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ESSAY

Big frugivores, big fruit and big seeds are beautiful

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"They were standing head to head, or walking to and fro across the ground in couples, or rocking and swaying all by themselves– scores and scores of elephants." The Jungle Book, Rudyard Kipling (1894), Toomai of the Elephants.

After being held in Mexico in 1985 (Estrada & Fleming 1986) and 1991 (Fleming & Estrada 1993), Brazil in 2000 (Levey et al. 2002) and Australia in 2005 (Dennis et al. 2007), the International Symposium on Frugivores and Seed Dispersal (FSD) went to France in 2010 (Forget et al. 2011). There, it was agreed that the next FSD symposium will move to South Africa, there to encounter the local megafauna (Galetti et al. 2018), as well as other lesser fauna, all engaged in dispersing and, frequently, preying upon small-to-large seeds, diaspores or other propagules. In 2010, the Academic Committee invited plenary speakers to review the literature on the roles of both Asian and African elephants (Campos-Arceiz & Blake 2011). The role of elephants in savannas was missing, however, and the program in 2015 accordingly aimed to highlight these pachyderms in Southern Africa. Thus, Jeremy Midgley opened the Seventh FSD event by discussing the 'Big Five' (the African elephant, black rhinoceros, Cape buffalo, lion and leopard), and opened our mind to the tightly interrelated processes of seed dispersal by megafauna and squirrels, as well as the overlapping networks of interactions that allow savanna trees to establish and to recruit (Helm et al. 2011, Midgley et al. 2012, Midgley et al. 2015). Landing at Johannesburg, our delegation was welcomed by a model of the megafauna and advertising for *Amarula Cream*, a liqueur produced out of the fruit pulp of the marula (*Sclerocarya birrea*, Anacardiaceae) (Fig. 1). Marula pulp is a delicacy for elephants and squirrels, both of them contributing to the primary and secondary seed dispersal of the plant, respectively, henceforth facilitating its recruitment and survival. But for how long? Indeed, today, elephants are disappearing at an alarming rate. It's sad to say that within one generation, that is, since the first FSD conference held in Mexico in 1985, several hundreds of thousands of elephants have been extirpated in Africa, several thousand years after the elephant-like proboscideans, or gomphotheres, disappeared from South and Central America. The exact reason for this disappearance is not known, but climate and habitat changes, and overhunting by human beings are all likely causes, eventually acting in combination. Will the next generation of FSD participants see the extinction of elephants in Africa and South East Asia?

When FSD2015 was planned, the Chair, Colleen Down, presented the provisional venue, in the St Lucia area of KwaZulu Natal, along the coast, nearby the Big Five False Bay Municipality (now known as Big Five Hlabisa Local Municipality). It would have been the perfect venue for the attendees wandering around between Hippo Street and Hornbill Street in St Lucia. However, between 2010-2015, climate change also 'decided to attend', intervening in this splendid scenario. Since then, the entire planet has experienced the most severe drought in history in 2014-2015. Southern Africa did not escape this impact (e.g. Government of South Africa 2015), forcing the local organizers and the participants to move, not across the ocean, nor the continents, but within the country to escape. The sci-

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Figure 1. Advertizing for the amarula fruit creme made out of marula (*Sclerocarya birrea*) fruit pulp and the elephant (*Loxodonta africana*) at Johannesburg Airport, South Africa. (© Pierre-Michel Forget, MNHN, 2015).

entists thus had to migrate North, and move uphill, to the Drakensberg mountains, halfway between Johannesburg and Durban, which were the nearest habitats where organizers could find water and shelter for a couple of hundred of travelers, many local but most, migrants from abroad. Certainly, the symposium lost a number of potential participants, disenchanted by the less attractive mountain biome, especially when the vegetation is dormant during the southern, dry, winter period.

Tropical terrestrial habitats are becoming too hot and too dry, are being deforested, burned, transformed to plantations of oil palm, soya, corn and other products: in short, vanishing with little chance of returning to their initial state. Waters are also warming, but we have barely evaluated how aquatic organisms are impacted, many being invisible below the surface. All scenarios now show clearly that due to climate change, temperatures of +1-2°C warmer than average, and a lack of water, many animal and plant species will have to adapt, move or die. If they are well adapted to undertake long travels with no return, they may migrate, dispersing along latitudinal gradients on land or in oceanic water, north or south, and deep below the surface or along altitudinal gradients on both continents and islands. They will likely have to move over dozens to hundreds of kilometers searching for new habitats that are more suitable for their feeding and reproduction, or simply to survive the lack of resources. Still, whether you dive deep or climb high, the volume and surface of liveable niches shrink, and become less hospitable and welcoming to migrating populations and species, and the race for survival leads to intense competition and conflict, and species extinction.

Likewise, in order to avoid the collapse of the FSD conference, the organizers of FSD2015 adapted, and had to relocate participants from zero to 1350 m in altitude in the

splendid Drakensberg Mountains, a big step between lowlands and the highlands. There, they did not have to experience shortages such as only three hours of water per day. In short, the local organizing committee rescued them and saved the symposium by re-settling it at an Alpine Health Resort with temperatures oscillating between 3-18°C, but with permanent water availability. At such altitude, there were no megafauna in the vicinity, only a landscape of plantation and cattle ranches, sheltering indoors during the winter. Instead of safari tours at the corner of the lodges, there was birding in the few forest fragments surrounding the resort, in the riverine habitats that had escaped burning by the landowners who maintain some forest cover for cattle in the hot summer. The same situation can be observed in the Pantanal of the Mato Grosso del Sul where the ranchers inadvertently help the conservation of many trees and animals by leaving intact forest for the cattle to take refuge in the shade.

