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Rediscovering and conserving orchids in a tropical city-state

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ABSTRACT. The conservation status of orchids in the city-state of Singapore mirrors the worldwide decline of this group of plants, one of the largest families of flowering plants. Despite this, the number of extant native orchids has been revised from 45 to 76 in the last 15 years largely due to taxonomic revisions and (re-)discoveries. Building on the history of orchid taxonomic research in the Singapore Botanic Gardens and the revival of plant systematics in Singapore, these recent successes reflect efforts in establishing resident taxonomists and field ecologists, embracing integrative taxonomy, undertaking comprehensive botanical surveys, and developing an opportunistic instinct to discover orchids in the field. Coupled with ongoing species recovery efforts, this provides a sense of optimism for conservation and suggests that small habitat fragments characteristic of cities could continue to be refugia for native orchids. This also further illustrates the important role that botanic gardens play in the conservation of endangered plant species.

Keywords. Botanic gardens, conservation, Orchidaceae, Singapore

Introduction

Singapore is renowned as one of the greenest high-density cities in the world (Tan, 2016). It is located in the Sundaland biodiversity hotspot in tropical Southeast Asia (Myers et al., 2000). When Singapore was first founded as a British colony in 1819, it was largely covered by lowland rainforest and mangroves along the coasts and rivers. By the mid-1800s, 40% of the primary forest had already been converted to agricultural land, including plantations, and urban areas. The pace of forest conversion picked up even more drastically in the second half of the 19th century, leaving only 3% of primary forest by 1900 and less than 1% by 1930 (Corlett, 1992). Today, approximately 0.28% of primary lowland dipterocarp and freshwater swamp forest still persist, while about 21% of the land area is covered in regenerated secondary forest, these different forest types existing as small habitat fragments within an urban landscape matrix (Yee et al., 2011). As with most cities, this landscape composition of small vegetation fragments amidst ornamental green spaces and urban infrastructure gives rise to novel ecosystems that present unique challenges for plant conservation (Hobbs et al., 2006) and promulgates the perception of cities as 'biological deserts' (Spotswood et al., 2021). While the density of native plant diversity could have declined substantively due to habitat loss and fragmentation, the remnant habitat fragments serve as critical refugia for native plants, including endemic ones (Soanes & Lentini, 2019; Spotswood

et al., 2021). While these small habitat fragments may carry a large extinction debt, they have also been found to be more resilient than previously thought, such that not all small populations may be predisposed to rapid extinction (Turner & Corlett, 1996; Wintle et al., 2019; Volenec & Dobson, 2020).

In the context of Singapore, the number of plant extinctions is significantly lower than that predicted by the species-area relationship. Turner et al. (1994) first attributed this to a time-lag in extinctions following habitat loss, whereby plant communities in the forest remnants have not yet reached equilibrium in terms of species losses. Around the same time, Tan et al. (1993) provided an account of two fern and 23 angiosperm taxa that were new records to the flora of Singapore. This suggested that there exists a window of opportunity for conservation, restoration and management interventions, and further provided optimism that some plant species may have been presumed locally extinct only because of the lack of botanical surveys and taxonomic studies (Er et al., 2022).

In the last 15 years, the first author and his colleagues at the National Parks Board (NParks) have been amazed at the numerous (re)discoveries of native plant species, including orchids, in Singapore. This is in spite of the fact that Singapore is probably the most botanically densely collected tropical country in the world (Middleton et al., 2019). Comparing between two national plant checklists from 2009 and 2023 (i.e., Chong et al., 2009 and Middleton et al., 2024 based on Lindsay et al., 2022), Neo et al. (2024) showed that there have been 173 rediscoveries and 155 new records documented after 2009, including 22 species new to science and five endemic species. Among the rediscoveries and new records, the Orchidaceae was one of the best represented families, with 26 rediscovered and eight new taxa. However, the proportion of rediscovered orchids remains significantly low when compared against the large proportion of orchids among the presumed nationally extinct flora.

