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Spatial behaviour and food choice of the Garden Warbler *Sylvia borin* during the non-breeding season

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Information regarding the spatial behaviour of migratory bird species on their wintering ground is important in understanding the factors that can influence breeding success and population size. The Garden Warbler *Sylvia borin* is a migratory species that has been well studied in West Africa. However, information regarding its spatial behaviour during the non-breeding season in sub-Saharan Africa is still limited. Consequently, we investigated the 50% and 95% kernel density home-range size and overlap as well as food choice of 10 radio-tracked Garden Warblers at Amurum, central Nigeria and Obudu, south-eastern Nigeria. Home-range overlap was estimated using the kernelUD function within the package adehabitat in R. The mean home-range was 7.0 ha and 3.3 ha at Amurum and Obudu, respectively, whereas the core of the home-range was on average 1.5 ha and 0.7 ha, respectively. Mean home-ranges were larger than the average territory of individuals on the temperate breeding grounds. Home-range overlap ranged between 19% and 57% at Amurum and 39% and 71% at Obudu, suggesting that Garden Warblers are not territorial during the non-breeding season in Nigeria. The diet of the Garden Warblers at both sites comprised of berries and insects and several individuals were often observed foraging together.

Comportement spatial et choix alimentaires chez la Fauvette des jardins *Sylvia borin* en dehors de la saison reproductive

Les informations concernant le comportement spatial des espèces d'oiseaux migrateurs sur leur territoire hivernal sont importantes pour comprendre les facteurs pouvant influencer le succès reproducteur et la taille des populations. La Fauvette des jardins *Sylvia borin* est une espèce migratoire largement étudiée en Afrique de l'ouest. Cependant, les informations concernant le comportement spatial de cette espèce en dehors de sa période de reproduction sont limitées en Afrique subsaharienne. Par conséquent, nous nous sommes intéressés au estimations de densités par le noyau à 50 % et 95 % de la taille et du chevauchement du domaine vital, ainsi qu'aux choix alimentaires de dix Fauvettes des jardins radio monitorées dans le centre et le sud-est du Nigeria, à Amurum et Obudu respectivement. Le chevauchement de l'aire vitale a été déterminé avec la fonction kernelUD du package adehabitat du logiciel R. L'aire vitale moyenne est de 7,0 ha à Amurum et de 3,3 ha à Obudu, tandis que le cœur de l'aire vitale est en moyenne de 1,5 ha et 0,7 ha respectivement. Les domaines vitaux moyens étaient supérieurs à la taille moyenne du territoire des individus sur les zones de reproduction tempérées. Le chevauchement des aires vitales va de 19 % à 57 % à Amurum et de 39 % à 71 % à Obudu, suggérant qu'au Nigeria les Fauvettes des jardins ne sont pas territoriales en dehors de leur saison de reproduction. Sur les deux sites le régime des Fauvettes des jardins comprenait des baies et des insectes et il était fréquent d'observer de nombreux individus fourrageant ensemble.

Keywords: diet, Garden Warbler, home-range, home range overlap, kernel density, spatial behaviour, utilisation distribution

Introduction

Every year billions of migrant birds depart their breeding grounds to wintering grounds in sub-Saharan Africa (Hahn et al. 2009). Many migrants from Central and Western Europe winter in West Africa (cf. Bairlein 1985). Although the number of studies focusing on the winter ecology of migrant birds in their West African winter quarters is increasing (e.g. Bensch et al. 1991; Morel and Morel 1992; Salewski et al. 2002; Ottosson et al. 2005; Bayly and Rumsey 2010; Iwajomo et al. 2011; Barshep et al. 2012), the number of studies are still relatively few when compared with studies conducted on breeding grounds. Generally, the conditions to which migrants are exposed during the non-breeding season can have carry over effects on breeding success and consequently population size (Newton 2004; Sanderson et al. 2006). Hence knowledge about the behaviour of migrant bird species

on their wintering ground and stopover sites is vital to our understanding of factors that drive population change.

