The bush dog *Speothos venaticus*: area requirement and habitat use in cultivated lands

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Abstract We radio-tracked a pack of bush dogs *Speothos venaticus* (7–10 individuals) near Água Boa in Mato Grosso, Brazil, for 18 months to investigate their use of habitat in cultivated land. The pack's home range was 709 km² (fixed-kernel 95%), which exceeds estimates of home range for the largest Neotropical carnivore, the jaguar *Panthera onca*. Of the 245 locations where the dogs were recorded 95% were within native vegetation (savannah and forest), even though these habitats comprised only 34% of the pack's home range. This indicates a preference for native vegetation, and this was reinforced by composition analysis of habitat use, which showed that the pack used savannah and forest more than expected and cultivated areas less than expected. Analysis of activity showed that the bush dogs were moving quickly in more than half of the locations in cultivated areas, foraging in most savannah locations and resting in most forest locations. Our results indicate that bush dogs can live in areas with a high proportion of cultivated land (66%), possibly because of the structural connectivity of the landscape (80% of the native habitat is within a single patch). However, their home range appears to be inflated compared to that of other carnivores, which may have a negative effect on the species in the long term.

Keywords Cerrado, compositional analysis, connectivity, Focal Patch, fragmentation, habitat use, Neotropics, radiotelemetry

This paper contains supplementary material that can be found online at http://journals.cambridge.org

Introduction

Reduction and isolation of native habitats are threats to biodiversity (Fahrig, 2003), and understanding how species respond to landscape change is fundamental to improving the effectiveness of conservation efforts (Knowlton & Graham, 2010). Home ranges, or the spatial distribution of animals within a population, are thought to reflect the distribution of preferred resources in the landscape (Mitchell & Powell, 2004). In human-modified landscapes home ranges may also reflect the ability of animals to move around the heterogeneous landscape to reach their preferred patches. Such ability is both landscape- and species-dependent. Animals may increase their home ranges in response to a reduction of their preferred habitats, as has been observed in bobcats *Lynx rufus* (Tucker et al., 2008) and raccoons *Procyon lotor* (Beasley & Rhodes, 2010), if there is high structural connectivity between preferred patches or if the animals are able to cross the surrounding matrix to move between patches (high functional connectivity, sensu Tischendorf & Fahrig, 2000). Alternatively, animals may reduce their home ranges, as seen among Eurasian red squirrels *Sciurus vulgaris* (Verbeylen et al., 2009) and European pine martens *Martes martes* (Mergey et al., 2011), if structural and functional connectivity are low. Evaluating how each species responds to distinct landscape contexts is essential for better conservation planning and to ensure long-term persistence of a diverse array of native species in the face of increasingly human-dominated heterogeneous landscape scenarios.

The bush dog *Speothos venaticus* is an elusive Neotropical canid categorized by the Brazilian Ministry of Environment as Threatened (MMA, 2003), and as Near Threatened on the IUCN Red List (DeMatteo et al., 2011). Information on the spatial needs and habitat preferences of bush dogs is scarce because it is difficult to record and monitor the species in the wild. In a fragmented landscape in northern Mato Grosso, Brazil, Michalski & Peres (2007) and Michalski (2010) recorded bush dogs only twice during a 2-year interview programme and twice during almost 5,000 camera-trap days. In an area of continuous forest in southern São Paulo, Brazil, a pair of bush dogs was recorded for the first time after 4,818 camera-trap days (Beisiegel, 2009). Based on a macro-scale analysis DeMatteo & Loiselle (2008) suggested that bush dogs were more likely to occur in pristine habitats (80% of records were in pristine habitats). At the local scale Michalski & Peres (2007), Michalski (2010) and Beisiegel (2009) reinforced the same hypothesis with records in patches > 1,000 ha and in continuous forest. In contrast, de Oliveira (2009) recorded bush dogs in habitats of varying quality. These studies indicate