The Orchidaceae is one of the largest families of flowering plants, with an estimated 28,000 to 30,000 species in around 736 genera (Chase et al., 2015). Orchids are distributed across vegetation types in every continent except the Antarctic (Dressler, 1981). Notwithstanding this widespread distribution, orchid species diversity is skewed towards the tropics (Vitt et al., 2023). Many orchid species are also naturally rare and exhibit a high level of endemism because of their distinct ecological life history traits and limited geographic ranges (Cribb et al., 2003; Fay, 2018; Vitt et al., 2023). At the same time, they tend to be sensitive to the effects of habitat loss and fragmentation from deforestation, agriculture, mining, urbanisation; disturbance from recreation and tourism activities; collection for trade; and climate change and pollution (Koopowitz et al., 2003; Swarts & Dixon, 2009b; Hinsley et al., 2018). This has resulted in orchids becoming one of the most threatened plant families in the world, with over 600 species having been listed as threatened in the global IUCN Red List (Wraith & Pickering, 2018; Wraith et al., 2020).

A major challenge in the conservation of orchids that confronts botanical institutions worldwide is the taxonomic survey and systematic description of orchid species. This forms the basis for establishing conservation priorities and strategies: what species to recognise, where they occur, and what their conservation status is

(Fay, 2018). While field surveys have become more extensive, our understanding of orchid systematics has been improving, and we now know of 25,434 orchid species with distribution data (89.3% of Orchidaceae), there remains a large number of orchid species to be documented, especially in the neotropics and Southeast Asia (Vitt et al., 2023). More importantly, only 5.6% of orchid species with accepted names have been assessed for their global IUCN conservation status, and only 26% have regional or national assessments (Bachman et al., 2019). Challenges in undertaking orchid systematic research and field surveys in many jurisdictions of Southeast Asia and the neotropics might include the lack of resident taxonomists and field ecologists, and inadequate investments into Floras, monographs and comprehensive botanical surveys (Dressler, 2005; Funk, 2006; Ahrends et al., 2011; Wilson, 2017; Grace et al., 2021).

While the conservation status of orchids in Singapore mirror the worldwide phenomenon of biodiversity decline, the renewed interest and advancement in orchid systematic and field surveys, and ex-situ conservation in the last two decades, have resulted in the (re-)discovery and recovery of native orchid species (Yam, 2023). In this commentary, we hope to share this journey of (re-)discovery and conservation in the last two decades in Singapore, and illustrate how cities can contribute towards orchid conservation. We first trace the history of orchid taxonomic research and conservation with the development of the Singapore Botanic Gardens in the early 1900s, and revival of plant systematics in Singapore through the 1990s till today. We then identify factors that contributed to the (re-)discoveries of orchid species through taxonomic revisions and field surveys in recent years, and further highlight the interventions in species recovery. This commentary is adapted from a Keynote address delivered by the first author at the 14th Asia-Pacific Orchid Conference, Singapore, on 16 August 2023.

Native plant and orchid systematic research at the Singapore Botanic Gardens

The Singapore Botanic Gardens (SBG) has been at the forefront of orchid systematics, conservation and hybridisation in Peninsular Malaysia and Singapore since the 1900s. In particular, the early directors of the Gardens, Henry Nicholas Ridley and Richard Eric Holttum, laid the foundation in orchid systematic research and conservation. Ridley came to the Gardens as its first Director in 1888 and remained until 1912. By then, he had already amassed a collection of more than 50,000 plant specimens from Peninsular Malaysia and Singapore, and the wider region (Middleton & Turner, 2019). These specimens contributed towards the publication of the first plant checklist of Singapore, the *Flora of Singapore* (Ridley, 1900). They were also integral to the preparation of the *Materials for a Flora of the Malayan Peninsula* between 1889–1915, led by Sir George King who was then Director of the Royal Botanic Gardens Calcutta. Ridley collaborated on this project by writing up the monocotyledons (Ridley, 1907). This also provided the foundation for the *Flora of the Malay Peninsula* (Ridley, 1922, 1923, 1924a, 1924b, 1925). Ridley had specialised in monocotyledons when he was at the British Museum of Natural History, and hence developed a special interest in the orchids of Peninsular Malaysia and the wider region when he assumed the appointment