The Garden Warbler *Sylvia borin* is a species that breeds in the Western Palaearctic and winters over a wide range of areas in eastern, western and southern Africa (Urban et al. 1997; Ryabitsev 2001; Wassink and Oreel 2007). Although the phenology, fuelling rate and moult of this species has been studied during its non-breeding season in West Africa (e.g. Ottosson et al. 2005; Smith 2007; Bayly and Rumsey 2010; Iwajomo et al. 2011), information regarding its spatial behaviour is still lacking. The species has been reported to feed nestlings with a predominantly insect diet, although occasionally supplementing the diet with fruits (e.g. Bairlein 1990). During pre-migration and migration, fruits form a major part of its diet, although fruit consumption is strongly influenced by its availability (e.g. Jordano 1988; Eggers 2000). This habit of frugivory continues even on the wintering grounds in sub-Saharan Africa (del Hoyo et al. 2006).

Within Nigeria, Garden Warblers have been shown to migrate through the Sahel region (north-eastern Nigeria; Ottosson et al. 2005), Guinea savanna (central Nigeria; Smith 1965, 1966; Ottosson et al. 2005) and the montane forest of the Obudu Plateau (south-eastern Nigeria; Iwajomo et al. 2011). This itinerant behaviour would require adaptations for maximising resource opportunities in different habitats. Considering that the vegetation composition and structure in the Sahel, Guinea savanna and montane forest of Nigeria differ, it is not known if Garden Warblers adjust their spatial behaviour as they migrate through these different habitat types that possibly have different feeding opportunities. In this study, we used radio-tracking to investigate the size and overlap of home-ranges in Garden Warblers trapped at central and south-eastern Nigeria during the non-breeding season. In addition, we investigated the food choice of Garden Warblers at the two sites through macroscopic and microscopic analysis of faecal samples.

Materials and methods

Study sites

This study was conducted at two sites: Amurum Forest Reserve, central Nigeria (9°53′ N, 8°59′ E) and Becheve Nature Reserve, Obudu, south-eastern Nigeria (6°25′ N, 9°22′ E) within the periods 19 October–15 November 2011 and 1–22 December 2011, respectively. Both sites are protected Important Bird Areas and serve as stopover sites for the Garden Warbler during the non-breeding season in Nigeria (Ottosson et al. 2005; Iwajomo et al. 2011). Becheve Nature Reserve (hereafter BNR; c. 70 ha) is located at an altitude of 1 500 m on the Obudu Plateau, a western extension of the Cameroon highlands (Borrow and Demey 2001). The BNR comprises fragments of montane forests, regenerating forests and montane grassland. On the other hand, Amurum Forest Reserve (hereafter Amurum; c. 300 ha) comprises granitic outcrops in dry scrub savanna interspersed with gallery forests and patches of grassland (Ezealor 2001).

Radio-tracking

At both sites, Garden Warblers were trapped using a combination of playback and mist nests and fitted with LB-2X radio transmitters for Warblers (weight 0.31 g, battery life 21 d; Holohil Systems, Carp, Ontario, Canada). Feathers were trimmed from a small area about 1 cm × 1 cm, below the interscapular region, and then the transmitter was glued to this area using LashGrip Eyelash Adhesive®, which does not cause skin irritation. The location of each individual was sought twice daily using a Biotrack® SIKA Radio-tracking receiver attached to a Yagi Antenna and then the position was marked using a Garmin GPS (GPSMAP® 60Cx). We tracked the individuals for as long as the batteries lasted. On some occasions, the location of an individual was obtained by triangulating the signals from the receiver. A total of 16 individuals (comprising seven adults and nine first-year birds) were tagged at Amurum, whereas 10 (comprising nine first-year birds and one adult) were tagged at BNR. Of this number, seven individuals were successfully located and tracked at Amurum and three individuals at BNR (Table 1). At Amurum one bird was retrapped three weeks after it was first trapped, its transmitter was still attached but not working. Hence, the number of individuals successfully tracked may be because some of the transmitters failed or that the birds were already in transit when trapped.

Home-range size and overlap has been shown to depend on the number of fixes. For kernel estimates based on least square cross-validation (LSCV), Seaman et al. (1999) suggested a minimum of 30 positions. Kenward (2001) however, considers 10–30 positions as adequate for home-range size to stabilise. Consequently, in this study, we only included individuals that had at least 10 GPS fixes in analyses.

