

POPULATION BIOLOGY OF THE MELON CACTUS *Melocactus violaceus* subsp. *violaceus* (CACTACEAE) ON A BRAZILIAN SANDY COASTAL PLAIN

Marcos de Souza Lima Figueiredo¹

¹ Programa de Pós-Graduação em Ecologia, Departamento de Ecologia, Instituto de Biologia, Universidade Federal do Rio de Janeiro. Ilha do Fundão. 21941-590, Rio de Janeiro, RJ, Brazil. CP 68020
E-mail: mslfigueiredo@gmail.com

ABSTRACT

There is a notable lack of ecological information about South American cacti species and the existing information isn't evenly distributed among life forms and geographic regions. Here, the population structure of a globose cactus species (*Melocactus violaceus*) on a Brazilian restinga was described and the patterns presented were compared with those reported to other *Melocactus* species. Cacti density observed on the study area was lower than that reported to other species of the genus. No association between population density and habitat selection or average diameter was found, implying that density-dependent factors are not important on this population. The population was dominated by young individuals and fitted a log-normal size distribution, which suggests that it was under constant germination and the establishment of seedlings was not subject to unstable environmental conditions. Following a cohort of *M. violaceus* through time would provide critical information on the population status of this threatened species.

Keywords: globose cactus; habitat selection; population ecology; restinga; size structure

INTRODUCTION

Cactaceae is a much diversified plant family, encompassing more than 1,400 species which are distributed mainly across American dry environments (Hunt *et al.* 2006). Its species present a diverse array of life forms and many studies concerning its morphology, physiology, and taxonomy were carried out, but there is a notable lack of ecological information about cacti species (Godínez-Álvarez *et al.* 2003), and the existing information is not evenly distributed among life forms and geographic regions. Little attention has been paid to globose cacti (Nassar & Ramírez 2004), and most of the studies have been carried out in North and Central America, with little information regarding the ecology of South American cacti (Godínez-Álvarez *et al.* 2003).

The lack of information is not different for species of the *Melocactus* genus, a morphologically homogeneous group of small globose cacti whose geographic range extends from western Mexico to south-eastern Brazil, encompassing Caribbean and Andean regions of Central and South America (Taylor 1991). Many species of the *Melocactus* genus are listed under IUCN red list (15 of 37

species; IUCN 2012) and CITES appendices (34 of 37 species; UNEP-WCMC 2013) largely due to a decline in its populations caused by illegal collecting and habitat destruction (Taylor 1991, 2002). The taxonomy and morphology of the genus were studied in detail (Taylor 1991), but only recently studies in reproductive biology (Nassar & Ramírez 2004, Colaço *et al.* 2006, Nassar *et al.* 2007, Fonseca *et al.* 2008), seedling mortality (Hughes *et al.* 2011), population genetics (Nassar *et al.* 2001, Lambert *et al.* 2006a, 2006b), and seed dispersal (Figueira *et al.* 1994, Fonseca *et al.* 2012) started to fill the knowledge gap regarding the ecology of this genus.

One species of *Melocactus* genus, *M. violaceus*, is distributed discontinuously throughout Brazilian eastern coast, occurring on sand plains from Rio Grande do Norte to Rio de Janeiro states, with disjunct populations established on *campos rupestres* in Minas Gerais and Bahia states (Taylor 1991). *M. violaceus* is classified as a vulnerable species by IUCN red list due to habitat loss (Taylor 2002), as the Brazilian sandy plains are under enormous anthropic pressure due real estate and touristic activities (Rocha *et al.* 2003). Similar to other species of the genus, there is almost no

information available on this species and the single paper published about its ecology deals with seed dispersal by lizards (Figueira *et al.* 1994). Here I present some new information regarding the reproductive biology, population density, and size structure of this species on a coastal sandy plain in south-eastern Brazil, and compare the results with those reported to other globose cacti species, especially those of *Melocactus* genus. The information presented here can be useful in future evaluations about the conservation status of this species.

