

# Parks of the Pleistocene: recreating the Cerrado and the Pantanal with megafauna<sup>1</sup>

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In the past few years, several researchers have proposed the introduction of large predators and herbivores to facilitate the reconstruction of natural ecosystems. The introduction of wolves, bears, pumas and even nonnative species such as elephants and camels, has been suggested by researchers to reestablish the ecological balance in several North American ecosystems, from forests to deserts (Martin & Burney, 2000). Even the well-equipped North American national parks failed to protect the entire diversity of great mammals such as bears, coyotes and wolves (Newmark, 1987). Predators at the top of the food chain are considered to be “keys” to the maintenance of the ecosystem, because they regulate the population of the herbivores. Without these predators, there is a disproportionate increase in the populations of herbivores and mesopredators (foxes, raccoons, and squirrels), which overtax the population of plants and small animals which are their foods (Terborgh, 1992; Crooks & Soulé, 1999).

Many years before the arrival of the first humans to America, the North American savannas held at least 41 species of great mammals, including wild horses, bison, camels, giant armadillos, mammoths and giant sloths (Anderson, 1995), while in South America that diversity was much larger (Cartelle, 1999; Fariña *et al.*, 1998).

These mega-mammals played an extremely important role in the structure of vegetation communities and the effects of their premature extinction are still poorly understood (Janzen & Martin, 1982; Janzen, 1986).

Some researchers suggest that there is sufficient evidence to demonstrate that primitive man played a primary role in the extinction of mammoths, giant sloths, camels, llamas, glyptodonts, horses and other species of large mammals, called “megafauna” (Martin, 1995; Haynes, 2001). A strong correlation exists between colonization and growth of human populations (visible

in the archeological record) and the extinction of great birds and mammals the world over. An important fact to observe is that, although the climatic changes at the end of Pleistocene happened at the same time all over the world, the extinction of the megafauna began 40,000 years ago in Africa and Australia, 12,000 years ago in America, and less than 1,000 years ago in Madagascar and New Zealand (Martin, 1995, Flannery, 1995).

However, other researchers suggest that climate changes alone could have exterminated the megafauna (ex. Cartelle, 1999; Ficcarelli *et al.*, 2003). With the increase of rain and temperature, the open savannas would have been reduced in size, detrimentally affecting the expansion of closed humid forests, causing the elimination of the megafauna due to a lack of favorable environment. These researchers don't accept the hypothesis that primitive man caused the extinction of the megafauna, alleging that there isn't a correlation with megafauna bones. However, areas with a human-megafauna interaction, though not abundant, exist, although this evidence is discredited (see Fiedel & Haynes, 2004). Beyond this, in many places the megafauna is not restricted to open spaces; elephants, rhinoceroses and other ungulates can be found in closed forests.

It is most probable that both hunting and climatic changes played important roles in the extinction of the South American megafauna. Owen-Smith (1992) proposes that the extinction of the Pleistocene megafauna involved climatic factors as much as anthropic ones. Widespread hunting by the Paleo-Indians would have caused an accentuated decline in the megaherbivore population (as happens today in several indigenous reservations and protected areas with a great deal of hunting). The changes in the climate, however, would have fragmented and restricted the distribution of those megaherbivores to places of low nutritional value, leaving them more vulnerable to local extinction as much to human, as to stochastic factors.

In addition to this, extinct mammals possess low reproductive rates, except for nocturnal or arboreal species (Johnson, 2002). The mammals and birds dependent on the megafauna (such as sabre-tooth tigers and condors) would have been wiped out as a result of the extinction of their prey.

Actually, we still know little about **what factors** caused the extinction of the megafauna, but, perhaps the most pertinent question is **what are the effects** of the extinction of the megafauna on neotropical savanna ecosystems.