Food choice

Faecal samples were collected from all individuals trapped at Amurum ($n = 17$) and BNR ($n = 27$) during the mist-netting sessions. Individuals were extracted from the mist nets and kept in bird bags prior to being ringed and processed for biometric information. To avoid contamination and also to ensure that the samples collected were independent, birds extracted from the nets were always kept in clean bird bags. The faecal materials from each individual were stored in sample bottles containing 70% ethanol and then transferred to the laboratory for macroscopic and microscopic inspection. Faecal material was poured into a Petri dish containing a small amount of 70% alcohol and stirred gently with a pair of forceps or dissecting needles to break up large clots. Care was taken so that the samples did not become saturated enough to cause motion when the dish was moved, neither was it left to dry out completely. A small quantity of water was added to the sample in the Petri dish, so that it became less cloudy and clear enough for effective scanning. Visual inspection was used to identify macroscopic prey items from faeces. As a means of identifying possible fruits fed upon by the species, we collected fruits from fruiting plants and trees at both sites. The fruits were carefully hand-crushed to reveal their seeds and thereafter we compared seeds from samples collected with those from fruiting plants and trees within the habitat. Microscopic inspection was done using a dissecting microscope with 10× magnification. Arthropod parts were identified to order or family level where possible using the identification keys described by Borror and White

(1970), Skaife (1979), Castner (2000) and Shattuck (2000). Following Deloria-Sheffield et al. (2001), we calculated the percentage occurrence of each arthropod taxon by dividing the number of samples in which an order was observed by the total number of samples examined.

Statistical analysis

Statistical analyses were carried out in R 2.15.0 (R Development Core Team 2012) and Excel 2007. We estimated the utilisation distribution of the individuals using the kernelUD function within the package adehabitat (Calange 2006) in R while using LSCV as the value for the smoothing parameter *h*. The home-range estimates were derived based on 50% and 95% kernel densities. Estimates derived based on the LSCV have been shown to have less bias compared with those for which the smoothing parameter was set at the *ad hoc* value href (e.g. Seaman and Powell 1996; Seaman et al. 1999). Thereafter we used the kerneloverlaphr function (Fieberg and Kochanny 2005) to derive estimates of the home-range overlaps and from this we calculated the average overlap for each individual. Homogeneity of variances of data from the two sites was tested using Bartlett's test. Thereafter we used a *t*-test for between-site comparisons of the home-range estimates.

Results

Home-range size

The average 95% kernel density home-range of Garden Warblers tracked at Amurum was 7.0 ha (range 2.9–14.4; $n = 7$; Figure 1, Table 1), whereas at BNR it was 3.3 ha (range 2.0–5.0 ha, $n = 3$; Figure 2, Table 1). The mean

Table 1: Home-range sizes (ha) of Garden Warblers radio-tracked at Amurum Forest Reserve, central Nigeria and Becheve Nature Reserve (BNR), Obudu, south-eastern Nigeria. Estimates are based on 95% kernel density for seven birds at Amurum and three at BNR. Average pair-wise overlap (%) is also provided

Amurum Forest Reserve				Becheve Nature Reserve			
Individual	Home-range size (ha)	Number of fixes	Average overlap (%)	Individual	Home-range size (ha)	Number of fixes	Average overlap (%)
1	9.9	12	39	1	2.8	28	58
2	4.6	18	49	2	5.0	22	39
3	3.0	16	19	3	2.0	49	71
4	14.4	18	26				
5	9.4	17	39				
6	2.9	16	54				
7	4.7	13	57				

