Temporal changes in the structure and distribution of *Magnolia virginiana* subsp. *oviedoae* (*Magnoliaceae*): implications for it's conservation status

Cambios temporales en la estructura y distribución de *Magnolia virginiana* subsp. *oviedoae* (*Magnoliaceae*): implicaciones para su estado de conservación

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ABSTRACT

Magnolia virginiana subsp. *oviedoae* is a threatened and endemic subspecies from Majaguillar swamp (Cuba). New surveys have shown an increase in the number of idividuals and occupied zones. Nevertheless, the magnitude and potential causes of this population growth, which could be key for the conservation of this species, are not known accurately. Our goal is to analyze the changes in the structure, distribution and conservation status of the population of *Magnolia virginiana* subsp. *oviedoae* between 2007 and 2017. In both population censuses the geographical position of each individual, vegetation type, height, type of growth (multi-stem or single-stem), and diameter were measured and referenced. For both years we calculated the habitat range, population density, rate of expansion, spatial arrangement and age structure. The conservation status was evaluated based on the population structure and distribution. The population increased 5.5 times within 10 years, with a net increase of 1,105 individuals. In both years all individuals were found in the swamp forest and swamp grassland. The height increased 2.44 times in 2017, compared to 2007, although the patch diameter remained similar in both studied years. The population showed a good age structure and aggregated spatial arrangement in both years. The subspecies is categorized as VU D2 because it has a restricted area of occupancy and a single location, with real threat in the future that could put the taxon in a higher category in a short period of time.

Keywords: age structure, Cuba, density, population ecology, spatial arrangement

RESUMEN

Magnolia virginiana subsp. *oviedoae* es una subespecie endémica y amenazada de la ciénaga de Majaguillar (Cuba). Nuevas prospecciones de campo han mostrado un aumento en el número de individuos y zonas ocupadas de la población. Sin embargo, no se conocen con precisión la magnitud y las posibles causas de este crecimiento poblacional, que podrían ser clave para la conservación de esta especie. El objetivo es analizar los cambios en la estructura, distribución y estado de conservación de la población de *Magnolia virginiana* subsp. *oviedoae* entre 2007 y 2017. En ambos censos de población se midió y referenció cada individuo, el tipo de vegetación, la altura, el tipo de crecimiento (multi-tronco o un simple-tronco) y el diámetro. Para ambos años se calculó el rango de hábitat, la densidad de población, la tasa de expansión, la disposición espacial y la estructura de edad. El estado de conservación se evaluó en base a la estructura y distribución de la población. La población aumentó 5,5 veces en 10 años, con un aumento neto de 1 105 individuos. En ambos años, todos los individuos se encontraron en el bosque de ciénaga y en los herbazales de ciénaga. En 2017 la altura aumentó 2,44 veces en comparación con 2007, aunque el diámetro del parche se mantuvo similar en ambos años. La población mostró una buena estructura etaria y arreglo espacial agregado en ambos años. La subespecie está categorizada como VU D2 debido a su área de ocupación restringida y una única localidad, con una amenaza real en el futuro que podría colocar al taxón en una categoría superior en un corto período de tiempo.

Palabras clave: estructura etaria, Cuba, densidad, ecología poblacional, arreglo espacial

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INTRODUCTION

Biological populations represent the basic units upon which conservation actions are conducted. Therefore, understanding population dynamics is one the goals of Ecology today (Iriondo & *al.* 2008). Gaining such knowledge is sometimes difficult, since population studies require high volumes of data and time, which usually make them infeasible. Nevertheless, studies on population structure have become quite relevant because they give a punctual record of the population dynamic, which requires less time and effort, and allow making fast and objective descriptions of populations (Begoña 2002, Shahid & *al.* 2012). Furthermore, combining analysis of population structure with the distribution of a species is useful to assess the conservation status of the species (UICN 2001) and design management plans (Sutton & *al.* 2017), especially for endemic and rare taxa (Gonzalez-Borrajo & *al.* 2016).

Magnolia virginiana L. (*Magnoliaceae*) was referred to as an endemic species to the United States of America (Treseder 1978, Callaway 1994) until Oviedo & *al.* (2006) reported a population of the species in Majaguillar Swamp (MSw), in the North of the Cuban province Matanzas. The Cuban population was described as a new endemic subspecies, *M. virginiana* subsp. *oviedoae* Palmarola & *al*. (Palmarola & *al.* 2008). The risk of extinction of the species is considered of Less Concern (LC) according to the IUCN red list criteria (Rivers & *al.* 2016). However, the Cuban subspecies is listed as Critically Endangered (CR), due to its small extension of presence and area of occupancy, the severe fragmentation of its population, and the continuous decline in the quality of its habitat (Palmarola & *al.* 2008, Palmarola & *al.* 2011). New surveys in Majaguillar in 2017 made it possible to identify more individuals than in the previous surveys (Palmarola & *al.* 2008). Nevertheless, the magnitude and potential causes of this population growth, which could be key for the conservation of the species, are not known accurately. Hence, the goal of this investigation is to analyze the changes in the structure, distribution, and conservation status of the population of *Magnolia virginiana* subsp. *oviedoae* between 2007 and 2017.

MATERIALS AND METHODS

Study area

Majaguillar Swamp is located on the Northeast side of the province of Matanzas (Martí municipality), with an area of 462 km^2 (Figure 1) (Gómez 2005). Its soils are swampy and muddy, with different degrees of salinization. The climate of this area is hot and humid (over 80 %), with rainfall ranging between 800-1,000 mm, and two seasons (rainy from May to October and dry from November to April). The average temperature is 25 °C, with a minimum temperature of 17.3 °C in winter and a maximum temperature of 32.5 °C in summer. The main types of vegetation in the area are mangrove forests, swamp forests and swamp grasslands. Swamp forests and grasslands occupy 78 km^2 (Palmarola & *al.* 2011). The MSw is not protected by the System of Protected Areas in Cuba (CNAP 2014).