Ironically, the manager of the Alpine Health Resort did not seem to pay much attention to the water shortage with a swimming pool being operational despite the cold temperature outside. Yet, apparently to save electricity, the buildings were not kept warm and the conference rooms gave a cold welcome to the first plenary speaker and participants of sessions. Consequently, while the rest of the globe was enduring drought and extreme temperatures in this uniquely warm year - the first one of the trio, 2015-16-17 - the FSD participants were freezing, dressed as if they were about to climb the Drakensberg Mountains, ready to twitch some more birds, and enrich their list of avian species never encountered before. At night, the bed sheets were warmed, electrically, and everyone endeavoured to warm up in the evening with South Africa Vita , or some local fermented beverage. In the morning, the rising sun warmed up the coffee break, and the buildings. Despite this, though unrecorded for accuracy, we noticed an increase in people coughing during the talks, forcing some of them to escape from the room so as not to disturb speakers and listeners.

It is perhaps ironic that the FSD symposium is now being affected by climate change, in company of all organisms on this planet, moving northward and upward to more temperate climes than the Mediterranean region of St Lucia, which was subjected to a 6-month drought between 2014-2015. Since this FSD symposium, many other meetings have also required adaptive visions for their next destinations, in order to take into account climate change issues that won't improve in a 5-yr or even 10-yr period. Having anticipated a warming tropical climate, the local organizing committee of FSD2020 in India plans to move the symposium to the Corbett Tiger Reserve landscape, which can accommodate attendees in the comfortable climate of northern India (FSD2020 2019). By the proposed date of 2-5 March 2020, in the year of the metal Rat following the year of the earth Pig, what will be the status of African and Asian elephants? Will the world have experienced new records of temperature as was the case during the first semester of 2015, and which persisted until 2018?* How many elephants will still be alive in the lowland and savannas of Africa, and in Asian forests, and will they have enough forest refuges, to find shade, water and fruit?

In Central, Eastern and Southern Africa, in India and Southeast Asia, will there be enough forests left to provide big fruits and big seeds to be dispersed by the big fauna? Will the climate affect the flowering and pollination so that trees won't produce enough resources there by exacerbating the pressures on fruits and seeds that might be experiencing greater predation by rats and pigs and/or spontaneous abortion? Will the fauna be saturated enough to move from patch to patch in search of adequate nutrients? Will the fauna be forced to concentrate in the few areas that are still rich in fruit, and will there be enough food to avoid famine as was already observed in '70-'80 in Central America (Foster 1982). In other words, will the megafauna destroy the crops that have been planted at the expense of much-needed habitats of megafauna, as observed by one of us (PMF) in Uganda. Indeed, at Bwindi Impenetrable Forest, elephants and rats are important for seed dispersal and the regeneration of plants in the Albertine Rift, such as that of the large-seeded *Carapa grandiflora* (Meliaceae) trees (Nyiramana et al. 2011). Local human populations already suffer from the presence of elephants, which do not hesitate to trample and consume banana and corn when the forest does not provide enough of the necessary staple food for them anymore, probably as a result of the disappearance of protected areas, and shrinking along with road expansion, deforestation and increased encroachment of infrastructures (e.g., Laurance et al. 2014). In the past 30, 40 or 50 years, when the forest was big, extensive, and unfragmented, the megafauna would have travelled over vast areas to search for alternative resources. But, where can they move now? There is no other choice, no plan B for them in the wild, but to raid the crops of the farmers. And so, conflicts arise.

In South Africa, with the largest population of elephants in the wild and in protected areas, the conflicts also exist. If climate change accelerates, these conflicts will increase, and elephants will roam upwards to the more watered regions. Squirrels might not move as fast as the elephants, leaving the marula seeds to a fate of high mortality, marooned within the elephant droppings. Marula trees won't

be able to regenerate anymore, at least naturally in the wild, because both elephants and squirrels are needed, in good proportions - with a little help from water - for efficient seedling recruitment of marula trees.

Rudyard Kipling's (1894) *Jungle Book* popularized during the 20th century by the animated musical comedy adventure film produced in 1967 by Walt Disney Productions, introduced several generations of kids and their parents to the wildlife of India and South-Eastern Asia, many of them frugivores and seed dispersers such as the elephant, orangutan and sloth bear. In the recent follow-up film *Mowgli: Legend of the Jungle*, (2016) the 'man-cub' who fell into the tiger pit is saved by the one-tusked King Elephant. In the 21st century, it is now time for both Kipling's and Mowgli's inheritors to save the rainforest in order to prevent the elephants, as well as other wildlife including the charismatic top predator, the tiger, becoming extinct, which will likely drive the collapse of rainforest diversity and of the carbon stock, and push the future climate of the planet further into the darkness of rising temperature. Those new generations of man-cub and scientists will speak out during the forthcoming 7th Frugivores and Seed Dispersal Symposium to be held within the Corbett Tiger Reserve landscape in northern India for which the main theme is *"Seed Dispersal in the Anthropocene: Bringing Together Research on Frugivory & Seed Dispersal in Changing Landscapes"*

> *"With the tiger and the hunter now gone, the future shimmered from darkness into light, Mowgli, man and wolf, both and neither, had given the jungle a voice, and for as long he stood watch, he would speak a lasting peace."* Ultimate voice-off in Mowgli: Legend of the Jungle (2016).

* **Post-scriptum:** since the completion of the FSD2015, we have experienced the four warmest years on record in a series - 2015, 2016, 2017 and 2018, and 2019 is expected to comply with this trend as a result of an El Niño event exacerbated by global warming according to the Climate Prediction Center (2019) at the National Oceanic and Atmospheric Administration (NOAA).

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