at the SBG. This is evident from the large number of published orchid monographs and taxonomic papers in his bibliography (Henderson & van Steenis, 1935). Notable examples included the monographs on *Liparis* that described 110 species (Ridley, 1886) and *Bromheadia* Lindl. that described four species (Ridley, 1891). The first account of the orchids of the Malay Peninsula could be considered to be Ridley's contribution to Stapf's *On the flora of Mount Kinabalu, in North Borneo*, where he listed species for Mount Kinabalu but also made mention of species found in Peninsular Malaysia and Singapore (Ridley, 1894). This account was subsequently incorporated into and expanded on in his *Materials for a Flora of the Malayan Peninsula: Monocotyledons 1* (Ridley, 1907) and *Flora of the Malay Peninsula 4* (Ridley, 1924b). Overall, Ridley described 13 new orchid genera and 200 new orchid species in Peninsular Malaysia and Singapore. He also collected 459 orchid specimens in Singapore including 35 type specimens (held in SING herbarium), comprising 59 genera and 154 species (Yam & Thame, 2005).

Isaac Henry Burkill succeeded Ridley as Director of the SBG and appointed Richard Eric Holttum as Assistant Director in 1922. Holttum subsequently took over from Burkill as Director in 1925. He built on Ridley's work on Malayan orchids and sought to update Ridley's *Flora of the Malay Peninsula 4* with *A Revised Flora of Malaya (Orchids)* (Holttum, 1953). Holttum also introduced Knudson's asymbiotic method of orchid germination to the SBG, which essentially allowed the germination of orchid seeds without the need for symbiotic fungi. This led to the production of the first SBG hybrid *Spathoglottis* Blume 'Primrose', and initiated the development of in-vitro propagation of orchids at the Botanic Gardens (Yam & Arditti, 2009). This would also prove to be critical for the ex-situ propagation and recovery of native orchids in later years.

Following Holttum, there was a lull in plant systematic research and field surveys, including that of orchids, at the SBG (Kiew, 1999; Middleton & Turner, 2019). This was revived when Kiat Tan was appointed the Director of SBG in 1990, and brought in practising taxonomists in the region, including Chin See Chung, Ruth Kiew and Benito Tan, to variously hold the position of the Keeper of the Herbarium at SBG (SING). This, coupled with the renaissance in plant systematics and ecology at the National University of Singapore under Hsuan Keng and Wee Yeow Chin, followed by Richard Corlett, Ian Turner and Hugh Tan, brought about an impetus in describing the flora of modern Singapore, including orchids. The momentum picked up a notch with the addition of Wong Khoon Meng and David Middleton at the SBG in 2010 and 2014, respectively. All in all, this produced four milestone checklists of the plants (including orchids) of Singapore over the last three decades (Er et al., 2022):

- The *Concise Flora of Singapore* (Keng, 1990; Keng et al., 1998). These two volumes listed 1,252 native gymnosperm and dicotyledon species, and 557 native monocotyledon species.

- *A Checklist of the Native and Naturalised Vascular Plants of the Republic of Singapore* (Turner et al., 1990). This listed 2,039 native species. This was followed

shortly by *The Names Used for Singapore Plants Since 1900* (Turner, 1993), which further revised the checklist of vascular plants with the key synonyms used in the 20th century, and streamlined the checklist to 2,340 native species. Based on this checklist, Turner et al. (1994) found that epiphytic species, including Orchidaceae, had the largest number of extinctions (about 62%). They attributed this to the loss of mangroves and large forest trees that are natural hosts for epiphytes, as well as epiphytic species being more susceptible to micro-climatic changes in the remaining forest fragments. This also led to the publication of Singapore's first Red Data Book on threatened plants and animals (Ng & Wee, 1994).