The taxon

Magnolia virginiana subsp. *oviedoae* is an evergreen shrub with multi-stem growth, 4-7 m tall, and an average patch diameter of 10 m (Palmarola & *al.* 2008, 2011). Young branches and abaxial surfaces of leaves are covered with a silver indumentum, later glabrous. Leaves lanceolate to subelliptic, 7.5-17 × 2.3-5 cm, apex narrowly acute, base cuneate, adaxial surface green (Palmarola & *al.* 2008). Flowers white to cream, tepals 8-12. Glabrous, reddish-orange, and ovoid polifollicles (Oviedo & *al.* 2006), 2.5-5.1 × 1-2.5 cm; seeds close to 0.6 cm long (Callaway 1994). The subspecies occurs only in the MSw (local endemic). Within the MSw, the taxon grows specifically in “Ciénaga de Gonzalito”. In this area, the taxon

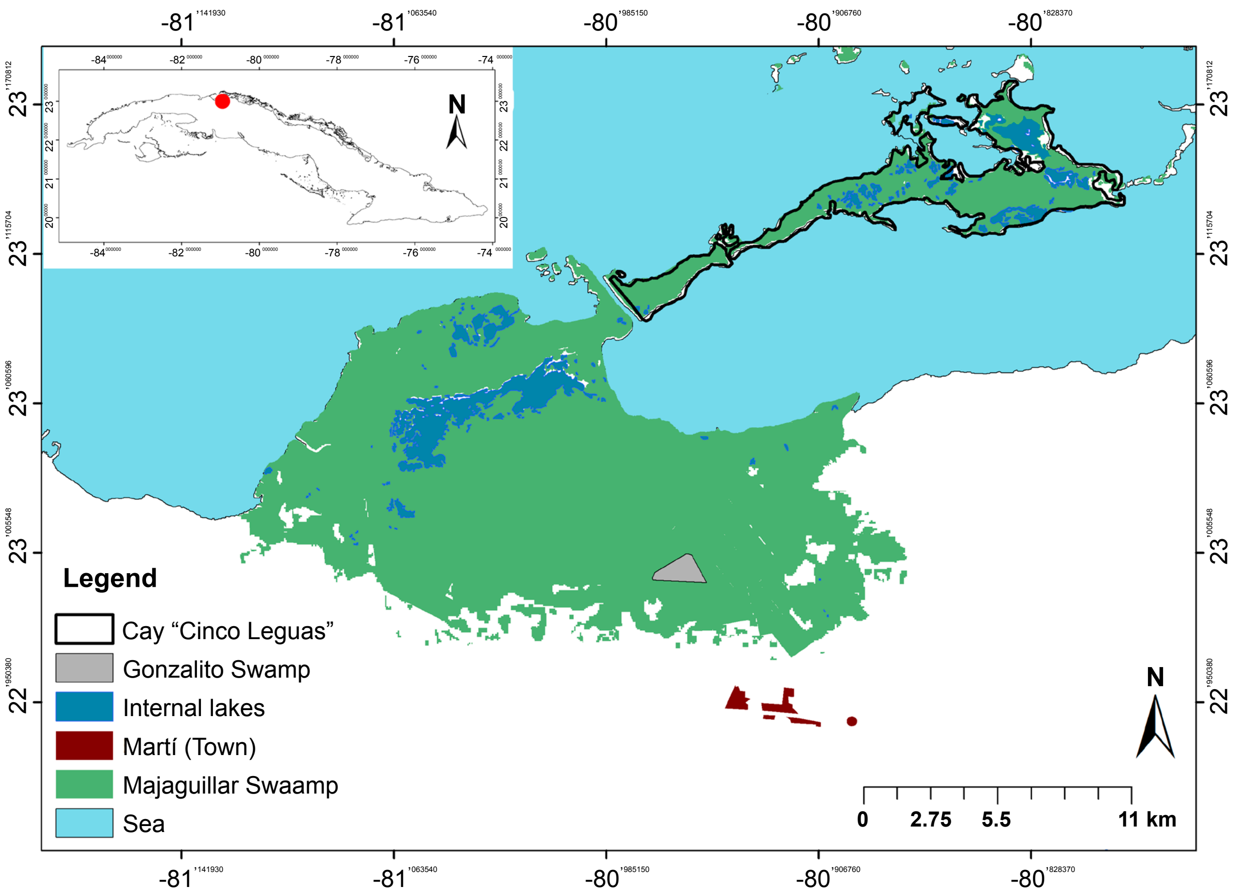

Fig. 1. Geographic location of the Majaguillar Swamp, Martí municipality, Matanzas province, Cuba.

Fig. 1. *Ubicación geográfica de la Ciénaga de Majaguillar, municipio Martí, provincia Matanzas, Cuba.*

lives in mounds or elevated areas of the swamp grassland, in the swamp forest, and in the ecotone between both vegetation types, always on peaty and waterlogged soils (Palmarola & *al.* 2011). In the continent the species has multi-stem and simple-stem growth (Zale 2009).

Data collection

We made two population censuses of *Magnolia virginiana* subsp. *oviedoae*, in 2007 and 2017. Each individual was georeferenced with GPS (*GPS Garmin* ± 2 m) and marked to avoid double counting. The type of growth of each individual (multistem or single-stem) was recorded, except for the ones less than 1 m height, since their growth cannot be classified. The height of each individual and the diameter of the biggest patch was measured with a measuring tape (± 1 mm). In 2017, the perimeter at breast height was also measured (only for single-stem individuals) following the procedure of Molina-Pelegrín & *al.* (2014). For individuals less than 1 m height, the perimeter was measured at half of the stem. The values of stem perimeter (P) were converted to diameter (D) (D = P/π).

Data analysis

The habitat range was estimated for both years using the Minimum Convex Polygon (MCP-global), which is the area contained inside the continuous imaginary limit that can be drawn to include all the known places in which a taxon can exist (UICN 2001) and the perimeter range. In addition, the Minimum Convex Polygon (MCP) and the perimeter range were calculated for the population kernels. The population density was calculated using the area of the MCP-global for each year. The distance between the population kernels was calculated as the distance between the most extreme individuals of each kernel. The rate of expansion of the population was calculated by dividing the values from 2017 by the values from 2007.

The geographic coordinates of the individuals were converted to metric coordinates using *Global Mapper v.15* (http://www.globalmapper.com). With the metric coordinates, we calculated the linear distances between the individuals using the Pythagorean Theorem. The distance to the nearest neighbor was calculated for each individual. This analysis was made for the entire population and the population kernels.