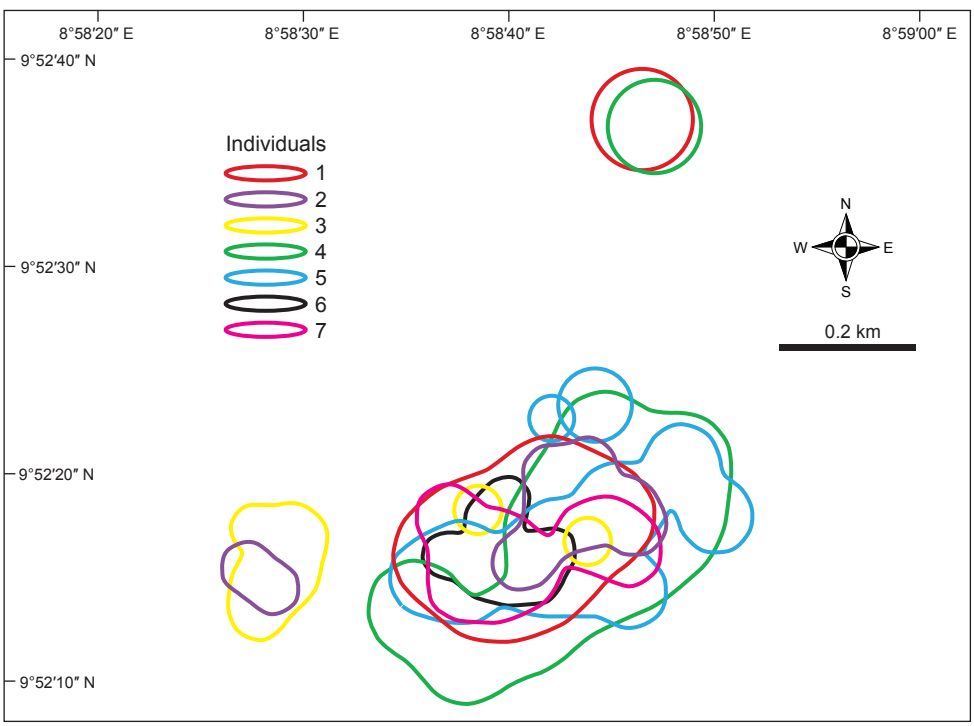

Figure 1: Home-ranges (based on 95% kernel density) of Garden Warblers radio-tracked at Amurum Forest Reserve, central Nigeria ($n = 7$). Individuals with less than 10 GPS fixes were excluded

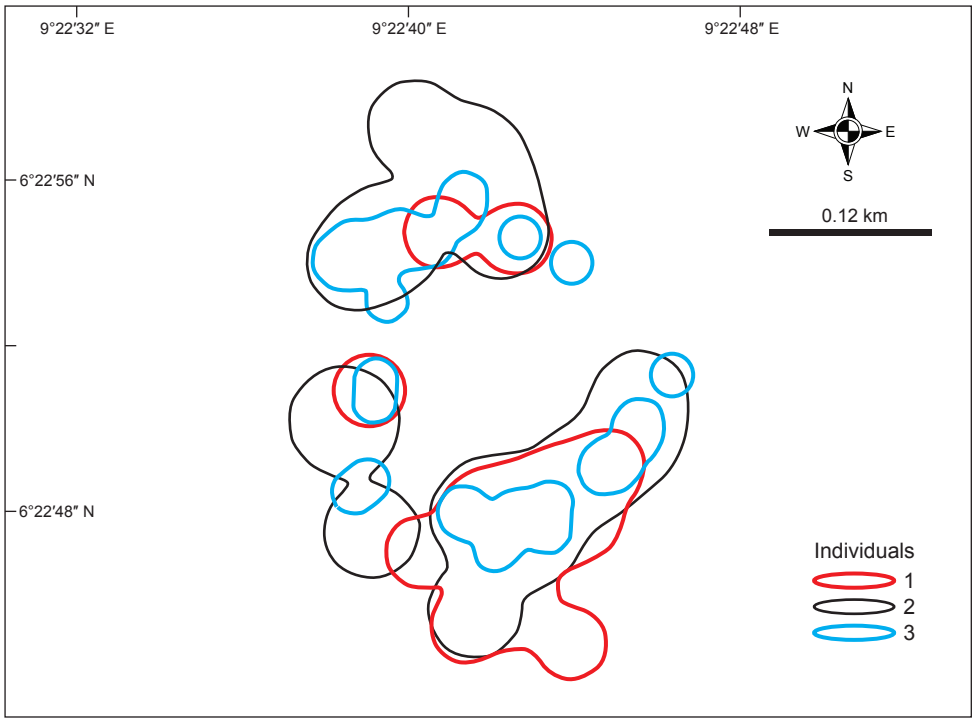

Figure 2: Home-ranges (based on 95% Kernel density) of Garden Warblers radio-tracked at Becheve Nature Reserve, Obudu, south-eastern Nigeria ($n = 3$). Individuals with less than 10 GPS fixes were excluded