- *A Checklist of the Total Vascular Plant Flora of Singapore* (Chong et al., 2009). This provided a comprehensive list of native and naturalised exotic species, of which 2,141 species were native (51% of the total flora). Among the 20 largest families comprising 1,159 native species, 402 (35%) were presumed nationally extinct. The Orchidaceae was the largest family listed with 220 native species, and also had the largest number of extinct species (175, about 80%) (Chong et al., 2009). Concomitant to this was the publication of the second edition of Singapore's Red Data Book (Davison et al., 2008).

- *Flora of Singapore: Checklist and Bibliography* (Lindsay et al., 2022). In the years following Chong et al. (2009), 97 native vascular plant species were newly recorded for Singapore, including those new to science and endemic to Singapore, and a highly significant number of 206 presumed nationally extinct native species were rediscovered (Er et al., 2022). This culminated in a new flora checklist, which recognised 2,388 native species including 223 native orchid taxa (Lindsay et al., 2022). On the basis of this latest checklist, Middleton et al. (2024) published updated conservation assessments for the Singapore flora in the third edition of the Singapore Red Data Book. In an earlier study, Kristensen et al. (2020) had revised downwards the proportion of vascular plants presumed to be extinct in Singapore from 31% to 22%, taking into account the (re-)discoveries up till that point. They further showed that the rate of species discovery had not plateaued, which suggests that there could still be more species to be (re-)discovered.

(Re-)discovery of native orchids in Singapore

To track orchid discovery in Singapore over time, we compared the orchids listed across Ridley's *Flora of Singapore*, Holttum's *A Revised Flora of Malaya* (Orchids), and the Singapore flora checklists of Turner (1993), Chong et al. (2009) and Middleton et al. (2024) based on Lindsay et al. (2022). With the exception of the dip in orchid species between Ridley and Holttum, which was due to the fact that Holttum did not specifically mention Singapore in the orchid descriptions, it is evident that the number of native orchid taxa recorded for Singapore continued to increase (Fig. 1). Additions of new records from 2009 to 2023 could be attributed largely to taxonomic revisions

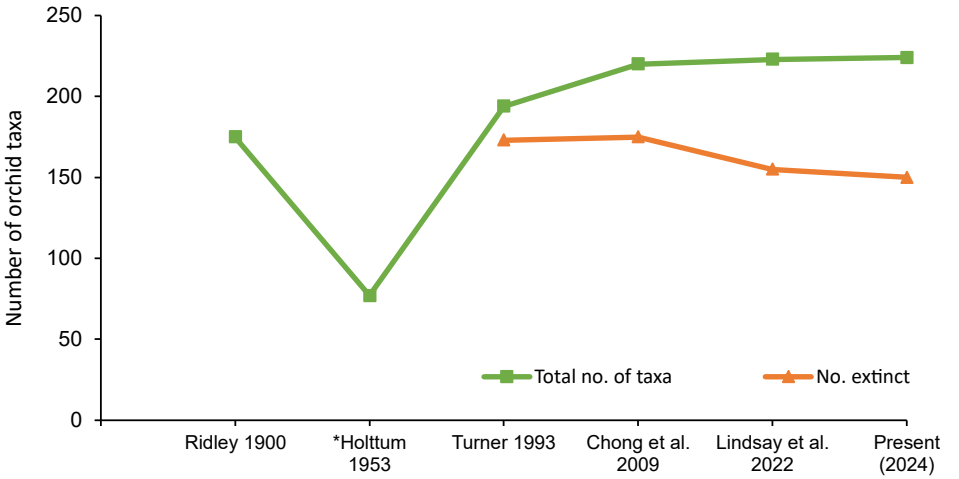

Fig. 1. Changes in the number of Singapore native orchid taxa listed from 1900 to present (2023). The green line (square markers) indicates the total number of taxa listed while the orange line (triangle markers) indicates the number of extinct taxa. *Holttum did not usually treat Singapore as separate from southern Peninsular Malaysia.