The spatial arrangement was calculated in the *Ecological Methodology Program v.6.1.1* (Krebs 2003), using the standardized Morisita Index (Ip), which assumes values between -1 and 1, with 95 % confidence intervals, where Ip = 0 represents a random spatial arrangement, Ip > 0 aggregated and Ip < 0 uniform (Krebs 1999). The spatial arrangement of the population according to the distance between individuals was calculated using the L(d)-d variant of Ripley's K function, in the *Past v.3.14* (Hammer & *al.* 2001). Values of L(d)-d > 0 indicate aggregation and L(d)-d < 0 indicate regularity in the pattern (Wiegand & Moloney 2004).

The descriptive statistics (mean, standard deviation, minimum and maximum) of the morphological variables (height, diameter of the patch, and stem diameter at breast height) were calculated considering all the individuals of the population for both years and by populational kernels. The delimitation of the state classes was based on the height of the plant, the diameter of the patch and the trunk diameter, the latter only for 2017. For the height of the plant, the following classes were delimited: I (< 2 m), II (2.1-4.0 m), III (4.1-6.0 m), IV (6.1-8.0 m), V (8.1-10.0 m), VI (10.1-12.0 m), VII (12.1-14.0 m), VIII (14.1-16.0 m), IX (16.1-18.0 m), and X (> 18.1 cm); for the diameter of the patch: I (< 2 m), II (2.1-4.0 m), III (4.1-6.0 m), IV (6.1-8.0 m), V (8.1-10.0 m), VI (10.1-12.0 m), VII (12.1-14.0 m), VIII (14.1-16.0 m), IX (16.1-18.0 m), and X (> 18.1 m); and for the trunk diameter: I (< 2.5 cm), II (2.5-5.0 cm), III (5.1-7.5 cm), IV (7.51-10.0 cm), V (10.1-12.5 cm), VI (12.51-15.0 cm), VII (15.1-17.5 cm), VIII (17.51-20.0 cm), and IX (> 20.1 cm).

Conservation status

The conservation status was evaluated using the population structure and distribution of the subspecies. The area of occupancy (AO) was calculated in *GeoCat* (http://geocat.kew.org/) with a cell size of 1 km^2 (Bachman & *al.* 2011). The categories and criteria proposed by the IUCN v.3.1 (UICN 2001) were used for the evaluation.

RESULTS

Changes in number and distribution of individuals between 2007 and 2017

For the year 2007, the population of *Magnolia virginiana* subsp. *oviedoae* was organized into two populational kernels (North and South) and an isolated individual (Figure 2), where the Northern kernel contained 60 % of the population (Table 1). For the year 2017, the population was equally organized in two populational kernels (North and South), although with a greater number of isolated individuals (33 new individuals). For this year, the 67 % of the individuals of the population were found in the Southern kernel. The population of *M. virginiana* subsp. *oviedoae* increased 5.5 times within 10 years, with a net increase of 1,105 individuals. The Southern kernel increased at 9.3 individuals per year, which was 3.3 times higher than the Northern kernel. The distance between the population kernels decreased by approximately 660 m. The area of the MCP-global doubled in 10 years, while the perimeter of the MCP-global increased by 20 % in 2017. The Southern kernel showed an expansion rate in the MCP area of 9.86, which is almost five times higher than the one recorded for the Northern kernel. The population density was 2.65 times higher in 2017 (Table I).

In 2007, all the individuals of the population showed a multistem growth. However, in 2017, 145 individuals showed a single-stem growth, of which 37 individuals were less than 1 m of height. The remaining 1,205 individuals had a multi-stem growth. In both years all the individuals were found in the swamp grassland and in the swamp forest. In 2007, 79.2 % of the individuals were found in the swamp grassland, while in 2017, it decreased to 65 %. For both years, all the individuals in the Northern kernel were in the swamp grassland (Figure 3). The number of individuals growing in the swamp forest was 9.2 times higher in 2017, while in the swamp grassland it was 4.5 times higher.

