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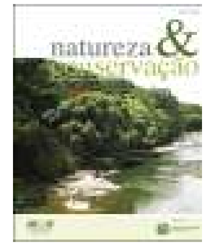

Policy Forums

Impacts of deforestation on some orchids of São Paulo State, Brazil

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Deforestation impacts

Countries that are home to high levels of biodiversity need to address a fundamental question: which is more important, conservation of valuable – but unexplored – biodiversity, or deforestation for economic development? Brazil is one prominent and typical example of this struggle, finding itself at a crossroad because it is one of the major biodiversity centers in the world (~20% of Earth's biodiversity) with one of the largest centers of endemism (Government of Brazil, 2012a). Brazil is also a nation with record-breaking deforestation, having led to the removal of more than 165,000 km^2 from the Amazon, the *Cerrado*, *Mata Atlântica* and other biomes within a period of five years, from 2000 to 2005 (Hansen et al., 2010). This is equivalent to double the total area of Austria. Brazilian deforestation was responsible for 30% of carbon emissions, between 2000 and 2010 mainly from replacement by cattle (71%) and soybean production (29%) in deforested areas (Karstensen et al., 2013). *In situ* conservation in Brazil is inefficient because government policies encourage the economic use of forests (Moran, 2011), similar to other countries such as Indonesia, which have similar policies and practices (Gilbert, 2014). This represents a major concern in countries recognized for their biodiversity because such policies undervalue natural biodiversity at the expense of economic development (Jones-Walters and Mulder, 2009). As a consequence, the effective conservation of plant species is placed at risk (Keith, 2014) and this may represent an invaluable loss to humanity. For example, about 67% of anticancer treatments contain natural products derived from plants and animals (NCI, 2007). The degree to which biodiversity is susceptible to losses is related to the type of species and range of human use (Redford and Richter, 1999) and this susceptibility to losses increases when human populations are near. Wild ornamental and medicinal plant species provide an opportunity for regional economic development while also preserving an intangible cultural asset, aspects that are often overlooked or undervalued.

São Paulo state in Brazil as a case study

Explosive economic development in the State of São Paulo (SP), Brazil caused by agriculture, industry, urbanization and other

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Fig. 1 – High pressure situation of natural marginal forest remnants from the São Paulo State due to the uses for economical purposes (A) and detailed deforestation of forest remnant of marginal area from Rio Pardo, at Águas de Santa Bárbara (SP), Brazil, for construction of a new hydroelectric station.

anthropogenic interferences has reduced the biomes in rich and diverse areas, such as *Cerrado* and *Mata Atlântica* to small forest remnants, affecting the lives and existence of most species and resulting in areas that are under extreme pressure for use in diverse economic applications (Fig. 1A). One of the clusters of organisms affected by these conditions are the wild orchid species of SP. Orchids are among the most threatened of all flowering plants due to over-collection, but mainly habitat loss caused many species to become extinct in the wild. As a result, all orchids have been placed on Appendix II or higher of the Convention on International Trade in Endangered Species (CITES) (Roberts and Dixon, 2008). Orchids face high environmental susceptibility to losses in biodiversity, which can be caused by genetic narrowing, and they may become critically endangered or extinct due to the loss of habitats associated with agriculture, urbanization and over-collection for economic purposes (Cardoso, 2014).

In SP, one reason for the loss of forest stands along the banks of rivers is the development of hydroelectric projects to generate electricity for expanding cities in the state, such as the Pardo and Novo rivers used to support the city of Águas de Santa Bárbara as well as additional nearby towns (Fig. 1A and B). Companies are required under law to restore wild forests in order to replace land newly occupied by water, but failure to implement and regulate this legislation, together with the lack of knowledge about many of the threatened plant species, provides a weak foundation for the efficient conservation and restoration of much needed biodiversity. Wild orchid species are not being restored in these new environments because of the complex requirements for their propagation and cultivation. In reality, new legislation written in 2012 resulted in weak support for the protection and restoration of biodiversity, and even though it established delimited areas for permanent preservation and legal reserves, it did not define the number and types of species that needed to be restored (Government of Brazil, 2012b). Restoration procedures conserve wild species, maintain genetic flow, and reduce urban heat islands (Pollock and Beechie, 2014; Staley, 2013). In addition, many riparian forests, the preferential habitat of most native orchids of SP, are now used for expanding sugarcane fields (Oliveira and Seraphim, 2011), pasture and urbanization, which is at odds with Brazilian environmental regulations.