and new discoveries in the field (Fig. 2; Neo et al., 2024). More significantly, the number of native orchids recorded for Singapore does not appear to have plateaued. It is likely that more orchid species will be uncovered, consistent with the observation of Kristensen et al. (2020). Indeed, the present number is 224 orchid taxa in 78 genera as of May 2024 (Middleton et al., 2024), which is one more than recorded in Lindsay et al. (2022) because of the recent discovery of *Claderia leontocampus* Niissalo (Niissalo et al., 2023). At the same time, the number of orchid taxa known to be extinct has also declined over the years owing to taxonomic revisions and re-discoveries. There were only 45 extant orchids listed in Chong et al. (2009). Owing to the persistence of taxonomic research and field surveys, we now know that we have 76 extant taxa (33.9% of 224 native orchid taxa; Middleton et al., 2024), an increase of about 68.8%.

Reflecting on the increasing number of new orchid species described and (re)-discovered for Singapore, especially during the period between Chong et al. (2009) and Middleton et al. (2024) based on Lindsay et al. (2022), it would appear that there was a renewed interest in orchid taxonomy and conservation, that went against the common phenomenon of taxonomic impediment elsewhere in the world (sensu Funk, 2006). Notwithstanding the fact that Singapore is small in comparison to most of the other botanical hotspots in this region, there were some underlying factors that made the (re-)discovery of orchids in Singapore possible.

Establishing resident taxonomists and field ecologists

There is increasing recognition that the discovery of species can be best expedited by building up a resident team of taxonomists and field ecologists who are familiar and in close proximity with the local flora and habitats (Moerman & Estabrook, 2006;

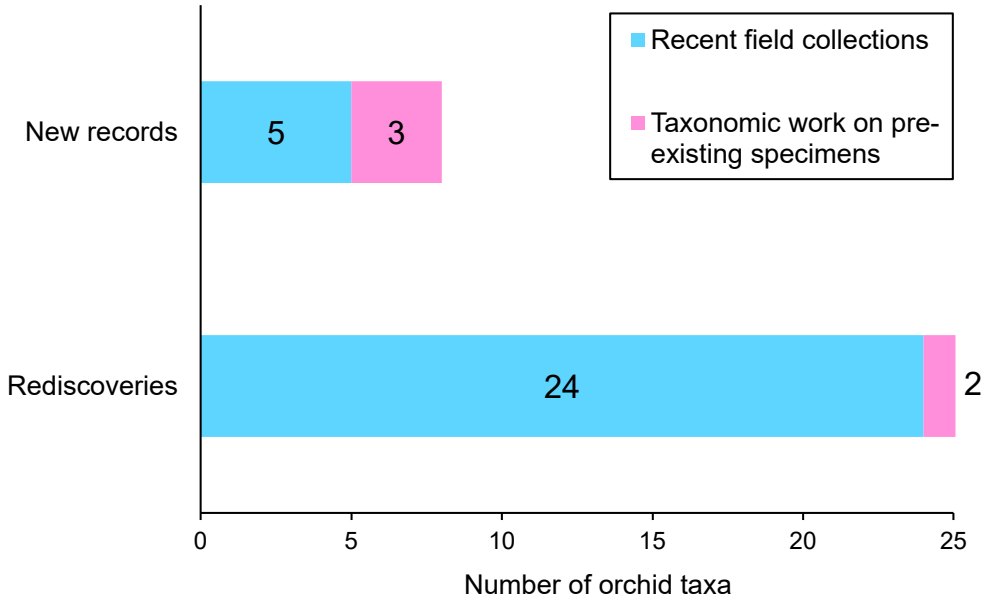

Fig. 2. The proportions of new orchid records and rediscoveries in Singapore from 2009 to 2023 which resulted from recent field collections and from taxonomic work on pre-existing specimens.

Joppa et al., 2011; Liu et al., 2023). However, for tropical cities like Singapore, there may be challenges in attracting tropical taxonomists and ecologists with international and regional experience, as Singapore does not have a large expanse of natural habitats and there may be fewer opportunities to undertake high-impact research in biodiversity. Without far more experienced taxonomists and ecologists, it will be challenging to train and establish a resident team that also comprises budding local taxonomists and field ecologists (Ahrends et al., 2011).