With the rapid elimination of South American megafauna (some authors suggest between eight and three thousand years ago – De Vivo & Carmignotto, 2004),

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the absence of large herbivores increased the dominance of some plants, resulting in an accumulation of dry vegetation biomass susceptible to fire. With the extinction of easy and naïve prey, such as the large megaherbivores, primitive man intensified the use of fire to facilitate the hunting of other mammals, initiating the alteration of the savannas (or, that is, the Cerrado) as we know them today. It is well known that all of the groups indigenous to the savannas use fire to hunt deer and giant anteaters (Prada, 2001). This type of hunting has such an impact that some species of large mammals are already extinct in indigenous reserves (Leeuwenberg, 1997).

My generation grew up greatly influenced by "Animal Planet" and other nature programs, all, almost without exception, about African savannas. I grew up thinking Africa was the continent of mammals, while South America was the continent of birds. The great African parks, like Serengeti, Okavango, Ngorongoro and Kruger, with their herds of zebras, elephants, gnus and so many other mammals, were the image of wild nature.

Large mammals have always attracted, and still attract, the interest of most people. One proof of this is the large number of people that visit the elephant or rhinoceros enclosures at zoos, compared to the numbers that visit the manned wolves or the capybaras. South American biologists have always been slightly jealous of African biologists, because of the lack of large animals in the Neotropics. Few people are aware, however, that the population of large South American mammals was, at one point, much richer than that found today in Africa.

If we could go back in time at least ten thousand years, to the end of the Pleistocene, the savannas of South America (such as the Cerrado and the Pantanal) were more spectacular than the savannas of Africa. Whereas in Africa there exist only five mammals of more than a ton (elephant, two species of rhinoceroses, hippopotamus and the male giraffe), in South America during the Pleistocene there were more than 38 genera above 100 kilos (220 lbs.), and from ten to twelve species above a ton, in one single place (Fariña *et al.*, 1998).

Herds of horses (*Equus* and *Hippidion*), giant sloths weighing up to five tons (*Eremotherium*), mastodon, which were similar to four ton elephants (*Stegomastodon* and *Haplomastodon*), *Xenorhynchium*, which looked like one ton camels, the *Toxodon*, similar in size and features to the hippopotamus, giant armadillos of up to two tons (*Glyptodon*), and capybaras weighing 150 kilos (330 lbs. - *Neochoeerus*) wandered our savannas and the Pantanal (as well as Caatinga<sup>4</sup> and southern fields) (Fariña *et al.*, 1998; Cartelle, 1999).

<sup>4</sup> Type of vegetation common to the arid regions of the

Based upon what we know about South American fossils, and knowing the ecological role of the megaherbivores in Asia and Africa, certainly all the ecosystems, which we know today, particularly the Cerrado and the Pantanal, are the result of a massive defaunation of great mammals and environments highly altered by primitive man.

What does the extinction of the megafauna thousands of years ago have to do with the conservation of today's savanna ecosystems, like the Cerrado and the Pantanal? The rapid removal of a diverse and abundant megafauna, responsible for a good deal of the wealth of species and certainly for most of the vertebrate biomass of those ecosystems, is reflected until today in the ecological processes of the neotropical savannas.

A comparison between the Emas National Park (Parque Nacional de Emas) in Goiás state with the Kruger National Park in South Africa, or with other African parks, can elucidate and open up new horizons in our understanding of our ecosystems.

Emas National Park is a savanna, 132 Thousand hectares (326 acres) in size, which has a significant diversity of large mammals including the pampas deer, the tapir, and the jaguar (Silveira *et al.*, 1999). Emas is considered to be the "Brazilian Serengeti" due to its similarity to the African park.

Any visitor will observe small groups of pampas deer (*Ozotocerus bezoarticus*) feeding on the vegetation (Rodrigues, 2003). It is estimated that the park shelters about 1,300 pampas deer, that is, a biomass of 35 kg/km<sup>2</sup> (199 lbs./sq. mi.) (Rodrigues, 2003). If we include tapirs, white-lipped peccary, red brockett deer and brown brockett deer, the biomass of "large" mammals doesn't exceed 100 kg/km<sup>2</sup> (570 lbs./sq. mi.) (F. H. G. Rodrigues, pers. comm.). In the African parks, on the other hand, the biomass of large herbivores can vary from 5,000 to 22,500 kg/km<sup>2</sup> (28,500 to 128,250 lbs./sq. mi.), where gnus, zebras, elephants, rhinoceroses, impalas and other mammals are easily seen (Caro, 1999).