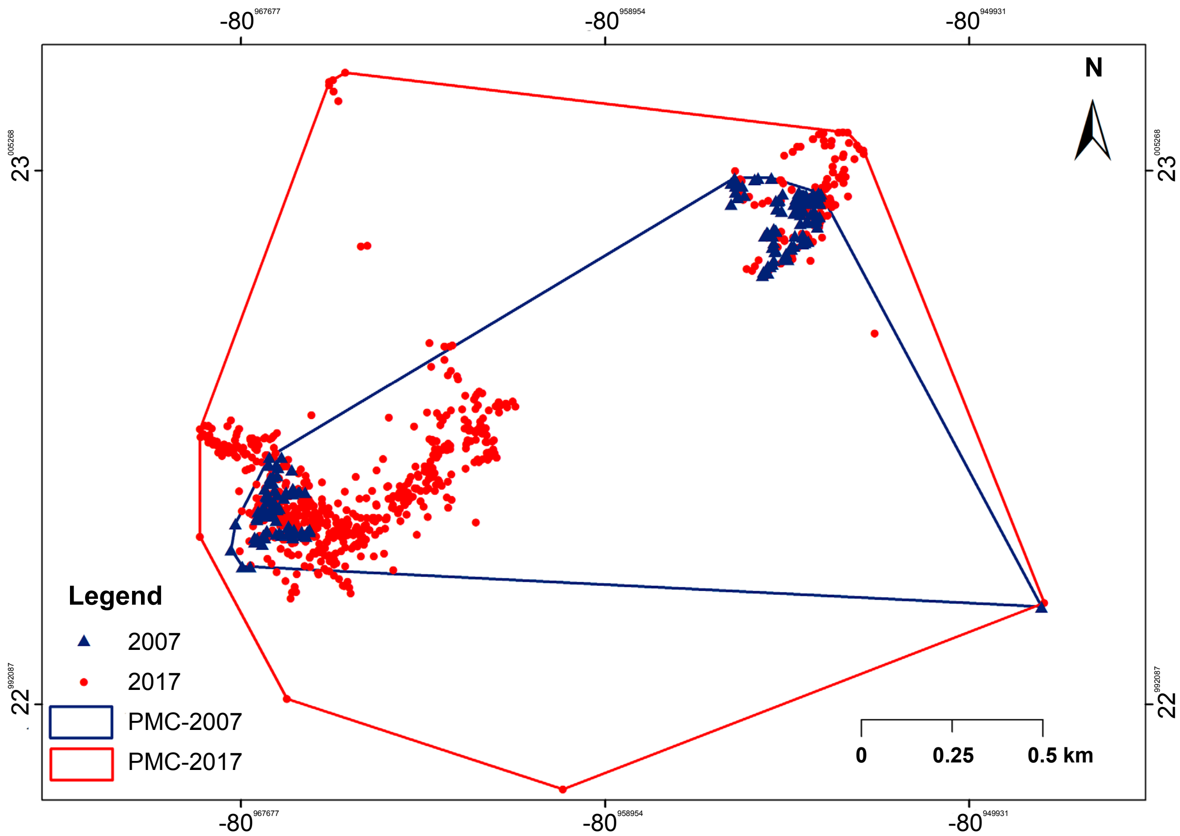

Fig. 2. Spatial distribution of *Magnolia virginiana* subsp. *oviedoae* in the Majaguillar Swamp, Matanzas, Cuba. 2007 (MCP = 1,424 km^2), 2017 (MCP = 2,955 km^2).

Fig. 2. *Distribución espacial de* Magnolia virginiana *subsp.* oviedoae *en la Ciénaga de Majaguillar, Matanzas, Cuba. 2007 (MCP = 1 424 km^2), 2017 (MCP = 2 955 km^2).*

TABLE I

Changes in the number and distribution of individuals of *Magnolia virginiana* subsp. *oviedoae* in the Majaguillar Swamp, Matanzas, Cuba, between the years 2007 and 2017

MCP: Minimum Convex Polygon.

TABLA I

Cambios en número y distribución de los individuos de* Magnolia virginiana *subsp. oviedoae en la Ciénaga de Majaguillar, Matanzas, Cuba, entre los años 2007 y 2017

MCP: Polígono Mínimo Convexo.

	2007	2017	Differences	Expansion rate
Number of individuals	245	1,350	1,105	5.51
Number of individuals in the Northern kernel	147	412	265	2.802
Number of individuals in the Southern kernel	97	904	807	9.319
Isolated individuals	1	34	33	34
Distance between populational kernels (km)	1.36	0.7	-0.66	0.514
Area of the global population MCP (km^2)	1.424	2.955	1.531	2.075
Perimeter of the global population MCP (km)	5.254	6.611	1.357	1.258
Area of the Northern kernel MCP (km^2)	0.041	0.084	0.043	2.0488
Area of the Southern kernel MCP (km^2)	0.037	0.3651	0.3281	9.8676
Population density (individuals/km^2)	172	456.8	284.8	2.655

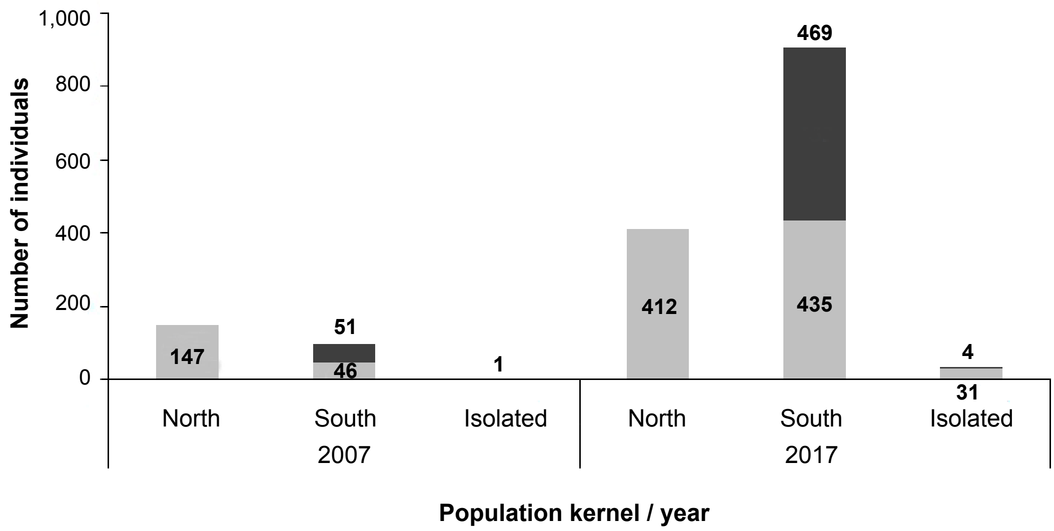

Fig. 3. Number of individuals of *Magnolia virginiana* subsp. *oviedoae* in the Majaguillar Swamp, Matanzas, Cuba, for years, population kernels, and plant formations. Grey bars: swamp grassland, black bars: swamp forest.

Fig. 3. *Número de individuos* de Magnolia virginiana *subsp.* oviedoae *en la Ciénaga de Majaguillar, Matanzas, Cuba, por años, núcleos poblacionales y tipo de formación vegetal. Barras grises: herbazal de ciénaga, barras negras: bosque de ciénaga.*

Spatial arrangement

The population of *Magnolia virginiana* subsp. *oviedoae* exhibited an aggregated spatial arrangement in 2007 (Ip = 0.5002) and in 2017 (Ip = 0.5001). Regarding the change in the type of aggregation pattern as a function of distance, for 2007 the population always showed an aggregated pattern. In 2017, at distances less than 900 m, the spatial arrangement was aggregated, and at greater distances it became random.

The average distance to the nearest neighbor between individuals of *Magnolia virginiana* subsp. *oviedoae* for the year 2007 was 10.5 ± 73.84 m, with a maximum value of 1.14 km. Without taking this individual (the only one over 100 m) into account, the average distance to the nearest neighbor decreases to 5.84 ± 6.77 m. The average distance to the nearest neighbor was 4.70 ± 4.22 m in the Northern kernel and 7.56 ± 9.17 m in the Southern kernel.

In 2017, the average distance to the nearest neighbor was 5.78 ± 31.92 m, 852.7 m being the largest distance between two closest neighbors. If individuals with distances higher than 100 m are eliminated (three individuals removed), the average decreases to 4.43 ± 6.48 m. The individuals of the Northern kernel had an average distance to the nearest neighbor of 2.52 ± 2.72 m, while the individuals of the Southern kernel were on average 5.38 ± 7.52 m. The number of individuals that had a distance to the nearest neighbor less than 5 m was 63 % in 2007 and 78 % in 2017 (Figure 4). For both years, 97 % of the individuals showed distances to the nearest neighbor less than 20 m.