MATERIAL AND METHODS

The study was conducted at the Restinga de Jurubatiba National Park, state of Rio de Janeiro, south-eastern Brazil, in an area located five meters a.s.l. This is a strictly protected area dominated by a mosaic of vegetation communities called restinga, which grows on sandy coastal plains formed in the late Quaternary. The dominant vegetation type on the park is the “open *Clusia* scrub formation”, which is characterized by *Clusia hilariana* dominated scrubs separated by exposed white sand or small clumps of the palm *Allagoptera arenaria*, the bromeliads *Aechmea nudicaulis* and *Neoregelia cruenta*, besides the columnar cactus *Pilosocereus arrabidaei* (Araújo *et al.* 1998). The area has a tropical climate, with an annual average rainfall of 1,000 mm, a dry season extending from April to September, and a mean annual temperature of 22.6 °C, but soil temperature can reach up to 70 °C on a summer day (Araújo *et al.* 1998).

The population of *M. violaceus* subsp. *violaceus* was sampled during a week in August 2006, on a one hectare plot (100 x 100 m) divided in 16 plots of 625 m² (25 x 25 m). Each plots was considered a sample unity where every cacti individual was identified, had its reproductive stage recorded, and its diameter and distance to the nearest vegetation above 50 cm measured (both in cm), in order to represent potential shadow cover in the area, as soil temperature is one of the main factors affecting the survival of globose cacti seedlings (Martorell & Patiño 2006). The cacti individuals were classified according their stage of growth as: immature (all green, without

cephalium), pre-breeding (with *cephalium*, but no flowers or fruits) and reproductive (with *cephalium* and flowers or fruits). As both flowering and fruiting in *Melocactus* are ephemeral events (Taylor 1991, Figueira *et al.* 1994), some events of reproductive activity may have been lost due the short sampling time. In order to reduce this problem, most of the analyses were performed merging the pre-breeding and reproductive categories; when these two stages are referred together in the text, the term ‘potentially reproductive’ is used.

Individuals were assigned to 1-cm size (diameter) classes to describe population structure and their occurrence on these size classes was compared to the log-normal expected distribution through the Chi-square test (Zar 1999). The fitting to the log-normal distribution describes the pattern observed in growing populations with constant recruitment, in opposition to an uneven distribution, that characterizes populations with regeneration pulses (Godínez-Álvarez *et al.* 2003, Medel-Narvaez *et al.* 2006). To evaluate the effect of population density on population structure, simple linear regressions (Zar 1999) were performed between number of individuals per plot (independent variable) and the diameter (average and maximum) of the cacti (dependent variables). Variables were log-transformed to meet the assumptions of parametric tests whenever necessary (Zar 1999).

To detect density-dependence in habitat selection, the occurrence of cacti individuals in five distance classes (<50cm, 51-100cm, 101-150cm, 151-200cm, >201cm) was compared with expected values by using contingency tables with log-linear models adjusted to the expected counts for the marginal sums of the contingency table. The plots were grouped in two classes (< 10 ind. and > 15 ind.) and a Chi-square test was employed to analyze the goodness of fit of the contingency table (Zar 1999).

RESULTS

The number of *M. violaceus* individuals per plot ranged from zero to 31, totalling 143 individuals in the entire plot (mean \pm SD = 8.9 \pm 9.3). Two of these individuals could not have had its distance to the nearest vegetation measured as

they were unrooted by unknown reasons, and so they were not included in any of the following distance analyses.

The majority of the cacti individuals in the area (57 %) were less than 50 cm from nearest vegetation, and only a few of them (2 %) were more than 200 cm away (Figure 1), with the largest measured distance being 227 cm. The occurrence of cacti individuals on the distance classes was independent of their density on the plots (Chi-square = 1.901, d.f. = 4, $p > 0.75$), as most of the individuals were on the nearest distance classes in both low and high abundance plots.