home-range did not differ significantly between the two sites (*t*-test; $t = 1.97$, df = 8, $p = 0.084$). The mean home-range pooled for both sites was 5.8 ha (SD 4.0). The core of the home-range was also larger for birds tracked in Amurum (mean 50% kernel density home-range 1.5 ha, range 0.7–2.9 ha) than at BNR (mean 0.7 ha, range 0.4–1.2 ha) but the difference was not significant (*t*-test; $t = 1.44$, df = 8, $p = 0.189$). On average the core of the home-ranges pooled for both sites was 1.2 ha. There was considerable overlap in the home-ranges of our study individuals (Table 1). The average pair-wise overlapping home-range for individual Garden Warblers was smaller at Amurum than in BNR (54% and 76%, respectively) but the difference was not significant (*t*-test; $p = 0.17$, $n = 7$ and 3 at Amurum and BNR, respectively).

Food choice

Visual inspection of faecal samples revealed the presence of seeds in 13 of the 17 samples collected at Amurum and 20 of the 27 samples collected at BNR (Figure 3). The seeds were compared with seeds from fruiting plants and trees from each site. We identified the seeds to be those of *Lantana camara* (for samples collected at Amurum) and *Psychotria succulenta* (for samples collected at BNR). In addition, we identified four orders and seven families of arthropods (Table 2) from analysis of faecal materials. The Hymenoptera taxon was the most frequently observed and comprised 80% and 40% of samples collected at Amurum and BNR, respectively. We were unable to identify some of the prey items in the samples and these were found in 29% and 15% of the samples examined at Amurum and BNR,

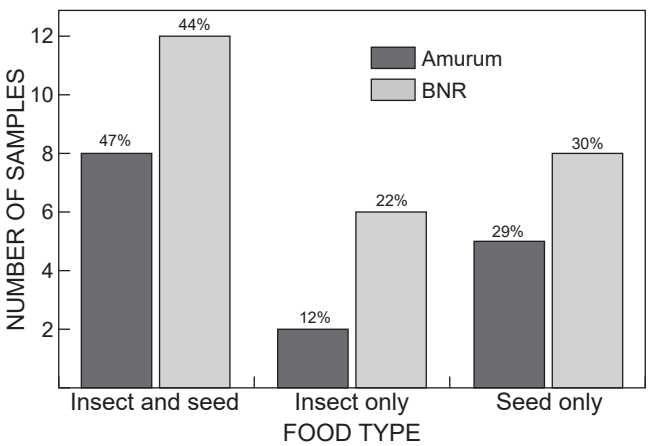

Figure 3: Number and percentage of Garden Warbler faecal samples containing insects only, insect parts and seeds, or seeds only at Amurum Forest Reserve, central Nigeria and Becheve Nature Reserve (BNR), Obudu, south-eastern Nigeria

respectively. Samples from a few individuals contained only seeds (two individuals from Amurum and three from BNR).

Discussion

The size of a home-range varies within species and also with the available food resources, mode of food collection, body size and metabolic needs of the species or individual (Smith and Smith 2006). Accordingly, variations

Table 2: Arthropods taxa identified from 17 and 27 Garden Warblers Sylvia borin trapped at Amurum Forest Reserve, central Nigeria and Becheve Nature Reserve, Obudu, south-eastern Nigeria

Order	Family	Amurum Forest Reserve		Becheve Nature Reserve	
		Number of samples	Percentage occurrence (%)	Number of samples	Percentage occurrence (%)
Coleoptera	Curculionidae			2	7
	Coccinellidae	1	6		
	Cantharidae			1	4
	Unknown			4	15
Hymenoptera	Formicidae	12	71	11	41
	Chalcidoidae			1	4
	Cynipidae	1	6		
	Unknown	1	6		
Homoptera	Cicadidae			1	4
Hemiptera	Unknown			1	4
Unknown		5	29	4	15

in the spatial and temporal distribution of food would result in variations in the size of home-range. The mean estimated home-ranges as well as the size of the core of the home-ranges of Garden Warblers at the two study sites were not significantly different. Territory sizes on the breeding grounds were in the range 0.19–0.85 ha in southern Sweden and 0.6 ha on average in Wytham, UK (Cody 1978; Garcia 1981), considerably smaller than the home-ranges estimated here. However, home-range sizes might be considerably larger than territory sizes also on the breeding grounds.