Morphological variables and age structure

The average height of the individuals of *Magnolia virginiana* subsp. *oviedoae* increased 2.44 times in 10 years (Table II). The difference in the averages between both years was 3.52 m. For the diameter of the patch the difference in the averages was 0.02 cm, while the increase in the maximum value was about 5 m in 2017. In 2007, the average height of the individuals was 1.6 m higher in the individuals in the Northern kernel. However, in 2017 the individuals in the Southern kernel were on average 1.95 m higher. The greatest increase in height between the surveys happened in the Southern kernel, where this variable increased its average 4.5 times. The maximum height for this kernel increased about 15 m. In the Northern kernel, the average increase was 1.57 m. Regarding the diameter of the patch, the average values in both years were higher in the Southern kernel. In this kernel a decrease of 48 cm was recorded in the patch diameter, while in the Northern kernel the difference was 13 cm; regarding the maximum values, for both years the individuals of the Southern kernel always had a greater diameter of the patch with respect to those of the Northern kernel. Non correlation were found between the height of the plant and the patch diameter (2007: $r = -0.089$, $p < 0.001$; 2017: $r = 0.24$, $p < 0.001$).

The population in both years showed an age structure in expansion, with high concentrations of individuals in the first classes and less individuals in the last size classes (in height and diameter), which represent the oldest individuals of the population. In 2007, the histogram of frequency of individuals based on the height classes showed an inverted J pattern. However, in 2017 it showed a Gaussian pattern, with asymmetry towards the first classes (Figure 5). In 2007, five classes were occupied while in 2017 four new classes of height were occupied (classes VI, VII, VIII, and IX). 136 individuals were included in these three new classes. In 2007 the highest concentration of individuals was in class I, while in 2017 class III was the most abundant.

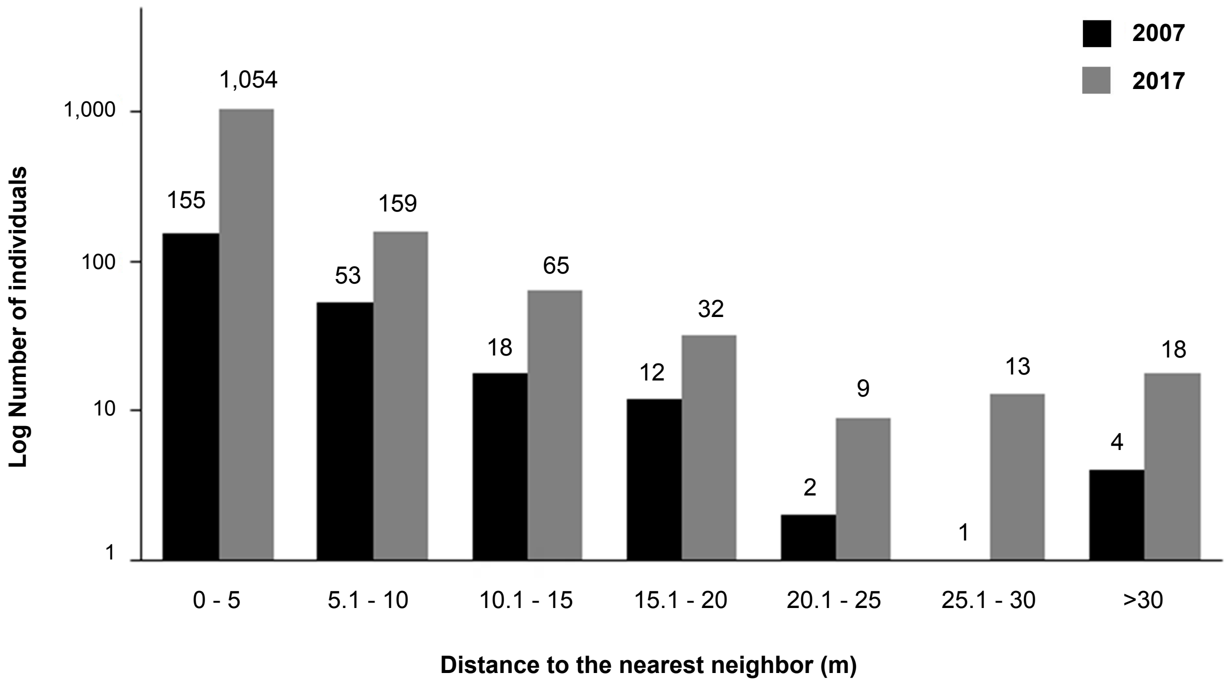

Fig. 4. Frequency histogram with the distances to the nearest neighbor of the individuals of *Magnolia virginiana* subsp. *oviedoae* in the Majaguillar Swamp, Matanzas, Cuba, for the years 2007 (N = 245) and 2017 (N = 1,350).

Fig. 4. *Histograma de frecuencia con las distancias al vecino más cercano de los individuos de* Magnolia virginiana *subsp.* oviedoae *en la Ciénaga de Majaguillar, Matanzas, Cuba, para los años 2007 (N = 245) y 2017 (N = 1 350)*

TABLE II

Descriptive statistics of the morphological variables evaluated in *Magnolia virginiana* subsp. *oviedoae* in the Majaguillar Swamp, Matanzas, Cuba, in the years 2007 and 2017

N: Sample size, Ave.: Average, SD: Standard Deviation, Min.: Minimum, Max.: Maximum.

TABLA II

Estadísticos descriptivos de las variables morfológicas evaluadas en* Magnolia virginiana *subsp.* oviedoae *en la Ciénaga de Majaguillar, Matanzas, Cuba, en los años 2007 y 2017

N: Tamaño de muestra, Ave.: Promedio, SD: Desviación Estándar, Min.: Mínimo, Max.: Máximo.