The diameter of the cacti in the area varied from 1.4 to 12.3 cm and the size class distribution presented an accentuated increase in abundance, followed by a slower monotonic decrease after the peak at the 4-cm size class (Figure 2), fitting a log-normal distribution (Chi-square = 17.5449, d.f. = 12, $p = 0.1303$). The smallest pre-breeding individuals measured 6.3 cm of diameter, while the largest immature individual measured 9.5 cm. Immature individuals were reported on every size class smaller than 10.0 cm, and this was the most frequent reproductive stage on every size class up to the 7th (7.0 to 7.9 cm); from the 8-cm

size class on the most frequent reproductive stage was the pre-breeding one (Figure 3). The log-transformed number of individuals per plot was negatively related to its average diameter ($F_{(1, 11)} = 7.3597$; $p = 0.0202$; $r^2 = 0.4009$), but no significant relationship was presented to the maximum diameter measured on the plot ($F_{(1, 11)} = 0.4226$; $p = 0.5290$; $r^2 = 0.0370$).

As for the reproductive stages, immature individuals were the most abundant ones (72.7 %), and the potentially reproductive individuals accounted for about one-quarter of the population (pre-breeding = 20.3 %; reproductive = 7.0 %). This pattern was repeated with slight modifications when the plots were considered separately; when only those plots with five or more cacti individuals were taken in to account, the representation of potentially reproductive individuals in the samples ranged from zero up to 40 %. When only those size classes larger than 6 cm (the size class with the smallest pre-breeding individual) were taken in to account, the representation of immature individuals was reduced to 43.5 %, and potentially reproductive individuals represented more than half of the adult population (pre-breeding = 42.0 %; reproductive = 14.5 %).

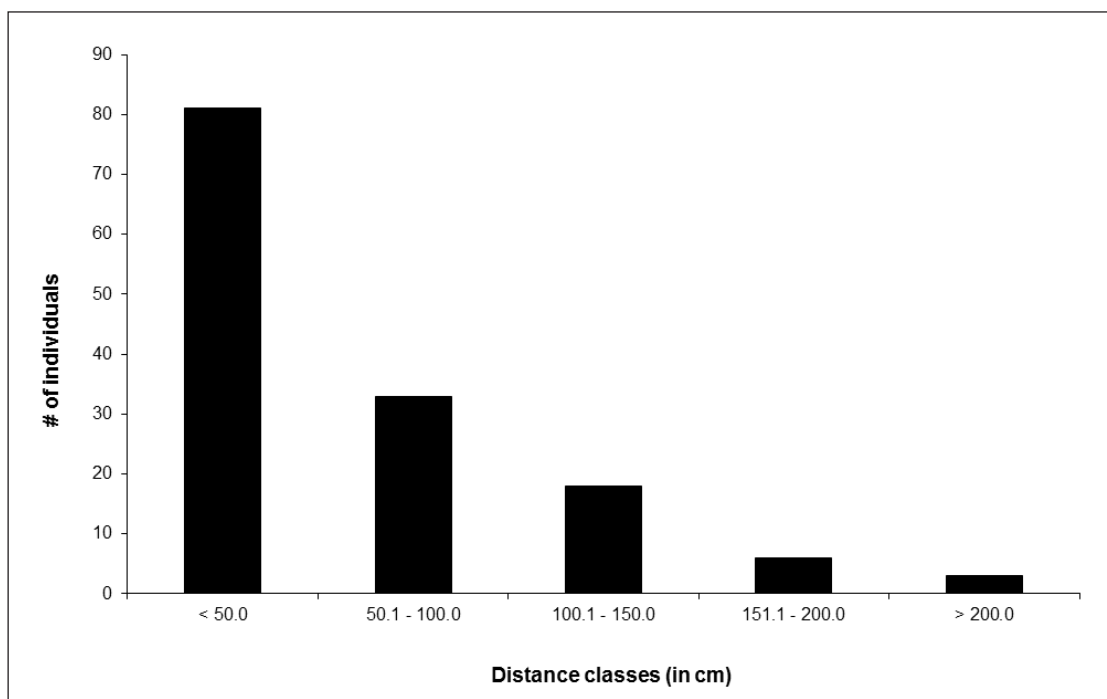


Figure 1. Number of individuals ($n = 141$) per distance to the nearest vegetation (in cm) on a population of *Melocactus violaceus* at Restinga de Jurubatiba National Park, Rio de Janeiro.