In the Pantanal, known as the place with the largest abundance of mammals in the neotropics, the biomass of the wild herbivores (like pampas deer, deer and capybaras) doesn't exceed 1,000 kg/km<sup>2</sup> (5,700 lbs./sq. mi.) (Tomás *et al.*, 2001; Mauro *et al.*, 1998; Galetti *et al.*, data not published), while the biomass of nonnative animals, like cattle, feral hogs and buffaloes can reach more than 5,000 kg/km<sup>2</sup> (28,500 lbs./sq. mi.) (not counting the horses) (Mourão *et al.*, 2002). This high biomass of nonnative megafauna is sustained by natural pastures, that certainly should have held large herbivores in the Pleistocene.

It is estimated that the North American savannas before the beginning of the Holocene sustained about 9,000 kg/km<sup>2</sup> (51,300 lbs./sq. mi.) of herbivores, such

as mammoth, horses, bison and other large mammals (Martin, 1995). In the area of the pampas, it is estimated that there was an historic biomass of mammals of 15,500 kg/km<sup>2</sup> (88,350 lbs./sq. mi.), of which 11,000 kg/km<sup>2</sup> (62,700 lbs./sq. mi.) represented just the megaherbivores (larger than one ton - Fariña, 1996).

The Pantanal, with an area of 140,000 km<sup>2</sup> (54,040 sq. mi.), consists of 31% natural pasture (around 43,400 km<sup>2</sup> (16,752 sq. mi.)) (Silva *et al.*, 2000). Using data regarding the support capacity the natural pastures of the Pantanal offer to cattle, that is, how many kilos of food each square kilometer (of pasture) can offer to the herbivore fauna, the results indicate that those natural pastures could sustain about 10,000 kg/km<sup>2</sup> (57,000 lbs./sq. mi.) of megaherbivores (if we stipulate a density of 29 cows/km<sup>2</sup> (75 cows/sq. mi.) and each cow weighs 350 kg (771 lbs.)) (Santos *et al.*, 2002).

This value is similar to some of the productive African savannas, but due to the seasonal and environmental differences of the Pantanal, it is probable that the ecosystem supports a larger biomass than the African ecosystem (see Fariña, 1996, for the southern fields of Paraguay).

Even if we take into account that ten thousand years ago the Pantanal was drier and colder, very different from today, and that there are large differences in productivity within the Pantanal due to flooding, the productivity of this ecosystem could support a high megaherbivore biomass.

There are several other indicators, which suggest that the Cerrado and the Pantanal are phytoformations that co-developed with large mammals, today extinct. In the Cerrado as well as in the Pantanal, the plants demonstrate several adaptations against the herbivorous practices of large mammals, such as thorns on their leaves and trunks (Janzen & Martin, 1982; Galetti, data not published).

In addition to this, many species have fruit which are too big and well-protected. Fruits like suari nut, *bocaiúva*, *indaiá* and several other species are too big to be consumed and dispersed by the current fauna (Guimarães & Galetti, 2001). Since 2002, Prof. Marco Pizo, of the Department of Botany of UNESP; Camila Donatti, of the Biology of Conservation Institute (Instituto de Biologia da Conservação) and I are studying the morphology of fruits in the Pantanal, and comparing it to our Atlantic Rainforest database (Galetti *et al.*, 2002).

It is well-known that the fruits of the Pantanal and Cerrado are larger and almost always yellow, brown or orange; colors typical of mammal dispersion. The tapir (the last wild representative of the frugivorous-herbivore megafauna), as well as cattle and feral hogs

(megafauna recently introduced) are the only species that disperse large fruit in the Pantanal.

