Belimbing (*Dipterocarpus grandiflorus*), Small-leaved Oil-fruit (*Elaeocarpus mastersii*) (Fig. 5), and the critically endangered Cengal Pasir (*Hopea sangal*) and Singapore Kopsia (*Kopsia singapurensis*).

Figs. 5. The Small-leaved Oil-fruit (*Elaeocarpus mastersii*) is a medium-sized tree that grows in primary and secondary lowland to montane forests. It occurs locally in the Bukit Timah and Central Catchment Nature Reserves. As its fruits and seeds are eaten and dispersed by birds, it is commonly planted to encourage natural recruitment through dispersal by birds. (A) Foliage of *Elaeocarpus mastersii*. (B) The greyish-blue, round-oval fruits of *Elaeocarpus mastersii*. (Photo credit: Ang Wee Foong)

Due to the heterogeneity in habitat type and landscaping narrative along the green corridor, different sections of the Rail Corridor will feature different planting palettes. The planting plan for the central stretch will mainly focus on forest species. Moving further north, the composition of species planted will gradually shift from forest species to back mangrove species, while in the south, the planting palette will incorporate native fruit trees and economically important species.

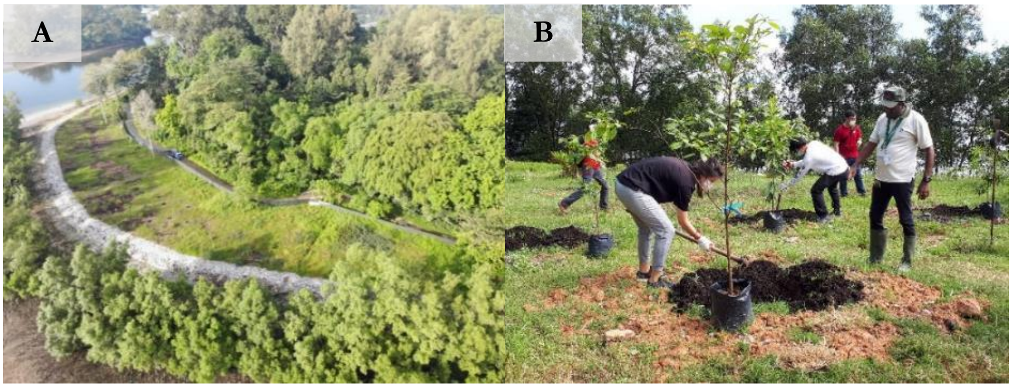
Traversing Singapore from north to south and linking several estates, the Rail Corridor also has a special role to play in connecting communities. In October 2018, around 200 volunteers came together to enhance a stream along Rail Corridor (Central) near Rail Mall. This stream used to be a concrete drain that served the railway tracks, but its walls had since collapsed. The volunteers planted a variety of species to help filter and clarify the water, making it more conducive for the aquatic species residing in it. *Magnolia singapurensis,* an endangered native swamp species, was also planted there as part of NParks' species recovery efforts. Since then, more than 55,000 native trees and shrubs have been planted by more than 930 members of the community as part of habitat enhancement efforts along the Rail Corridor (Fig. 6). NParks will continue to actively engage communities living along Rail Corridor, as well as the Friends of the Rail Corridor, to involve them in further intensifying the greenery of, and enhancing habitats along, the Rail Corridor.

Figs. 6. (A) A BES (Bachelor of Environmental Studies) Drongo member carrying out stream restoration planting at Rail Corridor (Central) in October 2018. (B) Planting of the endangered *Magnolia singapurensis* by Minister Desmond Lee, Adviser Christopher de Souza, Adviser Sim Ann, former Adviser Liang Eng Hwa, then NParks CEO Kenneth Er, and URA CEO Lim Eng Hwee. (Photo credit: (A) Jeanne Tan)

Kranji Coastal Nature Park

Kranji Coastal Nature Park, part of the Sungei Buloh Nature Park Network, contains a variety of habitats – secondary forest, coastal beach, as well as mangrove. Over the years, however, the coast has been affected by severe erosion, leading to the loss of plants and intertidal habitats. In addition, the damming of the river has reduced sedimentation, impeding natural recovery from occurring.