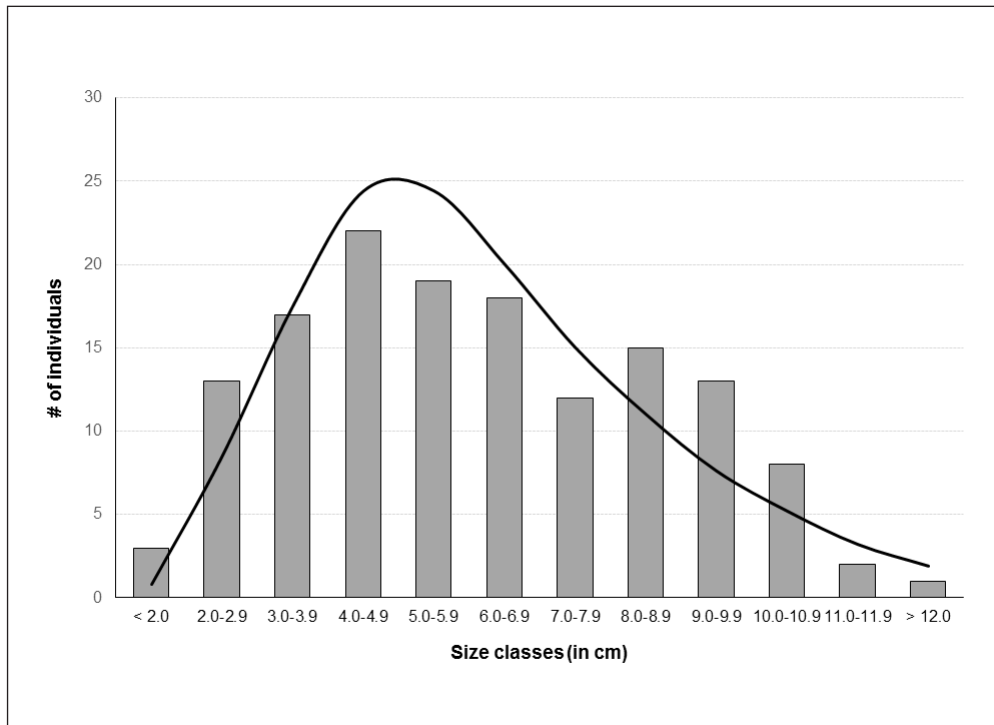


Figure 2. Population structure of *Melocactus violaceus* on the Restinga de Jurubatiba National Park. Bars represent the number of individuals detected in 1.0 cm size (diameter) classes and the line represents the log-normal expected distribution.