Fortunately, the SBG, a UNESCO World Heritage Site, is well-known for its herbarium collection and research in tropical plant taxonomy in Southeast Asia. The Gardens has also stayed focussed on its mission of plant taxonomy and conservation, and built up its strength in taxonomic research in several key families including the Orchidaceae, Rubiaceae, Zingiberaceae, Begoniaceae and Gesneriaceae over the years, echoing the calls of many that recognised the important role that botanic gardens play in plant conservation (Holttum, 1999; Swarts & Dixon, 2009a; Westwood et al., 2020). This has allowed the SBG to establish a core group of resident taxonomists and field ecologists, and an extensive network of plant taxonomists from other botanic gardens and research establishments with interests in the flora of the wider Southeast Asian region. This has been complemented by a growing team of field ecologists at NParks and researchers from local universities [National University of Singapore (NUS) and Nanyang Technological University (NTU)], who also undertake para-taxonomic work. Middleton & Turner (2019) noted that "The taxonomic research team in Singapore

Botanic Gardens has never before been as large and productive as it is now and has reached a critical mass that allows a project such as the *Flora of Singapore* to be possible".

The re-discovery of the then presumed nationally extinct ground orchid *Vrydagzynea lancifolia* Ridl. at the Bukit Timah Nature Reserve (BTNR) after nearly 80 years (Lim et al., 2014) is an example of how it is important to set in place a resident team with flora expertise, in collaboration with local and overseas research institutions. A group of young field ecologists at the NUS were surveying at the BTNR with Helena Duistermaat, a plant taxonomist from Leiden who was working on a revision of the genus *Amischotolype* Hassk. (Commelinaceae). They noticed the *Vrydagzynea lancifolia* individual which superficially resembled a Commelinaceae species. The plant was subsequently identified by Hubert Kurzweil, then orchid taxonomist at the SBG (Lim et al., 2014). As another example, the presumed nationally extinct *Plocoglottis lowii* Rchb.f. was re-discovered by Matti Niissalo, then a PhD candidate at NUS with an interest in the conservation genomics of *Zingiber* Mill. gingers, and Craig Williams and Daniel Thomas from the SBG, when they were surveying habitats suitable for native Zingiberales near the Upper Seletar Reservoir (Niissalo et al., 2016). The identification of this species was subsequently also confirmed with the help of Hubert Kurzweil.

Embracing integrative taxonomy

Plant diversity can only be effectively conserved when the taxonomic diversity is well understood. The ability to circumscribe species through alpha taxonomy, viz., the description and delineation of species based primarily on morphological characteristics, may, however, be inadequate for cryptic species (i.e., species that are poorly known and often superficially morphologically-indistinguishable from another species or species complex). Botanic gardens and research centres will need to combine alpha taxonomy with phylogenetic and ecological studies as part of an integrative taxonomy workflow to better identify cryptic species, and hence determine the number of species in the area of interest (Dayrat, 2005; Bickford et al., 2007; Webb et al., 2010; Mayo, 2022). This has been demonstrated for some complex orchid species such as the Asian *Nervilia* Comm. ex Gaudich., which has an ephemeral habit of emergence-dieback from the ground and temporal separation of the flowering and leafing phases (Gale et al., 2015, 2018). These characteristics tend to result in an under-representation of complete plant specimens in herbaria, thereby giving rise to vague and overlapping descriptions of many species, especially in the *Nervilia adolphi-punctata* alliance in section *Linervia* Schltr. (Gale et al., 2015, 2018).