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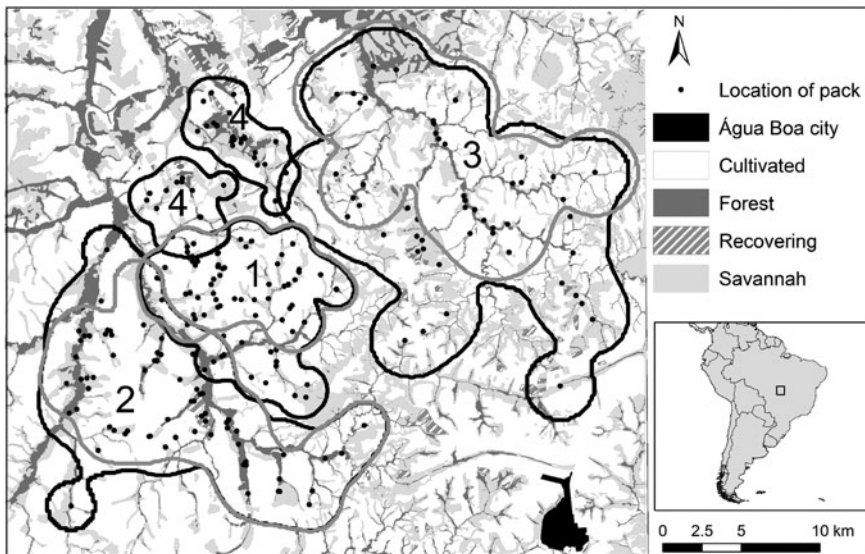‡Also at: Centro Nacional de Pesquisa e Conservação de Mamíferos Carnívoros, Atibaia, São Paulo, Brazil

Fig. 1 Habitat types, locations and sub-areas (fixed-kernel 95%) used by a pack of bush dogs *Speothos venaticus* (7–10 individuals) in the Água Boa district, Mato Grosso, Brazil, during May 2008–December 2009. The percentage of native habitat in the region is low (34% of the total area) but structural connectivity is high (80% of the native habitat is connected within a single patch). Most locations fall within native habitats (forest or savannah). Each area was visited for 1–2 months and then revisited after c. 1 year, in a rotational or semi-nomadic movement pattern. Areas are numbered chronologically, with black lines indicating first use and grey lines indicating second use.

that bush dogs have a preference for native habitats but can also be found in human-modified landscapes.

Knowledge of the bush dog's area requirements is essential for improved estimates of population density and size. Two early attempts to estimate the species' area requirements used a correlation between body size and home range of other canid species. Silveira et al. (1998) estimated a home range of 4.72 km² per individual. Beisiegel (1999) refined the correlation with a correction factor for dietary specialization and estimated a home range of 25 km² per individual. More recently Lima et al. (2012) reported a home range of 140 km² (95% fixed kernel) for a pack of 3–7 bush dogs in a relatively undisturbed area (86% native habitat), based on radio-telemetry data, which is close to the estimate of Beisiegel (2009). Nevertheless, information on how the bush dog's area requirements change with reduction and fragmentation of native habitats is still lacking, and such information is critical for improved estimates of population densities and sizes, and identification of priority habitats for conservation of the species.

The Cerrado is Brazil's second largest biome (Klink & Machado, 2005) and it encompasses 25% of the bush dog's distribution (K. Ferraz et al., unpubl. data). Since the 1960s the Cerrado has been converted for monocultures of soya bean, rice and wheat, and cattle ranches, and only 20% of its native vegetation remains intact (Klink & Machado, 2005). Here we report our findings on the area requirements and habitat use of a pack of bush dogs tracked by radio-telemetry in an area of the Cerrado with only 34% of native habitat but with high structural connectivity (80% of the native habitat is within a single patch). Our main objective is to report on how this elusive species of carnivore is adapting in a human-modified landscape and to aid understanding of how movement and use of space by carnivores are affected by habitat reduction.

Study area

The study was conducted at the headwaters of the Sete de Setembro River, c. 15 km north-west of Água Boa municipal district in the state of Mato Grosso, Brazil (Fig. 1). The economy of Água Boa is based on agriculture and cattle, and since 1970 a significant portion of its native vegetation has been cleared for cultivation. Native vegetation still remains in some areas, especially in swampy or elevated terrain and close to rivers (under the Brazilian Conservation Act, n. 4.771/1965 and n. 12.651/2012, native vegetation on river margins on private lands must be preserved, with distances depending on river width). The region is within the Brazilian Cerrado biome and the native vegetation is predominantly savannah (all native grassland formations, including swampy grassland, dry grassland, shrubby grassland, and grassland with scattered short trees), with patches of forest (gallery, dry and valley forests; see Oliveira-Filho & Ratter (2002) for descriptions and pictures of all distinct Cerrado vegetation types). In the 2010 population census Água Boa had a rural population of 4,097 people, at a density of c. 0.5 km^{-2} (IBGE, 2013). In 2006 there were estimated to be 280,797 cows in the municipality (38 km^{-2}; IBGE, 2013). The climate is characterized by two distinct seasons: rainy (October–March) and dry (April–September), with mean annual rainfall of c. 1,600 mm (Nimer, 1989) and no seasonal flooding.