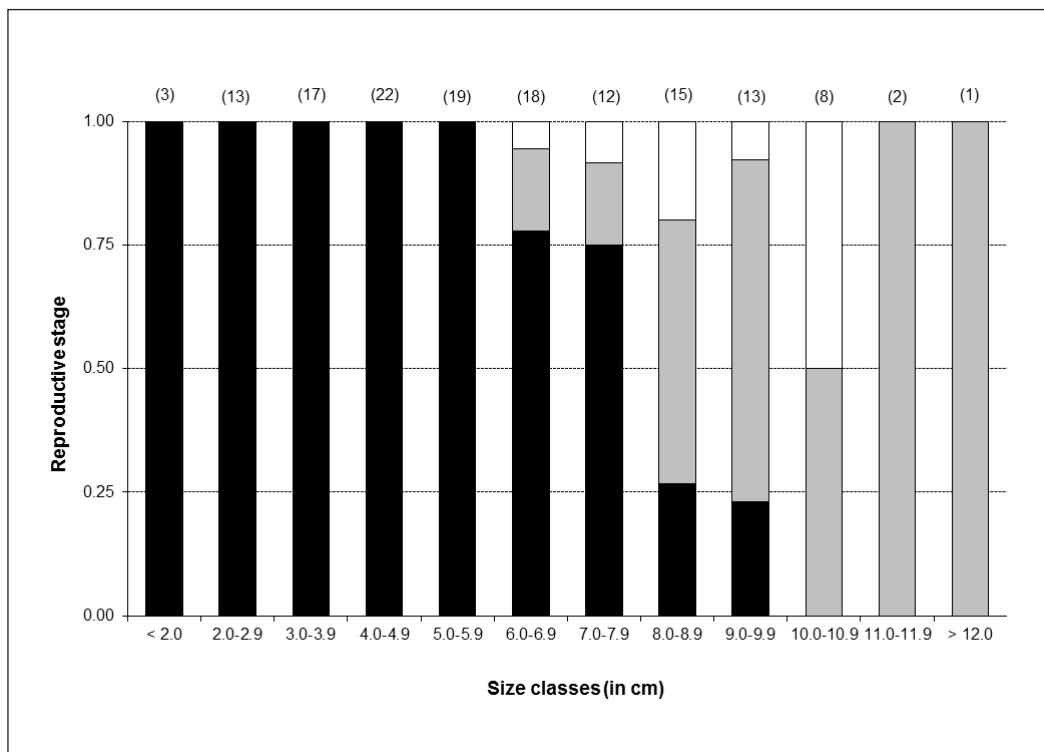


Figure 3. Variations on the frequency of reproductive stages on a population of *Melocactus violaceus* along 1.0 cm size (diameter) classes (in parenthesis, number of individuals on the size class). Legend: ■: immature, ▒: pre-breeding, □: reproductive.

DISCUSSION

The *M. violaceus* density on the Restinga de Jurubatiba National Park is lower than that observed in other species of the *Melocactus violaceus* group, but falls within the range reported to other *Melocactus* species (Table 1). Most of the studies reporting densities of *Melocactus* species were carried out in rocky or rupestrian soils, and, to my knowledge, this estimate of *M. violaceus* subsp. *violaceus* density is the first clearly obtained in a sandy soil. Hughes *et al.* (2011) states that abundance of *M. ernestii* subsp. *ernestii* is negatively related to the degree of weathering of the outcrops, but other estimates of *Melocactus* densities in sandy soils would be necessary to evaluate the generality of this pattern. In a review about cacti demography, Godínez-Alvárez *et al.* (2003) affirmed that it is difficult to make generalizations about cactus density as no clear trend among species is observed. Despite the enormous range of variation in *Melocactus* density, *M. violaceus* seems to be a relatively rare species when compared to its congeners, which is an especially concerning situation as this species is categorized as vulnerable at the IUCN Red List (Taylor 2002).

Most of the *M. violaceus* individuals were located near some kind of vegetation, but only a

few of them were observed under the direct cover of another plant species, and none of them could be found on the interior of the scrubs. The majority of the cacti individuals were located near enough to adjacent vegetation to be shadow-covered and avoid direct sunlight during some part of the day. This reduction to sunlight exposure enables the establishment of the individuals on exposed sand, as the overheating is an important issue to globose cacti germination (Rojas-Aréchiga & Vasquez-Yanes 2000) and survival (Martorell & Patiño 2006). On the same area, Zaluar & Scarano (2000) reported the positive association between *A. arenaria* and *P. arrabidae*, a columnar cactus, and the possible positive effect of the palm on the germination and establishment of this cactus, and both Reyes-Olivas *et al.* (2002), working on a Mexican desert, and Hughes *et al.* (2011), on the Brazilian caatinga, states that some species of globose cacti do not depend on scrubs to its establishment, but the effect of shading on their survival cannot be neglected. Despite this major limitation on cacti establishment, no denso-dependent effects were found on habitat selection, possibly due the fact that water, and not shadow cover, is one of the main limiting factors in arid systems (Fowler 1986).

The smallest diameter measured on a potentially reproductive individual on the area is

Table 1. Density estimates reported for species of the *Melocactus* genus in the literature. Groups as defined by Taylor (1991).

Species	Group	Habitat	Density (individuals ha ⁻¹)	Reference
<i>M. glaucescens</i> Buining & Brederoo	<i>M. violaceus</i>	rupestrian caatinga/ cerrado	500	Colaço <i>et al.</i> 2006
<i>M. paucispinus</i> G. Heimen & R. Paul	<i>M. violaceus</i>	rupestrian caatinga/ cerrado	800	Colaço <i>et al.</i> 2006
<i>M. violaceus</i> Pfeiffer	<i>M. violaceus</i>	restinga	143	This study
<i>M. ernestii</i> Vaupel	<i>M. oreas</i>	rocky outcrops	6,700	Hughes <i>et al.</i> 2011
<i>M. schatzlii</i> Till & Gruber	<i>M. curvispinus</i>	rocky valley slopes within xeric patches	Hundreds	Nassar <i>et al.</i> 2007
<i>M. andinus</i> Gruber ex Taylor	<i>M. curvispinus</i>	rocky valley slopes within xeric patches	20 to 30	Nassar <i>et al.</i> 2007
<i>M. curvispinus</i> Pfeiffer	<i>M. curvispinus</i>	xeric patches	Up to 1,290	Nassar <i>et al.</i> 2001