Currently, one of the largest problems at the Emas National Park, as with many protected areas in the Cerrado and the Pantanal, is fire, caused by lightning or by man.

It is estimated that most of the fires in Emas in the last ten years, were natural fires caused by lightning (Clayish, 2000). In 1994, the whole National Park burned, causing the death of about 330 giant anteaters (Silveira *et al.*, 1999). The park is, in its largest expanse, an open savanna covered by arrow grass (Clayish, 2000).

The wild mammals currently at Emas do not consume this grass (Rodrigues & Monteiro-Filho, 1999), which accumulates a high biomass and in the dry period becomes an ideal fuel for large burnings.

In decade of the 70's, when the Emas National Park was not fenced and was regularly invaded by cattle and horses from neighboring farms, neither fire nor arrow grass were common. (Silveira *et al.*, 1999).

The removal of the cattle caused large problems for the park: a higher incidence of fire and the invasion of nonnative plants. This isn't to say that cattle are the solution to fires in the Cerrado, but it does raise the question of the importance of nonnative species in the conservation of local biodiversity.

This same effect is found in temperate savannas, where the removal of large herbivores resulted in an accumulation of combustible material and a reduction in the diversity of pastures (Hartnett *et al.*, 1996; Kramer *et al.*, 2003). Today, the conservation projects for prairies and areas of open vegetation use a combination of controlled burning and the introduction of bison herds (and even cattle) to maintain the mosaic of habitats and to avoid the loss of species and harmful fires.

There is still a large controversy whether fire is a "natural" or simply an anthropic effect in the Cerrado and in other ecosystems (Caldararo, 2002; Svenning, 2002). Traces suggest that fire has been occurring in the Cerrado for more than 30,000 years, but about 8,000 years ago (when primitive man already occupied the Cerrado) fire began to occur with much greater frequency, indicating an increase in the human population of the area (Ledru, 2002).

We know that the Xavantes Indians and other ethnicities that live in the Cerrado, as well as the first people that occupied that area, constantly use fire to hunt, for war and to renew the crops (Prada, 2001). Whether fire is natural or not, the fact is that the Cerrado, currently, without megaherbivores, accumulates a high biomass of fuel annually, which burns easily and quickly.

Several studies in Asia, Africa and North America have demonstrated that large herbivores exercise a great influence over the vegetation, regulating the abundance of competitively superior species, and thus, in low densities, can increase the local diversity (Harrison *et al.* 2003). In the African savannas the great herds of herbivores, such as elephants, buffaloes, impalas, gnus and zebras consume a large portion of the biomass of grasses, leaving little fuel for possible natural fires.

Anyone can foresee what would happen if we removed all of the megaherbivores from the Serengeti or from the Kruger. There would be a brutal increase in the vegetation biomass, the vegetation community would be simplified, resulting in a few species becoming dominant and, even with a subsequent increase in herbivore insects (such as termites and leaf-cutter ants) the area would have high propensity for fire.

The megaherbivores' impact is sufficient to shape the structure of an entire ecosystem. The different divisions of the physiognomies in the African savannas are based as much on the fertility of the soil as on the impact of fauna (mainly elephants) and on a regimen of burnings (van Langevelde *et al.*, 2003). In Brazil, the definitions of the types of savanna (such as *campo-cerrado* - scattered trees in dense grass, *cerradão* - dense savanna woodlands, *campo-sujo* - grassy scrublands, etc.) take into account just abiotic factors (such as soil fertility, pluviosity and the frequency of burnings), and neglect the effect that the megaherbivores would have on every type of vegetation.

One of the ways for us to evaluate the past impact of large mammals in the Cerrado and in the Pantanal is to compare it to the modern analogy of the African savannas, even though the African savannas are much poorer in megafauna than the South American savannas of the Pleistocene. An African elephant weighing three tons can consume 150 kg (331 lb.) of vegetation a day, returning 135 kg (298 lb.) of fertilizer to the environment (Owen-Smith, 1992).