Variable	2007					2017				
	N	Ave.	SD	Min.	Max.	N	Ave.	SD	Min.	Max.
Height (m)	245	2.44	1.24	0.16	9.04	1,350	5.96	3.19	0.1	17
Southern Kernel	97	1.46	0.33	0.16	1.87	904	6.59	3.37	0.14	17
Northern Kernel	147	3.07	1.21	1.89	9.04	412	4.64	2.19	0.1	11
Isolated individuals	1	4.97	-	-	-	34	5.11	3.48	1.8	14
Patch diameter (m)	245	3.07	2.84	0.35	18.83	1,205	3.09	2.42	0.18	23.74
Southern Kernel	97	3.61	3.57	0.35	18.83	802	3.13	2.45	0.18	23.74
Northern Kernel	147	2.71	2.19	0.4	13.11	373	2.84	2.16	0.25	15
Isolated individuals	1	1.85	-	-	-	30	4.92	3.72	0.47	17
Trunk diameter (cm)	-	-	-	-	-	145	13.32	14.92	1	64
Southern Kernel	-	-	-	-	-	102	10.5	14.65	1	55
Northern Kernel	-	-	-	-	-	39	20	13.21	2	64
Isolated individuals	-	-	-	-	-	4	19.8	18.8	10	48

In 2007, the first two classes included 87.7 % of the population, while in 2017, these same classes only included 35 % of the individuals. The class that experienced the highest increment was the third, with a rise of 296 individuals, followed by class II with 222 new individuals. In 2007, only 11 individuals were found that were less than 1 m height, while in 2017, 49 individuals were less than 1 m.

The frequency histograms based on the patch diameter showed an inverted J pattern in both years (Figure 5). In 2007 and 2017, the first and second classes included 77.1 % and 78.7 % of all individuals, respectively. The biggest increase was in the first class with 382 new individuals. The differences in classes II and III were 377 and 110, respectively. The trunk diameter classes showed an inverted J pattern, with 70 % of the individuals grouped in the first two classes (Figure 5). The average of this variable was 13.32 cm, and the Northern Kernel showed the higher (average 20 cm).

Conservation status

Based on the IUCN Red List criteria, the restricted area of occupancy (6 km^2) and the number of locations (1), *Magnolia virginiana* subsp. *oviedoae* is listed as Vulnerable (VU), under the criteria D2.

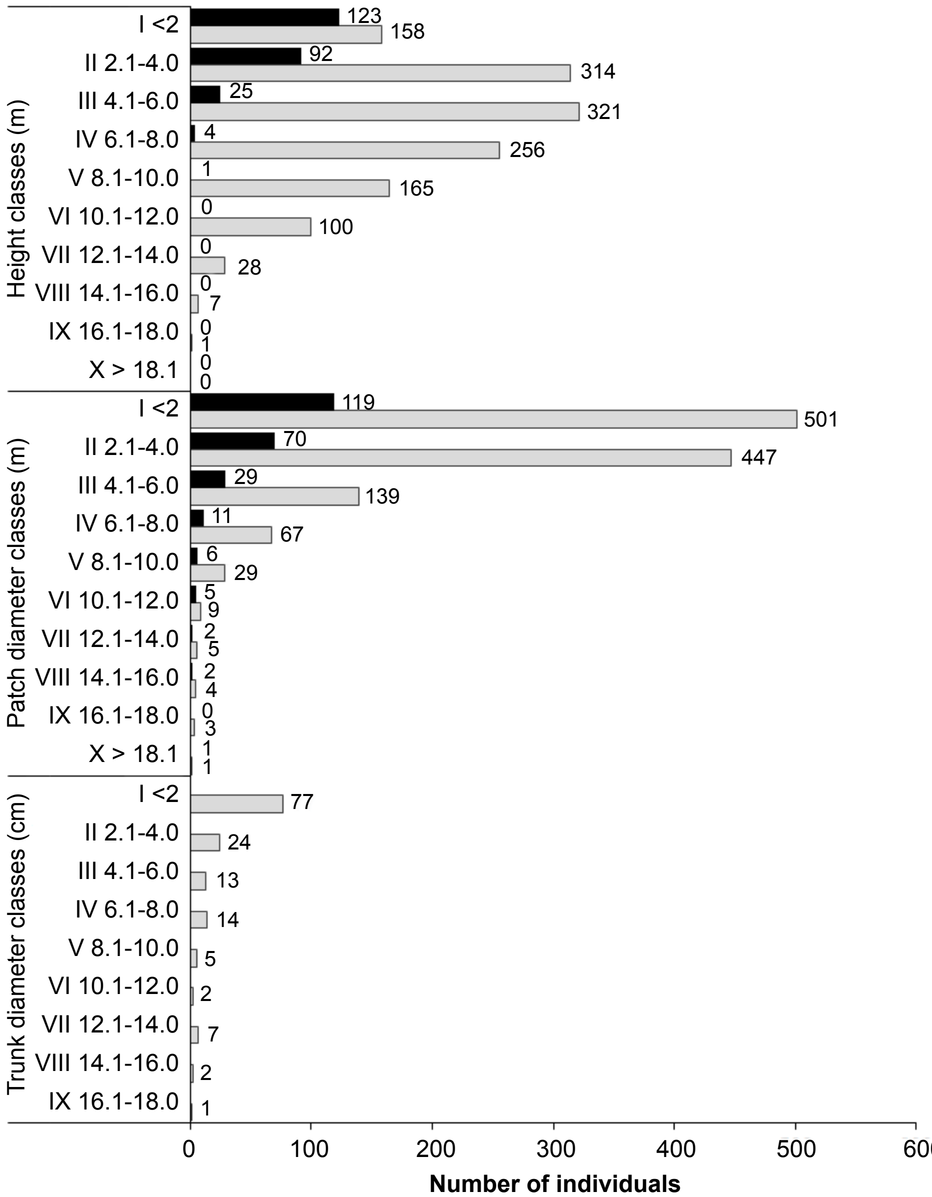

Fig. 5. Frequency histograms by classes of morphological variables of individuals of *Magnolia virginiana* subsp. *oviedoae* in the Majaguillar Swamp, Matanzas, Cuba. Height classes, 2007: N = 245 and 2017: N = 1,350; Patch diameter classes, 2007: N = 245 and 2017: N = 1,205; Trunk diameter classes, 2017: N = 145. Black bars: 2007, grey bars: 2017.