Methods

Capture and monitoring

On 25 May 2008 we captured a pack of bush dogs (Supplementary Material 1) comprising 10 individuals: two dominant adults (one male, one female), three young adults

TABLE 1 Home range of a bush dog *Speothos venaticus* pack (7–10 individuals) radio-tracked in Água Boa district, east Mato Grosso, Brazil (Fig. 1) during May 2008–December 2009, with minimum convex polygon (MCP) and fixed-kernel estimates.

	No. of locations	No. of individuals	MCP[1] (km^2)	Fixed kernel[2] (km^2)		
			95%	95%	75%	50%
May 2008–Dec 2009	245	7–10	544.6	708.8	379.8	189.3
July 2008–July 2009	160	9–10	546.7	702.2	388.8	204.0

[1]MCP with 95% of the most central locations (5% outliers excluded)
[2]Grid cell for the fixed kernel was 100 × 100 m (10 × 10 m, 50 × 50 m and 150 × 150 m were tested, yielding similar results)

(one male, two females) and five juveniles (four males, one female).

All dogs were sedated with an intramuscular injection of 5 mg per kg tiletamine hydrochloride and zolazepam hydrochloride (Zoletil 50, Virbac, Brazil) for morphometric measurements and estimation of age (through analysis of teeth development). The adults and young adults were fitted with 164-MHz VHF radio collars (Advanced Telemetry Systems, Isanti, USA) of an optimum design for the species (DeMatteo & Kochanny, 2004). Each collar was equipped with an activity switch. To determine the age of each animal we examined their size, fur colour, and teeth (type, quantity and quality). For full information on the handling and release of the animals see Supplementary Material 1.

We tracked the bush dogs for 81 weeks, during 25 May 2008–4 December 2009. The pack was monitored from the ground, using a TR4 radio receiver and RA-14 H-directional antenna (Telonics, Mesa, USA). We returned to the area every day to attempt to locate the pack. Geographical coordinates were recorded using a global positioning system (GPS) and in all instances the pack was located by direct observation (i.e. either by visual or auditory contact within 10–20 m or by den location).

Home range, habitat preferences, and activity patterns by habitat type

Locations from all five collars were considered as a unit (pack location) as the dogs were always within 10–20 m of each other. Home range was estimated using the fixed-kernel method (95, 75 and 50%; Worton, 1987, 1989; Table 1), using *IDL v. 8.2.3* (Exelis Visual Information Solutions, Boulder, USA). The fixed-kernel method needs a smoothing parameter (h) in its calculation, which determines the width of each kernel. In practice, h determines whether a kernel distribution will be more or less detailed (Seaman & Powell, 1996). The least-squares cross-validation (LSCV), used in this study, is an unbiased method of determining h (Seaman & Powell, 1996). We also used the deterministic minimum convex polygon (95%; Mohr, 1947; Hayne, 1949; Table 1) to determine the home range, for comparison with the home ranges of other carnivore species.

To evaluate if habitat use was random relative to availability we used a compositional analysis (Aebischer et al., 1993), with proportions of use and availability log-transformed to eliminate non-independence. Proportions of use were generated from the fixed-kernel utilization distribution rather than direct locations because the utilization distribution quantifies use within the home range with a probabilistic and continuous metric and eliminates concerns about independence between points (Marzluff et al., 2004).