similar to the diameter reported by Taylor (1991) to adult individuals of this species (6.0 cm), but it is smaller than that reported by Figueira *et al.* (1994) to reproductive individuals in similar vegetation on Espírito Santo, Brazil (7.9 cm). The negative relationship between the abundance and the average diameter is probably a sampling artefact, as the plots with most individuals are also those with most younglings, which reduce the average diameter; when only the largest individuals per plot are considered on the analysis, the relationship disappears. So this negative relationship, although statistically significant, probably do not reflect any density-dependent factor acting on cacti growth.

The *M. violaceus* population at the Restinga de Jurubatiba National Park is dominated by immature individuals, as indicated by the fitting of the data to a log-normal size distribution (Godínez-Álvarez *et al.* 2003, Medel-Narvaez *et al.* 2006). The low abundance of individuals from the first size classes (below 3 cm) is probably due the study have been carried out in the end of the dry season, as seedling recruitment is positively related to humidity and occurs in pulses after rainfall events (Hughes *et al.* 2011). This kind of distribution is expected to be found in growing populations of perennial plants with constant recruitment (Solis-Montero *et al.* 2005), and was already reported for another *Melocactus* species (Hughes *et al.* 2011). This suggests that the National Park presents favourable conditions that allow constant germination and establishment of seedlings once, as a protected area, it is not subject to anthropogenic disturbance that can promote unstable environmental conditions, which would result in an uneven pattern, as exhibited by populations under sporadic recruitment pulses (Godínez-Álvarez *et al.* 2003).

Despite the fact that half of the cacti population on the area could be classified as adults, the potentially reproductive category comprises only about one quarter of them, and less than one-tenth of the sampled population is included on the reproductive category. When only individuals larger than 6.0 cm of diameter are taken into account (the size class with the smallest pre-breeding individual), the frequency of reproductive individuals on this population is similar to the

minimum values reported to *M. curvispinus* (about 20%; Nassar & Ramírez 2004), and *M. glaucescens* (about 15%; Colaço *et al.* 2006), but higher than values reported to *M. paucispinus* (less than 5%; Colaço *et al.* 2006). These three species presented flowering activity during most of the year, but flowering peaks were observed in all three species (Nassar & Ramírez 2004, Colaço *et al.* 2006). In *M. curvispinus* population, flowering peaks coincided with the rainfall peaks (Nassar & Ramírez 2004), but the patterns reported by Colaço *et al.* (2006) to *M. glaucescens* and *M. paucispinus* populations are not conclusive, and no clear factor associated with their flowering peaks. The low percentage of *M. violaceus* individuals flowering or fruiting on the area suggests that this population doesn't have a flowering peak or it was not sampled on it. As this study was conducted at the end of the winter, which is characterized by strong water deficit (Araújo *et al.* 1998), flowering peaks on this species may be related to rainfall peaks, as in *M. curvispinus*, but no conclusion can be taken without a year-round population monitoring.

Since most of the studies on cacti ecology are concentrated on reproductive biology and biotic interactions, and analyses of its population ecology and size structure are incipient (Godínez-Álvarez *et al.* 2003), the information presented here becomes relevant as the ecology of globose cacti species from South American is little known. As there was no temporal accompaniment on this population, demographic parameters as survivorship and fecundity, as well as the age of first reproduction, could not be obtained. Thus, following a cohort of *M. violaceus* through time would enable the construction of reliable matrix models and provide critical information on the population status of this threatened species.