At least seventy species of fruit are dispersed by forest elephants, and some species show a very low replenishment rate in the absence of elephants (Alexandre, 1978; Nchanji & Plumptre, 2003). The mastodons, members of the family of neotropic elephants which lived in America about ten million years ago and succumbed to the human invasion only 13,000 years ago, must have had a substantial impact on the vegetation of the Cerrado and the Pantanal just as they had in the North American prairies (Haynes, 2002). How much could a mastodon weighing four tons consume, or even a giant sloth, which could weigh up to five tons, and what are the implications of the biomass cycle caused by these megaherbivores?

Therefore, the low fertility of the soil in the savannas could be partially explained by the absence of

megaherbivores. In the African savannas it has been shown that the megaherbivores contribute greatly to the quality of the soil (McNaughton, 1976). The nutrients in the feces and urine of these megaherbivores are immediately available to the plants, accelerating the nutrient cycling of the ecosystem.

Beyond this, it is quite reasonable to assume that great megaherbivore herds must have migrated across the Cerrado and the Pantanal seeking for more adequate pastures, as happens today with cattle. During the flood periods in the Pantanal these megaherbivores probably migrated to higher areas, such as the Cerrado. In the Serengeti it is estimated that a million gnus, 300 thousand zebras and another 300 thousand impalas migrate to the African savanna, feeding about three thousand lions (Wolanski *et al.*, 1999).

Migrations of large herbivores, in reality, happen on all continents, from the frozen tundras of the Tibetan plateau to the African savannas and, in the past, to the neotropical savannas (Berger, 2004). Currently, the only species of large mammal that migrates is the feral hog (Peres, 1996). The interruption of this system of migration certainly must have affected the genetic flux via seeds of several plants in the Cerrado and in the Pantanal. It is not uncommon for geneticists to conclude that some species of trees in the Cerrado possess low interpopulational genetic variability probably due to a reduction in the genetic flux via seeds, as already demonstrated by the pequi (*Caryocar brasiliensis*) (Collevatti *et al.*, 2003).

Therefore, programs for the conservation of the Cerrado and the Pantanal should take into account the conditions of these ecosystems before the arrival of the first humans. What do we want to preserve? The Cerrado as it is today, with an incomplete complement of fauna that is difficult to manage and full of vague niches, which is a direct reflection of the great wave of extinction at the beginning of Holocene, or try to recreate an ecosystem that co-developed over millions of years possessing a great diversity and biomass of megaherbivores? It is well-known that large herbivores have a fundamental role in the structuring of the savannas all over the world and conservationist biologists and decision-makers cannot ignore this fact.

Currently, there is a group of researchers that propose the use of the fire to manage the Cerrado (see Ramos-Neto & Pivello, 2000). I believe that the use of fire as a means to manage the Cerrado can cause greater damage to the planet, releasing tons of carbon monoxide into the atmosphere, thus worsening the greenhouse effect. A large part of the carbon monoxide released into the atmosphere comes from burnings in the savannas. An alternative could be the management of the Cerrado and the Pantanal through the re-introduction of megaherbivores. As giant sloths, toxodons, macrauchenias and mastodons don't exist

anymore, we would have to turn to their closest relatives, or ecological equivalents, even if they are considered to be “exotic.”

Certainly the introduction of horses, impalas, elephants and other megaherbivores into our savannas will shock many conservationists, but I believe that controlled experiments in confined areas of the Cerrado and Pantanal (outside of conservation areas) can help us a great deal to understand the dynamics of these ecosystems. Today, horses, cows and feral hogs (all introduced into the Pantanal less than 200 years ago), when in controlled densities, are important dispersers of large seeds and controllers of invasive herbs.

More than two million nonnative animals, such as cattle, buffaloes, horses and feral hogs wander the Pantanal (Mourão *et al.*, 2003). We still know very little about how this introduced megafauna molds the vegetation, and if we should really completely remove this nonnative fauna from the Pantanal. The impact of large herbivores will depend largely on their density within the environment. In recent years, several researchers have been debating the impact of recent, and Pleistocene, extinctions to current ecosystems (Levin *et al.*, 2002; Ellsworth & McComb, 2003). This theme is fertile ground ready to be tested in neotropical savannas.