Furthermore, the home-range of most individuals overlapped with one another to varying extents. This suggests the absence of established territories unlike the situation on the breeding ground. Although the number of birds tracked, especially at BNR, were few, we opine that the home-ranges obtained in the study gives insight into how much space the species utilises during the non-breeding season. Considering also the extent of overlap in the home-ranges, we conclude that the level of interactions between individuals is high and establishment and defence of territories may not occur on non-breeding grounds.

Foraging interactions

While tracking radio-tagged individuals, several Garden Warblers were observed foraging together during most of our observations. Fransson et al. (2008) have also reported this behaviour in autumn-migrating Garden Warblers prior to the desert crossing in Greece. Although on a few occasions some individuals were displaced or chased by others, it is unlikely that the behaviour was due to territory defence. During this study, Garden Warblers were additionally observed foraging with bird species such as the Blackcap *Sylvia atricapilla* and Willow Warbler *Phylloscopus trochilus*. During these encounters there was no aggression from either species. On two occasions we observed interspecific aggression; Garden Warblers were chased by Common Nightingale *Luscinia megarhynchos*, and a male Blackcap. On another occasion, a Mountain Robin-chat *Cossypha isabellae* displaced a Garden Warbler on a tree before the latter flew away. Competition for space has been shown to exist between Blackcaps and Garden Warblers on their breeding grounds, with the former often intruding into the territory of the latter (Garcia 1983). Perhaps this explains the aggressive encounter we recorded between a male Blackcap and Garden Warblers.

Diet analyses

Analysis of remains of food items from the droppings of captured Garden Warblers revealed that the species fed on both arthropods and berries. The Hymenoptera taxon (formicid ants) was the most common arthropod prey at both sites. Laursen (1978) reported that the Homoptera and Lepidoptera taxa formed a major portion of the diet of spring migrating Garden Warblers on the Island of Hjelm, Denmark. Insectivory has been shown to be common during the breeding season, particularly among adult Garden Warblers (Eggers 2000), but a shift towards a predominantly frugivorous diet occurs during autumn migration (Thomas 1979; Jordano 1988). At both sites, Garden Warblers seemed to take advantage of the availability of fruiting trees and shrubs. Vegetable materials other than fruits have also been shown to form part of the diet of Garden Warblers on their spring migration, although this is thought to have been ingested along with arthropod prey (Laursen 1978). Hence, we speculate that some of the unidentified food items we recorded may be vegetable materials.

While it appears that fruits form the dominant component of the diet of Garden Warblers in the two study sites, it is possible that some prey items may have been completely digested and so were absent in the faecal samples. For example, our study was conducted at the end of the rainy season when it is possible that some arthropods, particularly their larvae, may be less abundant than during the peak of the rains. This could potentially result in a greater representation of adult arthropods than their larvae in the diet analysis considering that the appendages and exoskeletons of adults make them less digestible than soft-bodied larvae. The fruits of *Lantana camara* and *Psychotria succulenta* consist of a single seed surrounded by a fleshy pulp, so that the number of fruits consumed by an individual may be estimated from its faeces. However, counts of animal versus plant food items may not be reflective of food preference. This is due to the relative

difference in digestibility of the two categories of food items. Furthermore, a bird that consumes relatively more soft-bodied insects than berries may still have relatively more seeds in its droppings.

Studies have shown that during migration, fat accumulation and the oxidisation of proteins play an important role in body mass increase (Lindström and Piersma 1993; Bauchinger and Biebach 1998). Bairlein (1991a) showed that Garden Warblers fed *ad libitum* with experimental diets showed preference for diets rich in long-chain unsaturated fatty acids (C_{18}), which form a major composition of plant lipids (see Bairlein 1998). Furthermore, it has been shown that the rate of mass gain was higher in birds that fed on a combination of insects and fruits diet than on purely fruits (Thomas 1979; Bairlein 1991a, 1991b). It seems, therefore, that even on the non-breeding grounds, a combination of insectivory and frugivory may be an optimal foraging behaviour for this species.

In conclusion, this study shows that on the non-breeding ground, Garden Warblers do not establish and defend territories. Also during this period, the foraging habit of this species includes insectivory and frugivory, which is similar to the diet of individuals on the breeding ground as well as during post-breeding migration.

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