ACKNOWLEDGEMENTS

L.M. Lage e A. Del'Duca provided enormous help on fieldwork. D.S.D Araújo cleared some doubts about the geographical distribution and reproduction of *M. violaceus*, and provided some useful references cited here. She, D. Loretto, R. Crouzeilles and two anonymous reviewers made very useful comments and suggestions on an early draft of this manuscript. Logistic support on this project was provided by C.E.V. Grelle. This project was developed under the "Ecologia de Campo" graduate course, from the Programa de Pós-Graduação em Ecologia (PPGE-UFRJ), funded by CAPES. During this project, I was supported by fellowships from CNPq and CAPES/FAPERJ – PAPD (102.366/2010).

REFERENCES

- Araújo, D. S. D., Scarano, F. R., Sá, C. F. C., Kurtz, B. C., Zaluar, H. L. T., Montezuma, R. C. M., & Oliveira, R. C. 1998. Comunidades vegetais do Parque Nacional da Restinga de Jurubatiba. In: F. A. Esteves (Ed.), *Ecologia das lagoas costeiras do Parque Nacional da Restinga de Jurubatiba e do município de Macaé (RJ)*. pp. 39-62. Macaé: NUPEM/UFRJ.
- Colaço, M. A. S., Fonseca, R. B. S., Lambert, S. M., Costa, C. B. N., Machado, C. G., & Borba, E. L. 2006. Biologia reprodutiva de *Melocactus glaucescens* Buining & Brederoo e *M. paucispinus* G. Heimen & R. Paul (Cactaceae), na Chapada Diamantina, Nordeste do Brasil. *Revista Brasileira de Botânica*, 29(2), 239-249. DOI: 10.1590/S0100-84042006000200005
- Figueira, J. E. C., Vasconcellos-Neto, J., Garcia, M. A., & Souza, A. L. T. 1994. Saurocory in *Melocactus violaceus* (Cactaceae). *Biotropica*, 26(3), 295-301. DOI: 10.2307/2388850
- Fonseca, R. B. S., Funch, L. S., & Borba, E. L. 2008. Reproductive phenology of *Melocactus* (Cactaceae) species from Chapada Diamantina, Bahia, Brazil. *Revista Brasileira de Botânica*, 31(2), 237-244. DOI: 10.1590/S0100-84042008000200006
- Fonseca, R. B. S., Funch, L. S., & Borba, E. L. 2012. Dispersão de sementes de *Melocactus glaucescens* e *M. paucispinus* (Cactaceae), no Município de Morro do Chapéu, Chapada Diamantina - BA. *Acta Botanica Brasílica*, 26(2), 481-492. DOI: 10.1590/S0102-33062012000200024
- Fowler, N. 1986. The role of competition in plant communities in arid and semiarid regions. *Annual Reviews of Ecology and Systematics*, 17(1), 89-110. DOI: 10.1146/annurev.es.17.110186.000513
- Godínez-Álvarez, H., Valverde, T., & Ortega-Baes, P. 2003. Demographic trends in Cactaceae. *Botanical Review*, 69(2), 173-203. DOI: 10.1663/0006-8101(2003)069[0173:DTITC]2.0.CO;2
- Hughes, F. M., Rot, M. C., Romão, R. L., & Castro, M. S. 2011. Dinâmica espaço-temporal de *Melocactus ernestii* subsp. *ernestii* (Cactaceae) no Nordeste do Brasil. *Revista Brasileira de Botânica*, 34(3), 389-402. DOI: 10.1590/S0100-84042011000300012
- Hunt, D., Taylor, N., & Charles, G. (Eds.). 2006. *The new cactus lexicon: descriptions and illustrations of the cactus family*. Milborne Port, UK: DH Books: p. 900.
- IUCN. 2012 IUCN Red List of Threatened Species. Version 2012.2. Retrieved from <http://www.iucnredlist.org>
- Lambert, S. M., Borba, E. L., & Machado, M. C. 2006a. Allozyme diversity and morphometrics of the endangered *Melocactus glaucescens* (Cactaceae), and investigation of the putative hybrid origin of *Melocactus x albicephalus* (*Melocactus ernestii* x *M. glaucescens*) in north-eastern Brazil. *Plant Species Biology*, 21(2), 93-108. DOI: 10.1111/j.1442-1984.2006.00155.x