Further compounding this problem and inhibiting orchid conservation in SP is limited knowledge about the interaction of many species in the Orchidaceae with biotic and abiotic factors of forest remnants. Fundamental research is essential to allow an understanding of the complex relationships among orchids and the environmental conditions that influence them and are involved in the reproduction and dissemination of these species. Two complex questions that need answers are: Why do some terrestrial and epiphytic orchids live in small, restricted populations, while others are widely disseminated? What factors prevent the wide dissemination of some of these small, restricted populations within a forest remnant? In fact, some of these species have highly restricted and small populations, which influences the methodologies that can be used to survey them, as observed in different cities of SP (Cardoso, 2014; Cardoso and Israel, 2005). Two orchid species showing contrasting scenarios are *Galeandra beyrichii* (Tribe Cymbidieae, Subtribe Catasetinae) (Fig. 2A) and *Oeceoclades maculata* (Tribe Cymbidieae, Subtribe Eulophiinae) (Fig. 2B). The former is highly restricted to small populations in forest remnants located in specific sites of SP (Cardoso, unpublished data; Fig. 2C), while the latter is widely distributed in populations with variable numbers in different environmental conditions and cities, and even widely distributed within the same or different forest remnants (Cardoso, 2014; Cardoso and Israel, 2005). Similarly, two epiphytic species, *Oncidium crispum* and *Lophiaris pumilla*, both in the Subtribe Oncidiinae show more restricted and more widely distributed populations, respectively (Cardoso, 2014). A recent survey in the subtropical Brazilian forests of the state of Rio Grande do Sul confirmed the hypothesis that some terrestrial orchid species are very restricted while others are widely distributed (Colla, 2014). The status of a species for conservation based on IUCN's seven classes of nomenclature is defined by equations that calculate the estimated number of plants. However, some Brazilian orchid species are unique to forest remnants. Caution is thus needed when using the IUCN's estimate as it

Fig. 2 – Some orchid species, *Galeandra beyrichii* (A) and *Oeceoclades maculata* (B) from environmental wild areas from the state of São Paulo under high environmental pressure. See the details of a population of restricted specie *G. beyrichii* in a marginal area from Rio Novo (Águas de Santa Bárbara, SP, Brazil), observed by inflorescence emission (red arrows). bf, bud flower; fd, fruit development; of, opened flower; pf, pollinated flower.

may result in an overestimation of actual populations, placing these orchids under a lower status for conservation, and consequently reducing the actual need to conserve these classes of orchids. A recent survey of the forest remnants of SP discovered only one (or no) individual of some orchid species, *e.g.* of the *Cattleya* genus, over a large sampled area (Cardoso, 2014). Furthermore, for the majority of plant species, data on population size and number of viable individuals are not readily available, making it more difficult to have accurate estimates.

Surveys, which may require sampling over several seasons since terrestrial orchids show variable growth in different seasons (Cardoso, 2014), allow for an increase in knowledge about pollinators, modes of reproduction, level of hetero- or homozygosis, the capacity of recombination, and additional genetic factors that would allow more efficient conservation and restoration programs to be established (Cardoso, 2014; Cardoso and Israel, 2005; Magalhães and Maimoni-Rodella, 2012).