We calculated proportions of different habitat types, using a 2007 Spot satellite image (2.5-m resolution) of the study area as a reference. The satellite image was acquired from the Secretary of Environment of the state of Mato Grosso. Six categories of habitat were identified, using *ArcGIS v. 9.2* (ESRI, Redlands, USA). These were (1) savannah (all native grassland formations, including swampy grassland, dry grassland, shrubby grassland, and grassland with scattered short trees), (2) forest (gallery, dry and valley), (3) cultivated areas (pasture and agricultural crops), (4) recovering vegetation (abandoned cultivated lands with native pioneer species present), (5) urban areas (cities and surroundings), and (6) water bodies. Only three categories were included in the final compositional analysis (savannah, forest, and cultivated lands) because the pack's home range did not encompass urban areas, only 0.03% of the range comprised recovering vegetation, and there were no locations in water bodies.

We created a resource utilization function (Marzluff et al., 2004), using the *Focal Patch* extension of *ArcView v. 3.2* (ESRI, Redlands, USA), which expresses the correlation between the utilization distribution and the vegetation categories. Finally, we generated a contingency table of level of use (low, medium, high) by vegetation category, and used a G-test to test for statistically significant differences in the proportion of use and availability per vegetation type (Supplementary Material 2).

For each location we categorized activity (Supplementary Material 3) as inactive, foraging/moving locally or moving fast, to correlate activity with the habitat types used by the pack. Significant differences between actual and expected frequencies of category of activity were tested using a G-test.
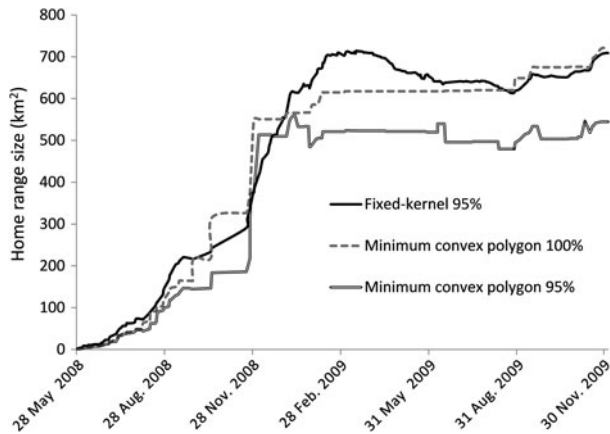
FIG. 2 Cumulative home range size (fixed-kernel 95%, minimum convex polygon 100% and 95%) of a pack of bush dogs (7–10 individuals) in the Água Boa district, Mato Grosso, Brazil (Fig. 1), during May 2008–December 2009. The increase in the fixed-kernel 95% estimate after January 2009 is probably an effect of sample size.

Results

We tracked the pack of bush dogs to 245 locations. More than half of the consecutive records (53%, n = 130) were made on consecutive days. Nine locations (4%) were recorded on the same day. Of the remaining locations, 9% were recorded within 2 days, 14% within 3 days, 11% within 4 days, 5% within 5 days and 2% within 6 days. Four consecutive locations were recorded at intervals of >9 days (10, 16, 18 and 36 days). During these periods we lost track of the pack temporarily (27 September–15 October 2008; 16 October–21 November 2008; 17 June–3 July 2009; 12–22 October 2009). On average, we located the pack 3 days per week. Periods when the pack was recorded on consecutive days lasted 2–6 days (77 periods in total), with 42 2-day periods, 23 3-day periods, seven 4-day periods, three 5-day periods and two 6-day periods.

Home range estimates for the 18-month study period were 709 km² (fixed-kernel 95%; $h_{(LONG)LSCV} = 1,672$ m and $h_{(LAT)LSCV} = 2,008$ m; grid cell size = 100 × 100 m) and 545 km² (minimum convex polygon 95%; Table 1). From May 2008 to January/February 2009 the home range size increased, with no signs of levelling off (Fig. 2). In February 2009 the home range reached an asymptote as the pack started to move towards areas within the home-range boundaries (Fig. 1). After the period of reproduction (February–April 2009; Area 4, Fig. 1), the pack started returning to areas used previously (Areas 1, 2 and 3, Fig. 1). The increase and posterior decrease in the fixed-kernel 95% estimate after January 2009 (Fig. 2) is probably an effect of the probabilistic method. Once the pack started to move within the home-range boundaries, the kernel peaks of the fixed-kernel estimate became more accentuated as more locations were included and the fixed-kernel 95% boundaries
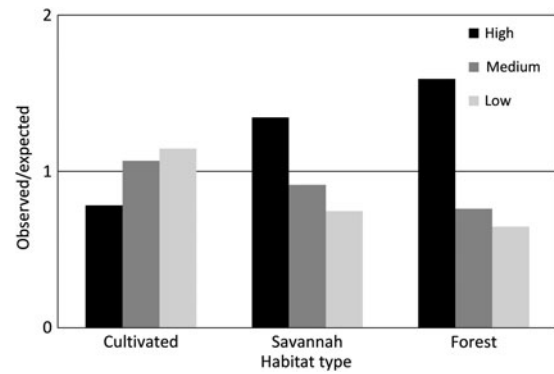