- Lambert, S. M., Borba, E. L., Machado, M. C., & Andrade, S. C. S. 2006b. Allozyme diversity and morphometrics of *Melocactus paucispinus* (Cactaceae) and evidence for hybridization with *M. concinnus* in the Chapada Diamantina, North-eastern Brazil. *Annals of Botany*, 97(3), 389-403. DOI: 10.1093/aob/mcj052
- Martorell, C., & Patiño, P. 2006. Globose cacti (*Mammillaria*) living on cliffs avoid high temperatures in a hot dryland of Southern Mexico. *Journal of Arid Environments*, 67(4), 541-552. DOI: 10.1016/j.jaridenv.2006.03.021
- Medel-Narvaez, A., Luz, J. L. L., Freaner-Martinez, F., & Molina-Freaner, F. 2006. Patterns of abundance and population structure of *Pachycereus pringlei* (Cactaceae), a columnar cactus of the Sonoran Desert. *Plant Ecology*, 187(1), 1-14. DOI: 10.1007/s11258-006-9128-1
- Nassar, J. M., & Ramírez, N. 2004. Reproductive biology of the melon cactus, *Melocactus curvispinus* (Cactaceae). *Plant Systematics and Evolution*, 248(1), 31-44. DOI: 10.1007/s00606-004-0193-4
- Nassar, J. M., Hamrick, J. L., & Fleming, T. H. 2001. Genetic variation and population structure of the mixed-mating cactus, *Melocactus curvispinus* (Cactaceae). *Heredity*, 87(1), 69-79. DOI: 10.1046/j.1365-2540.2001.00910.x
- Nassar, J. M., Ramírez, N., Lampo, M., González, J. A., Casado, R., & Nava, F. 2007. Reproductive biology and mating system estimates of two andean melocacti, *Melocactus schatzlii* and *M. andinus* (Cactaceae). *Annals of Botany*, 99(1), 29-38. DOI: 10.1093/aob/mcl229
- Reyes-Olivas, A., García-Moya, E., & López-Mata, L. 2002. Cacti-shrub interactions in the coastal desert of northern Sinaloa, Mexico. *Journal of Arid Environments*, 52(4), 431-445. DOI: 10.1006/jare.2002.1018
- Rocha, C. F. D., Bergallo, H. G., Alves, M. A. S., & van Sluys, M. 2003. A biodiversidade nos grandes remanescentes florestais do estado do Rio de Janeiro e nas restingas da Mata Atlântica. 1st ed. São Carlos, SP: RiMa: p. 160.
- Rojas-Aréchiga, M., & Vasquez-Yanes, C. 2000. Cactus seed germination: a review. *Journal of Arid Environments*, 44(1), 85-104. DOI: 10.1006/jare.1999.0582
- Solis-Montero L., Flores-Palacios, A., & Cruz-Angón, A. 2005. Shade-coffee plantations as refuges for tropical wild orchids in Central Veracruz, Mexico. *Conservation Biology*, 19(3), 908-916. DOI: 10.1111/j.1523-1739.2005.00482.x
- Taylor, N. P. 1991. The genus *Melocactus* (Cactaceae) in Central and South America. *Bradylea*, 9, 1-80.
- Taylor, N. P. 2002. *Melocactus violaceus*. In: IUCN (Ed.), 2007 IUCN Red List of Threatened Species. Retrieved from <http://www.iucnredlist.org>
- UNEP-WCMC. 2013. UNEP-WCMC Species Database: CITES-Listed Species. Retrieved from <http://www.cites.org/eng/disc/species.shtml>
- Zaluar, H. L. T., & Scarano, F. R. 2000. Facilitação em restinga de moitas: um século de buscas por espécies focais. In: F. A. Esteves & F. R. Scarano (Eds.), *Ecologia de restingas e lagoas costeiras*. pp. 3-23. Macaé: NUPEM/UFRJ.
- Zar, J. H. 1999. *Biostatistical analysis*. 4th ed. Upper Saddle River, NJ: Prentice Hall: p. 663.

Submitted on 14 March 2013
Accepted on 16 January 2016