Fig. 5. *Histograma de frecuencia por clases de variables morfológicas de individuos de* Magnolia virginiana *subsp.* oviedoae *en la Ciénaga de Majaguillar, Matanzas, Cuba. Clases de altura, 2007: N = 245 y 2017: N = 1 350; Clases de diámetro del parche, 2007: N = 245 y 2017: N =1 205; Clases de diámetro del tronco, 2017: N = 145. Barras negras: 2007, barras grises: 2017.*

DISCUSSION

Changes in number and distribution of individuals between 2007 and 2017

The population of *Magnolia virginiana* subsp. *oviedoae* showed a significant increase within 10 years, which could be related to good conditions in MSw for its expansion. The results seem to reveal the recent origin of this population, which was discovered in a process of expansion and colonization of the new environment. The hypothesis of expansion after the recent arrival is supported by Vilá & *al.* (2008). These authors state that in a new environment many species find empty ecological niches (Grinnell´s concept of niche (Soberón & Nakamura 2009)) and a lesser number of natural enemies, which can exert a positive influence on the colonization process. Also, the environmental changes resulting from oil exploration that is taking place in the coastal zones of MSw since 25 years ago (García-Martínez 2010) could favor the expansion of the taxon. This activity closes many natural water channels of the swamp, which alters the natural hydric regimens. According to Maisenhelder (1970) and Zale (2009), *M. virginiana* occurs in the border of rivers, bays, lakes and swamps. Basically, *M. virginiana* "prefers" growing near the water, but not inside the water. Hence, the population could be favored by the reduction of flooded areas in MSw.

The population expansion rate in 10 years is higher than the reported for *Magnolia dealbata* Zucc., whose population doubled in 14 years (Sánchez-Velásquez & Pineda-López 2006). If *M. virginiana* subsp. *oviedoae* keeps the current expansion rate, the population will overcome 8,000 individuals within the next 10 years. However, keeping the same expansion rate it is almost impossible because the population will eventually stabilize based on habitat conditions. According to Jørgensen & Fath (2008), population growth is determined by the availability of resources and the suitability of the habitat.

The expansion process recorded for *Magnolia virginiana* subsp. *oviedoae*, in number of individuals and in distribution area, is similar to the reported for exotic species when arriving in a new environment. The number of individuals in the population of these species, once established, can rise in a short period of time (less than five years) (Vilá & *al.* 2008). However, *M. virginiana* subsp. *oviedoae* cannot be considered an invasive species, because there is no record of human introduction and its former distribution range is close to MSw (Oviedo & *al.* 2006). It is thought that the species was brought to Cuba from North America by migratory birds. This hypothesis is supported by the bird dispersal syndrome of *Magnoliaceae* (Callaway 1994, Zale 2009). According to Callaway (1994), the high concentrations of carbohydrates and oils in the aril of the seed are an important source of energy for the migratory birds. Moreover, there is overlap between the fruiting period of *M. virginiana* (August-October) (Zale 2009) and the migratory period of 115 bird species that come from North America (Garrido & Kirkconnell 2011). According to González (2002), the region between Hicacos Peninsula and MSw is crossed by the migration route of the Atlantic Coast, which also passes by many areas with populations of *M. virginiana* in the United States (Azuma & *al.* 2011).

The seed dispersal could have been mediated by birds of the Turdidae family, which are one of the main dispersers of magnolias (Hernández 2016). According to Garrido & Kirkconnell (2011), there are nine species of Turdidae family that arrive in Cuba between August and October. All of them have sizes between 15 and 25 cm (Garrido & Kirkconnell 2011); hence, they can satisfy their energy requirements with seeds of *Magnolia virginiana*, which are 0.6 cm approximately in size (Callaway 1994). The nine species are considered to be rare winter residents and passerbys, which could agree with the existence of only one population in Cuba and its restricted distribution. Based on these facts, we can infere that the arrival of *M. virginiana* in Cuba may have been a stochastic event.

One of the most significant differences between the population censuses was the type of growth. According to Oviedo & *al.* (2006), the taxon tends to form patches (multi-stem growth), and Palmarola & *al.* (2008) described the subspecies as a multi-stem shrub. Both criteria agree with the type of growth found in 2007, but differ from the results from 2017, when individuals with both types of growth (multi-stem and single-stem) were found. The presence of both types of growth in the Cuban population is similar to the reported for the continental populations of *M. virginiana* (Treseder 1978, Callaway 1994, Zale 2009, Azuma & *al.* 2011). The presence of multi-stem and single-stem individuals in MSw supposes three hypotheses: (1) "The type of growth depends on the environmental conditions of the place where each individual lives"; (2) "The Cuban population has multiple origins with seeds coming from several populations in the continent with different types of growth"; and (3) "The individuals with multi-stem growth change to single-stem due to the loss of stems during ontogenetic development."

Magnolia virginiana subsp. *oviedoae* only grows in the swamp forest and in the swamp grassland, a fact reported by Oviedo & *al.* (2006) and Palmarola & *al.* (2008) that agrees with Maisenhelder (1970) and Zale (2009) for the continental population. In the continent, the species can also be found in the deciduous forests and borders of rivers and lakes. The taxon was more abundant in the grassland swamp during both censuses, which could be related to less limitation in sunlight exposure due to lower canopy coverage and, in consequence, less competition for sunlight. However, in the grassland swamp the coverage of *Cladium jamaicense* Crantz (*Cyperaceae*), a dominant species in the locality, could limit the establishment of seeds and the growth of the saplings of *M. virginiana* subsp. *oviedoae*.

Spatial arrangement

The existence of an aggregated spatial pattern in the population of *Magnolia virginiana* subsp. *oviedoae* agrees with Begon & *al.* (2006) and Liu & *al.* (2013), who say that these patterns are the most common in natural populations. The aggregated pattern could be the result of seed dispersal, regeneration dynamics, environmental conditions, and interaction be-

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tween individuals (Seidler & Plotkin 2006, Liu & *al.* 2013). Other magnolias have shown similar patterns: *M. cubensis* subsp. *acunae* Imkhan. in Cuba (Palmarola & *al.* 2018), *M. dealbata* in Mexico (Gutiérrez & Vovides 1997), *M. officinalis* subsp. *biloba* (Rehder & E.H. Wilson) W.C. Cheng & Y.W. Law in China (He & *al.* 2009), and *M. cylindrica* E.H. Wilson in China (Li & *al.* 2017).