The setting up of an orchid molecular lab at the SBG in the early 1990s coupled with the employment of researchers in phylogenetic studies and conservation genetics in recent years, have greatly facilitated the advent of integrative taxonomy. Using a combination of morphological traits and phylogenetic analysis, Niissalo et al. (2020) were able to describe a newly discovered patch of *Nervilia* at BTNR as a new species: *Nervilia singaporensis* Niissalo. Interestingly, this was traced to a herbarium specimen at SING collected by Ridley as *Nervilia punctata* (Blume) Makino from Bukit Timah

in 1891, with a painted illustration by the artist James de Alwis. The illustration matched the flower morphology of the newly discovered plants. Phylogenetic analysis also proved to be important in distinguishing a new ground orchid species, *Claderia leontocampus*, collected from BTNR and the Central Catchment Nature Reserve (CCNR). Before this, the little-studied genus *Claderia* Hook.f. was thought to contain only one or two species, i.e., *Claderia viridiflora* Hook.f. and possibly its synonym *C. papuana* Schltr. (Niissalo et al., 2023).

Undertaking comprehensive field surveys

Taxonomic revisions and the description of species must be accompanied by the mapping and surveying of species in the field if we are to have a complete picture of the species most threatened with extinction or those which are indeed extinct in the wild (Chong et al., 2012). While advances in molecular genetics and information technology have made it possible to undertake a rapid scan of the biodiversity that is present in any habitat, what we are most in need of is 'boots on the ground' (Wilson, 2017). NParks has been undertaking comprehensive botanical surveys of the nature reserves (BTNR and CCNR) since 1992. The first comprehensive botanical surveys were conducted from 1992 to 1997, and, by the end of these first surveys, 1,634 vascular plant species had been recorded from both reserves in total, of which orchids numbered 88 (Chew et al., 1997). The survey at BTNR has been repeated, while a repeat survey of CCNR is ongoing. Repeating these surveys serves to monitor the state of the flora, and also allows for plant species to be (re-)discovered. For example, the repeated survey at BTNR from 2014 to 2018 contributed 10 rediscoveries of presumed nationally extinct species and one new native species record, even though no new orchid species were (re-)discovered (Ho et al., 2019). In addition, targeted surveys as part of studies of unique habitats within the reserves have also been conducted, e.g., of the Nee Soon Freshwater Swamp (NSFS) within the CCNR (Turner et al., 1996; Chong et al., 2018). The NSFS surveys have collectively resulted in the (re-)discovery of nine native orchid species between 2010 and 2013: *Bulbophyllum singaporeanum* Schltr. (Yam et al., 2010b), *Callostylis pulchella* (Lindl.) S.C.Chen & Z.H.Tsi (Lok et al., 2012), *Coelogyne rochussenii* de Vriese (Lok et al., 2011a), *Dendrobium aloifolium* (Blume) Rchb.f. (Ang et al., 2010), *Hetaeria obliqua* Blume (Leong & Yam, 2013), *Liparis barbata* Lindl. (Lok et al., 2010), *Polystachya concreta* (Jacq.) Garay & H.R.Sweet (Lok et al., 2011b), *Renanthera elongata* (Blume) Lindl. (Ang et al., 2011), and *Trichotosia velutina* (Lodd. ex Lindl.) Kraenzl. (Ang et al., 2012). Complementing these surveys in the nature reserves are botanical surveys on the offshore islands, and in nature parks and areas on the main island (Er et al., 2022), which have also yielded a few (re-)discoveries such as *Dienia ophrydis* (J.Konig) Seidenf. (Hassan Ibrahim et al., 2011), *Robiquetia spathulata* (Blume) J.J.Sm. (Yam et al., 2016), and *Hetaeria oblongifolia* Blume (Leong et al., 2021).

Developing an opportunistic instinct to look for orchids

In spite of all the resources that one could muster and invest into taxonomic research and comprehensive surveys, the one key ingredient that constantly intrigues most of us