FIG. 3 Compositional analysis of a grid of intensity of use (low, medium, high) vs main habitat types (cultivated lands, forest, savannah). There were significantly more high-use cells than expected in the savannah and forest, and fewer than expected in cultivated lands.
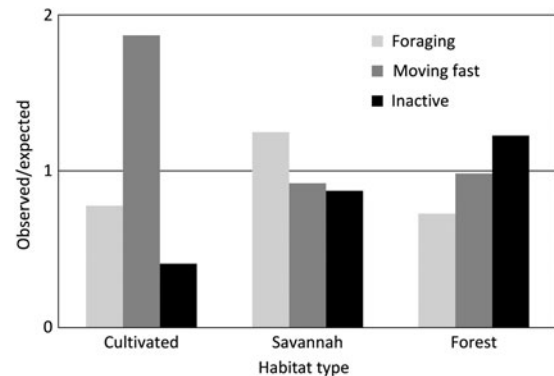

FIG. 4 Compositional analysis of activity pattern (foraging/moving locally, moving fast, and inactive) vs habitat type (cultivated lands, forest, savannah). At most locations recorded in cultivated lands the animals were moving fast, at most locations in the savannah they were foraging, and at most locations in the forest they were inactive.

decreased. Overall, after 1 year (in May 2009) the pack used the same areas again (Fig. 1), suggesting a pattern of rotational use or semi-nomadic movement.

Although most of the region comprises cultivated land (66% of the pack's home range), the pack predominantly used native vegetation (230 of 245 locations; Fig. 3). A G-test of the resource utilization function confirmed this preference, with the pack using forest and savannah habitats significantly more than expected (forest: G = 44.02, df = 2, P < 0.001; savannah: G = 42.07, df = 2, P < 0.001) and cultivated land significantly less than expected (G = 45.82, df = 2, P < 0.001; Fig. 4).

We were able to determine the activity at 237 of the 245 locations (89 inactive, 70 foraging/moving locally, and 78 moving fast). Of these, 122 were in savannah, 102 in forest and 13 in cultivated areas. When considered in the context of habitat type (forest, savannah, and cultivated areas) our results showed that foraging/moving locally occurred

more than expected in savannah, inactive occurred more than expected in forest, and moving fast occurred more than expected in cultivated areas ($G = 12.33$, df = 4, $P = 0.015$; Fig. 4).

Further details of our results can be found in Supplementary Material 4.

Discussion

We found that a pack of bush dogs (7–10 individuals) covered an area of 709 km² over a period of 18 months, which exceeds the estimates of home range for other Neotropical carnivores, such as the jaguar *Panthera onca* (30–270 km²; Rabinowitz & Nottingham, 1986; Crawshaw & Quigley, 1991; Cascelli de Azevedo & Murray, 2007; Cavalcanti & Gese, 2009) and the maned wolf *Chrysocyon brachyurus* (20–130 km²; Dietz, 1984, 1985; de Melo et al., 2007; Jácomo et al., 2009). Our estimate is similar to the largest estimates for the African wild dog *Lycaon pictus* (210–830 km²; Woodroffe, 2011). African wild dogs usually live in packs that are similar in size to those of bush dogs (3–15 individuals; Woodroffe, 2011) but they have larger body sizes (18–36 kg; Sillero-Zubiri et al., 2004) and therefore one would expect that packs of bush dogs would have smaller home ranges.