Diluting and solving the problems

One approach to finding solutions to the problems previously described is the utilization of new technologies and model organisms. Exotic *Dendrobium* is a model orchid genus that has been used frequently in many studies involving biotechnology. Biotechnology can provide valuable tools that play a major and significant role in establishing efficient propagation and conservation methods for orchids. Related studies with *Dendrobium* include *in vitro* propagation techniques (Teixeira da Silva et al., 2015), low temperature and cryopreservation of seed, protocorms and pollinia (Vendrame et al., 2007; Vendrame et al., 2008; Teixeira da Silva et al., 2014a), and *in vitro* flowering (Teixeira da Silva et al., 2014b). *In vitro* seed germination is a viable technique that allows increase in population numbers and subsequent reintroduction of endangered orchids back to their native habitats, provided that local laws are in place to foster such activities and protect reintroduced orchids, as demonstrated in China for *Paphiopedilum wardii* (Zeng et al., 2012) and *Renanthera imschootiana* (Wu et al., 2014).

However, within the Brazilian context, the question remains on how germplasm propagated *in vitro* should be conserved and restored to native habitat areas. Legislation should protects and encourage restored areas near rivers and other types of water bodies named ‘Permanent Preservation Area’, as well as ‘Legal Reserves’, extensions of areas with wild vegetation defined by legislation according to different regions. In SP, Legal Reserves represent about 20% of every rural property (Government of Brazil, 2012a,b).

Additional questions that need to be addressed include: Are seeds from a few or limited plants from one specific population enough to conserve most genes accumulated in that population? Are populations found in different environments genetically different from others? Clues to these questions may be found in two orchid species from SP that are now restricted in wild areas, namely *Cattleya coccinea* (Novello et al., 2013) and *Epidendrum denticulatum* (Pinheiro et al., 2013). Widely distributed species face greater limitations in pollination, such as the capacity of a pollinator to transport the pollinia from one plant to another, and in the type of pollination, affecting pollination and fruit/seed development. Cohen and Ackerman (2009) focused on the conservation of the widely invasive terrestrial *Oeceoclades maculata* in the light of forest disturbance, showing that populations were very reduced in small remnants with low canopy cover, and that the population of native species was negatively correlated with increases in the population size of the invasive *O. maculata*. In addition, molecular analyses using ISSR primers showed that intra-population plants of *O. maculata* had low indices of diversity while plants from different populations showed higher estimated diversity (Ueno et al., 2015). This was also observed for other orchid species in similar conditions. Research showed low levels of intra-populational heterozygosity within two populations of *Cattleya coccinea* from SP, probably due to intensive habitat fragmentation caused by economic exploitation of land (Novello et al., 2013).

The genetic relationships of actual forest remnants also need to be emphasized. Wider intercrossing among genotypes and species could result in future generations of orchid germplasm that actually are highly limited by anthropogenic activities, similar to small forest island populations as compared to mainland populations. Island populations have less genetic variation than mainland populations, resulting in inbreeding and loss of genetic variation, therefore accelerating species extinction (Frankham, 1997). In fact, wild biomes are actually used for economic purposes in SP, such as agriculture or urbanization, and the creation of isolated and fragmented forest remnants results in similar 'genetic islands' for orchids (Fig. 1). This will directly impact germplasm conservation since genetic factors are a cause of higher extinction rates in island populations than in mainland populations (Frankham, 1997) for groups of species. In addition, the Orchidaceae faces large-scale extinction due to changes in climatic conditions (Swarts and Dixon, 2009).

The conservation and restoration of orchids in SP must be based on more than one population or species, avoiding population isolation and limited reproduction that could increase the risk of extinction. Biological and ecological studies can be improved by the use of biotechnology tools aimed at mass propagation to increase population numbers, restore species back to their native habitats, and preserve rare or important germplasm using cryopreservation techniques.

This study makes the case for the revision and improvement of the Brazilian environmental legislation. It is necessary to define the number of orchid species (as well other species) facing an endangered status or extinction, species richness and diversity, and how such orchids can be reintroduced and restored to reforested areas. Natural forest stands have highly complex systems of species reproduction and only complex models and detailed legislation will define the success of conservation of future wild biomes in an era of economic exploitation. Such considerations may positively impact the loss of orchid diversity caused by deforestation in SP.

Conflicts of interest

The authors declare no conflicts of interest.

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