is how someone could even spot a rare or presumed extinct plant. In the 25 years that the lead author has undertaken research in forest ecology and conservation, the sense is that there must be such a thing as botanical instinct and a nose for following up on leads in the field. This is necessary and can only be inculcated in young early career scientists if the relevance of fieldwork is recognised as integral to conservation science (Dijkstra, 2016; Rias-Saldana et al., 2018) and if they are not constantly assessed solely on the basis of the impact factors of papers that they publish (Fitzsimmons & Skevington, 2010; Ferreira et al., 2016). The latter is a challenge especially for plant taxonomists, as much of their work is published in journals of institutions where the material is found or lodged (Krell, 2002). Investment must be made to train botanists and plant ecologists to identify species in the field, failing which it will be difficult to keep up with the momentum of (re-)discovering species in the field (Ahrends et al., 2011; Chapman et al., 2015). For example, the (re-)discovery of orchids such as *Pinalia floribunda* (Lindl.) Kuntze (Leong et al., 2017) and *Bromheadia alticola* Ridl. (Yam et al., 2012) in Singapore were possible only because field ecologists had the instinct to survey the fallen trees on which these orchids were growing after storm events. The SBG today runs a course on the vegetation and plant diversity of Southeast Asia to students enrolled in the undergraduate degree course in Life Sciences at the NUS, in order to bridge knowledge gaps in botany and plant sciences (Choong, 2022). Hopefully, this will help to equip young plant ecologists with the necessary skills to identify plant species in the field, and perhaps even attract them to pursue a course in plant taxonomy in the future.

Advancing the conservation of orchids

Of the 76 extant native orchid species in Singapore, 65 are Critically Endangered (Middleton et al., 2024). The recovery of species will require interventions, in view of the fact that these species occur in small isolated populations that may not persist (Rabinowitz et al., 1986). Efforts to recover orchid species threatened with extinction require botanic gardens to not only undertake research to understand the ecology of the plants, but the know-how to successfully propagate offsprings of known wild individuals for ex-situ conservation and subsequent reintroductions (Swarts & Dixon, 2009a). The SBG has had a long history of micro-propagation and ex-situ plant conservation, with a strong focus on orchids in the 1990s and 2000s (Yam & Thame, 2005). The orchid conservation programme was initiated in 1995, and it successfully propagated and re-introduced five native orchid species over the next decade or so, including the world's largest epiphytic orchid by weight, *Grammatophyllum speciosum* Blume (Lamb, 2011), which was last sighted in Tuas and Pulau Ubin (Ridley, 1900) and is now presumed extinct in the wild in Singapore (Yam et al., 2010a). This was accelerated between 2009 and 2012, when another 15 native orchid species were reintroduced (Yam et al., 2011). Research was also undertaken in collaboration with researchers at the NUS to better understand niche requirements, including the availability of orchid mycorrhizal fungi on roadside trees, for translocated orchids to survive and persist

long-term in an urbanised landscape (Muhammad Izuddin et al., 2018, 2019a, 2019b). This research, coupled with the experience from the early trials, enabled the scaling up of this programme, which has since successfully propagated and re-introduced more than 60 native species and 40,000 plants throughout Singapore (Yam, 2023). This programme is now bolstered by the expansion of the National Orchid Garden nurseries and the establishment of the Seed Bank at SBG, where endemic and rare native orchid species are prioritised for propagation and their seeds are cryo-preserved.

Conclusions

The story of orchid (re-)discoveries and conservation in Singapore highlights how small forest fragments, especially the BTNR and CCNR, can be important refugia for orchid species. These species are probably more resilient to disturbance than we might think, but there may be a time-lag to their extinction as they are found in isolated populations. Nonetheless, there is a window of opportunity for continued research and surveys, which we must seize, and not let up in momentum. This is where botanic gardens can play an important role and should continue to invest in taxonomic research, botanical surveys, and, more importantly, nurture local expertise. With these efforts, we hold on to optimism that we will continue to (re-)discover many more native orchids in Singapore.

The first author hopes that this commentary will inspire others to continue in their quest to (re)-discover native orchids in the wild and to conserve them for future generations, as Balmford (2017) would remind us: "While there is as great a need as ever for us to track changes in the natural world, detect and communicate new threats, and devise interventions to address them, celebrating conservation's many and diverse accomplishments is also vital: to inspire people rendered hopeless by what can seem like an unending torrent of bad news, and motivate them to purposeful action; to learn more about what works—and hence be able to sharpen our efforts; and so that we can reinforce rather than let drift the many gains that the conservation movement is making."

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