There is evidence that the large home range of the bush dog pack we studied may be related to the limited area of native habitat, although we acknowledge that inferences from our results are weakened by our sample size of one. In a previous study of bush dogs in a nearby region (Nova Xavantina, Mato Grosso) we estimated the home range of a pack to be c. 140 km² (fixed-kernel 95%; 3–7 individuals tracked for 13 months; Lima et al., 2012). For a better comparison between the two estimates, we estimated the home range of the Água Boa pack for the same period (July 2008– July 2009; 702.2 km²; Table 1). We also corrected our estimate by the number of individuals (70.2 km² per individual in Água Boa and 3–7 individuals), assuming that home range increases linearly with the number of individuals in a pack. With the corrected estimate, the home range of the Água Boa pack is still 1.5 to 3.5 times that of the pack from Nova Xavantina (210–490 km² vs 140 km²), considering the same period and number of individuals in both packs. The difference in the amount of native habitat remaining in the two areas may explain the differences in home range sizes. In Nova Xavantina 86% of the area comprises native savannah and forest, whereas in Água Boa only 34% of the area comprises native habitats. Both packs preferentially used native habitats (either forest or savannah) and avoided cultivated land. In our study most records of the pack in cultivated land indicated they were passing through quickly, whereas in the forest and savannah they were foraging, eating or resting. These results suggest that

the bush dogs from eastern Mato Grosso adjust the size of their home range depending on the availability of native habitat.

It is important to note that towards the end of the study of Lima et al. (2012) three of the seven animals developed hair loss and eventually died (the events suggest the deaths were related to hair loss but parasitological analyses were inconclusive). Hence the smaller home range of the Nova Xavantina pack may have been a result of illness affecting their movement. However, complementary analyses of daily distance moved, and our own observations of both packs, do not support this hypothesis. Both packs behaved and moved similarly, covering similar distances every day (Nova Xavantina: median daily distance = 1,124 m; Água Boa: median daily distance = 974 m), using the same habitat types, and killing armadillos at the same rate (on average, every other day), and therefore we believe that the spatial comparison between the two packs is valid. The main difference in the movements of the packs was that the Nova Xavantina pack returned to a central area every 2 months (Lima et al., 2012; Fig. 3) whereas the Água Boa pack used areas on a rotating basis (Fig. 1), possibly because resources are more widespread spatially in the Água Boa region.

Studies of space utilization and habitat fragmentation show that some mammals respond to fragmentation by reducing their home range (e.g. Eurasian red squirrels, Verbeylen et al., 2009; European pine martens, Mergey et al., 2011) and others by home range expansion (e.g. bobcats, Tucker et al., 2008; raccoons, Beasley & Rhodes, 2010). Our findings indicate that the bush dogs in Água Boa are in the second category and expand their home range in response to a decrease in availability of native habitat. This is probably attributable to the high structural connectivity in the area (sensu Tischendorf & Fahrig, 2000), with 80% of the remaining native habitat connected in a single patch. It has been shown that in landscapes with < 50% of native habitat remaining, connectivity becomes increasingly important for persistence of more sensitive species in the remaining patches (Martensen et al., 2008, 2012). Our results suggest that the persistence of bush dogs in our study area may be attributable to the structural connectivity between patches of native vegetation.

The pack displayed a pattern of rotational use of areas, or semi-nomadic movement (Fig. 1). Information about seasonal movement in mammals is usually associated with seasonal migration (sensu Berger, 2004) between two discrete areas not used at other times of the year. Tropical and temperate ungulates are known to make seasonal migrations associated with changes in water and food supply (Mduma et al., 1999; Ferguson & Elkie, 2004). Marine mammals (e.g. cetaceans) also migrate seasonally (Mackintosh, 1966; Branch et al., 2007). Wolves *Canis lupus* are known to follow migratory caribou *Rangifer tarandus* if abundance of moose *Alces*

alces becomes critically low (Ballard et al., 1997). However, to the best of our knowledge yearly rotational movements, such as those reported here and in Lima et al. (2012), have not been reported for any other mammalian species.

The Brazilian Parliament has passed a bill to reduce the percentage of areas to be preserved in private landholdings (Brazilian Conservation Act no. 12.651/2012). Our study indicates this may negatively affect bush dog populations by increasing their spatial requirements. Expansion of the bush dog's home range in human-modified environments may have other negative effects, such as increased exposure to human-related diseases (Jorge et al., 2007a,b; Lima et al., 2009) and lower probability of successful dispersal of subadults. These issues still need to be addressed.

Acknowledgements

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