To prevent further erosion and restore the habitats, NParks undertook the installation of a rock revetment beyond the mangroves in 2019, following which regrading works and soil backfilling were also done (Fig. 7A). This regraded area was incorporated within NParks' coastal forest restoration plan in Kranji Coastal Nature Park, a plan that seeks to restore the secondary forest, coastal forest, and mangrove forest habitats. The restoration approach for this site entails the planting of suitable framework species, such as nitrogen-fixing legumes to improve the disturbed soil, and fruit-bearing trees to attract dispersers like birds to bring in species from the adjacent forests. Specially selected coastal and back mangrove species such as Nyatoh Puteh (*Palaquium obovatum*), Sparrow's Mango (*Buchanania arborescens*), Pelir Musang (*Fagraea auriculata*), and Sepetir (*Sindora wallichii*) are also planted. Additionally, the mangrove forests are now naturally recruiting on their own due to the rock revetment slowing down coastal erosion. Over time, the restored mangroves will serve to protect the area from coastal erosion – a form of nature-based solution. Since June 2020, planting efforts in Kranji Coastal Nature Park have intensified (Fig. 7A), and a wide spectrum of the community has been roped in to join in the efforts, including the Friends of Sungei Buloh Wetland Reserve, nature groups, and educational institutions like NUS and Singapore University of Social Sciences (Fig. 7B).



Figs. 7. (A) Aerial view of the restoration site situated between the rock revetment and the existing secondary forest, taken before forest restoration efforts began at this site. (B) Volunteers from NUS planting at the restoration site.

Monitoring forest restoration efforts

On top of the ongoing forest restoration efforts, monitoring and research form an important component of FRAP, in order that the methods used may be continuously finetuned and improved upon where necessary, and the capacities and best practices in forest restoration be developed. To this end, NParks has been working alongside researchers and members of the community.

One such research project, led by Dr Chong Kwek Yan (then from NUS) and his students, Lorraine Tan (2016–2017) and Tan Boxin (2019–2020), investigated the effects of understorey weeding in Singapore's secondary forests. Through the setting up of experimental plots at Labrador Nature Reserve, Bukit Batok Nature Park, and Windsor Nature Park, it was found that weeding can reduce native seedling mortality and increase native seedling recruitment, but periodic weeding and long-term monitoring are required for these effects to be discernible. Monitoring will be continued at all three sites and re-weeding will be done in the two nature parks. Belowground-aboveground linkages that may help explain the differences in weed re-invasion success between plots, will also be further explored, which will help shed light on the mechanisms through which invasive species affect native seedling survival and recruitment. This project has important implications for the way we understand and conduct invasive species management.

Past land use can greatly influence the trajectory of forest recovery – different land-use histories may hence necessitate different restoration strategies to accelerate the forest regeneration process. Another project, conducted by Dr Chua Siew Chin and her NUS RVRC students, leverages the varied land-use history and vegetation types across Chestnut Nature Park to test different restoration strategies (Fig. 8). The team first assesses the existing site conditions of a plot, including the vegetation cover, plant diversity, and soil quality. They then implement the appropriate site preparation work and planting strategy, and subsequently follow up with regular monitoring of the survival and growth rates of the planted trees. Over two years of monitoring, they have found that under specific light and soil conditions, certain planted species have higher survival and growth rates than others, and that mulch application leads to marginally higher growth rates at sites with degraded soil. They are presently experimenting with filling the planting holes with improved soil mixture at degraded sites. The team has also determined that a higher planting density of 1 to 1.5 metres' distance between trees, rather than 2 to 2.5 metres, is more effective at achieving canopy closure after one year. RVRC's monitoring efforts will continue to help inform the best practices for forest restoration through the iterative process of adaptive management.

Fig. 8. Dr Chua Siew Chin and her RVRC students conducting research and monitoring on the survival and growth rates of tree species in the Chestnut Nature Park restoration plots. (Photo credit: RVRC)

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