However, where would this megafauna to be introduced come from? Our circuses have about two thousand animals for exhibition (almost always in humiliating conditions). The great majority of these circuses are succumbing financially, since the public increasingly prefers circuses without animals. Additionally, there are animals in zoos that lack appropriate facilities to maintain the animal's well-being.

Couldn't we designate some areas in the Cerrado and the Pantanal for experiments like those in the so-called “Pleistocene Parks?” A model of a Pleistocene Park already exists in Siberia, where researchers discovered that the dominance of mosses in the tundras is a result of the removal of mammoths, horses and bison, and that the reintroduction of the megafauna which survived hunting and climatic changes (such as bison and horses), resulted in the appearance of a vegetation dominated by grasses and bushes (Zimov *et al.*, 1995).

The Pleistocene Parks would, obviously, not be placed in strictly protected areas. Certainly a lot of wetland farms and the Cerrado could house the “Pleistocene Parks.” Obviously, the introduction of elephants, horses, guanacos and even hippopotami (similar to Toxodons) is not an act of scientific imprudence, but should be controlled and constantly monitored. The accidental introduction of diseases is the largest threat posed by programs of reintroduction, for this reason the introduced animals should go through a rigorous health inspection and they should be constantly evaluated.

In addition, large predators, such as lions, would be excluded from these parks and the population of herbivores would be controlled by the park management, as occurs in African parks. In a short time, the “Pleistocene Parks” could attract as many tourists as the African parks, help to reduce the release of carbon monoxide caused by burnings, and produce valuable scientific information.

Several characteristics of the physiognomy of the Cerrado and Pantanal are anachronistic and reflect an environment molded by the absence of large mammals, whether this is due to climatic changes or to the anthropic effect of primitive man. The extensive consumption of plants by ants and termites (the famous “cupinzeiros” of Emas), the reduced genetic variation of some plants, the low fertility of the soil, the clustered distribution of many vegetation species, and the current importance of fire in the structuring of communities in the Cerrado, are some of the ecological patterns that should be looked at in terms of the absence of the pleistocenic megafauna.

Actually, the extinction of the megafauna did not stop during the Pleistocene/Holocene transition, and it is just one part of the history of man's disturbances to the planet. Today, many areas of the Cerrado, Atlantic Rainforest and the Amazon are suffering from a process of continual megafauna elimination. It is estimated that sixty million animals are hunted annually for consumption in the Amazon alone (Reford, 1997). Add to this millions more that are captured in illegal live animal trafficking.

The first animals to disappear in areas impacted by hunting are, once again, the large mammals, such as woolly monkey (*Lagothrix*), muriqui (*Brachyteles*), tapirs and feral hogs. About 80% of the biomass of the hunted animals is frugivorous-herbivore. In other words, its removal from the environment causes a cascade effect that is reflected in the entire community. Without frugivores, many plants are doomed to local extinction because of the loss of their dispersers (Peres & Roosmalen, 2002; Wright, 2003).

This reduction of fauna occurring in many ecosystems, has caused several researchers to demonstrate that many fruit species with large seeds have their days numbered, because of an absence of dispersors. In some fragments of the Atlantic Rainforest the reduction of fauna is so extreme that there are no seed dispersers larger than a squirrel (Galetti *et al.*, data not published). Therefore, the Pleistocene removal, as much as the current removal of megafauna, caused, and still causes, a large impact on the vegetation, which is reflected in the entire ecosystem and directly affects the quality of life of human beings.

I believe that the plans to manage the Cerrado and the Pantanal should take into account an historical process

as important as the extinction of the unique and abundant megafauna. The question is not **if we** should manage the megafauna in these environments, but **how will** we do it. Controlled scientific experiments can give us a clue as to **how we should** do it (Damhoureyeh & Hartnett, 1997; Hart, 2001).



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