Morphological variables and age structure

The average values of height recorded in 2007 are below the reported by Palmarola & *al.* (2008) in the original description of the subspecies (average height between 4-7 m); and the high value reported in the present work was higher that the reported by this authors. The values of the Cuban subspecies are higher than *M. virginiana* var. *virginiana* (max. 9 m) and lower than *M. virginiana* var. *australis* Sarg. (max. 27 m) (Callaway 1994, Zale 2009, Azuma & *al.* 2011). This change could be consecuences of more time of stablished and development of the individuals.

The patch diameter did not show differences between the censuses, which could be explained by the new individuals of the population, which were born after 2007. In this case, the average is affected by these new individuals, due to the fact that it is sensitive to extreme values. The height of the plants showed more changes than the patch diameter. A possible reason for this is that individuals tend to grow more along the vertical axis, as a mechanism to obtain more sunlight. Also, growing along this axis could be less energetically expensive. The patch growth implies the appearance of new trunks that are energetically more expensive. It is also possible that the internal competition of the patch can restrict its growth, which was proved for *Fagus engleriana* Seemen *ex* Diels (*Fagaceae*) by Cao & Peters (1998). Maybe in the future the species will tend to grow more in patch diameter, once the individuals are well established and overcome other species in the swamp. Although the patch diameter did not increase its average values between 2007 and 2017, the maximum values are higher than those reported by Palmarola & *al.* (2008).

The inverted J pattern found represents the ideal pattern for a natural population, where most of the individuals are juveniles that will contribute in an active way to the population replacement (Shahid & *al.* 2012). In 2017 the height of the individuals showed a Gaussian pattern with a deviation to the first classes, due to the high concentration of individuals in classes II and III. The individuals of the first two classes (< 4 m) could be considered as juveniles that could contribute to the population increase. The continental population shows a good rate of natural regeneration and abundance of young individuals (APGA-USFS Tree Gene Conservation Partnership 2015).

Based on the Gaussian pattern observed in 2017 for the height, we can assume that the population of *Magnolia virginiana* subsp. *oviedoae* presents problems with natural regeneration, an insufficient population replacement, a population decline, and past perturbation, according to the criteria of Rollet (1971), Lamprecht (1990), Oostermeijer & *al.* (1994), Zagt & Werger (1997). The behavior of the natural population that shows a Gaussian pattern does not match for *M. virginiana* subsp. *oviedoae*. Taking the results into account, the present work shows that the population is in an expansion process. The most accurate explanation of the low representation in the first class in the graphic of height in 2017 (Figure 5) is the poor detectability of individuals with low height (< 50 cm). The low detectability becomes more relevant in communities with dense vegetation (Bullockm 1996), just like the swamp grassland in MSw, where *Cladium jamaicense* Crantz covers the soil. If higher detectability of the small individuals had been possible, the height pattern would probably be different.

Conservation status

The re-categorization of *Magnolia virginiana* subsp. *oviedoae* as Vulnerable (VU) does not match with Palmarola & *al.* (2015), who consider the subspecies to be Critically Endangered of extinction (CR) under the criteria B1ab(iii)+2ab(iii). According to the results of the current work, the extent of occurrence and the area of occupancy match with Palmarola & *al.* (2015): less than 100 km^2 and 10 km^2, respectively. However, even though the taxon has a single location, which accomplishes the condition a for CR, the species is not experiencing a continuing decline in any of the parameters required for accomplishing the condition b: (i) extent of occurrence, (ii) area of occupancy, (iii) area extent and/or quality of habitat, (iv) number of locations or subpopulations, or (v) number of mature individuals. Therefore, based on criterion B, the species would be listed as Near Threatened to extinction (UICN 2001). As this work provides more comprehensive information about the dynamics of the population, area of occupancy and extent of occurrence of the taxon, we could also apply the criteria C and D to recategorize it. Under criterion C the species would be considered of Less Concern because though it has less than 2,500 mature individuals, which matches with one of the conditions to be considered as Endangered to extinction, its population is not declining rather increasing. According to UICN (2001), the criterion or set of criteria that give the highest risk of extinction are the ones used for red listing. Hence, the current category of *M. virginiana* subsp. *oviedoae* is based on criterion D, since it shows the highest risk of extinction.

Protecting the Cuban population of *Magnolia virginiana* subsp. *oviedoae* is important because is one of the largest populations of the species, the southernmost and the only one outside the United States. Also, this population might have genetic differences with respect to the northern ones, which is of paramount relevance for the species to survive in a changing world. The fact that in just ten years the population has increased almost six times and that the age structure has changed significantly shows that the swamp in Majaguillar is an ideal habitat for the species, hence, it has to be preserved.

Furthermore, this swamp is one of the entry points and resting/feeding area of the migrating birds coming from North America. This migration process plays a crucial role in dispersal, pollination and biological control for the Caribbean ecosystems.

Unfortunately, the area where the subspecies is distributed is not included into the Cuban system of protected areas with threatened like exotic species, oil extraction and ways, which makes its long-term protection very difficult. Nevertheless, the high recognition of the species of magnolia among the international community could be used as flag to create regional and national policies to preserve the area and the other species.

CONCLUSION

Magnolia virginiana subsp. *oviedoae* presented an aggregate spatial arrangement and an expanding age structure for both years, with an increase in the number of individuals for each class between both years, which indicates its good state of conservation. The height was the variable that presented the greatest increase between 2007 and 2017, while the diameter remained stable. From 2007 to 2017 the population of *Magnolia virginiana* subsp. *oviedoae* presented an expansion process due to the increase in the number of individuals, their range of habitat, area of occupation, the distance between population centers and population density.

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AUTHOR´S CONTRIBUTION

E. Testé, A. Palmarola and L.R. González-Torres conceived the original idea. E. Testé, A. Rodíguez-Meno, A. Palmarola and L.R. González-Torres took the data. E. Testé, A. Rodríguez-Meno y M. Hernández analyzed the data. E. Testé wrote the first version of the manuscript. All authors contributed to discussion of results and critical revision of the manuscript.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest: The authors declare that they have no conflict of interest.
Ethics approval: All authors have carried out fieldwork and data generation ethically, including obtaining appropriate permitting.
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