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Home Range and Habitat Use of the Moustached Warbler (*Acrocephalus melanopogon*) during the Reproductive Period in the Eastern Iberian Peninsula

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Abstract

Many populations of the Moustached Warbler (*Acrocephalus melanopogon*) have suffered a noticeable decrease over the last decades. This work has the aim of estimating the home range of the Moustached Warbler and its habitat use during the reproductive season. We captured 11 males during the reproductive period with mist nets and marked them with radio transmitters. We determined the home range by calculating minimum convex polygon and kernel areas at 95% (home range) and 50% (core area). Then, to study the habitat use, we registered the proportion of the different vegetation types within these areas and carried out a compositional analysis to investigate if there is a detectable habitat preference. The results seem to indicate that the marked individuals did not show territorial behavior, given that the overlaps between home ranges and also the core areas were over 70%. The compositional analysis showed that *A. melanopogon* prefers tall and short reeds and mixed vegetation with rushes and bulrushes. Thus, maintaining heterogeneous and stratified vegetation would favor this species.

Keywords

Compositional Analysis, Core Area, Radio Tracking, Reproduction, Spain, Vegetation, Wetlands

1. Introduction

Nowadays, we see more and more the importance of wetlands as part of ecosys-

tems, as they offer a great number of ecological services [1]. The term "wetland" groups a large variety of aquatic environments, like marshes, swamps, bogs, or surfaces covered with water independently of it being natural or artificial, permanent or temporary, stagnant or fluent, fresh, brackish or salt water, including sea areas where the water depth on low tide does not exceed six meters [2]. Wetlands are among the most productive ecosystems. The high input of water and sediment allows them to maintain a high primary production rate [3] [4]. Between terrestrial and aquatic ecosystems, they present a great diversity of organisms, some of which are exclusive to these environments [5]. For birds, these ecosystems play a fundamental role as resting and feeding points during their long- and short-distance migrations, or during juvenile dispersal [6]. Therefore, it is especially interesting to periodically obtain data from passerine birds in these areas.

The Moustached Warbler (*A. melanopogon*) is a medium-sized passerine (about 16 cm wingspan and 12 g weight); the coloration is mainly brown with a remarked white eyelash (Figure 1). It is a wetland passerine with scattered and fragmented populations associated with coastal wetlands, river deltas, and some continental lagoons or lakes across the Eurasian region [7]. In Europe, this species is a resident or short-distance migrant [8] [9]. For instance, reproductive populations from the Neudsiedler Lake and Camarga marshes winter in wetlands located in Serbia, Bosnia, Italy and the Mediterranean coast of the Iberian Peninsula. Spanish (Iberian and Balearic) reproductive populations present a more sedentary character, with high philopatry [9] [10] and short-distance movements related to juvenile dispersal or during the reproduction period between Spanish Mediterranean wetland systems [7] [10].

The term "home range" is widely used in ecological studies and it can be described as the territory an animal inhabits, where it moves to satisfy its needs

Figure 1. Photograph of the study species (*A. melanopogon*). Photographed by Robby Drechsler.

and which it potentially defends from other individuals of the same species [11]. The Moustached Warbler is a more habitat-selective species than other *Acrocephalus* species with which it cohabits. Males of *A. melanopogon* construct a nest between 30 - 60 cm above the water level in areas with dense reed vegetation [12]. Its presence is associated with marshy vegetation with open areas and clean water (small reed isles, canals of old rice fields, etc.). The term "habitat use" can be described as how an organism uses the resources of the area, for example, when feeding or looking for shelter. Therefore, there can be more than one category of use within the same area, which can also vary in time (seasonality) and space (spatial heterogeneity) [13]. The habitat selection of an individual involves a series of inborn and learned decisions [14] [15]. In the case of the Moustached Warbler, this selection is possibly related to the feeding habits of the species as it tends to capture insects near the water surface [16]. It avoids large monospecific reeds and inhabits areas with more heterogeneous vegetation, with species like *Typha dominguensis*, *Cladium mariscus*, *Juncus* sp. or *Scirpus* sp. [7]. Several studies correlate precipitation before reproduction with the reproductive success of *A. melanopogon* because it depends on the presence of flooded areas [17]. If this does not happen, they can abandon the reproduction areas too early [17]. Furthermore, it is known that several environmental factors, including prey availability and climatic conditions, have significant effects on the breeding phenology of the species [18].

This study aims to estimate both the home range and habitat use of Iberian populations of *A. melanopogon* during the reproductive season by analyzing radio tracking data of males. Measuring the overlap between the individual home ranges and the degree of habitat similarity (*i.e.* type of vegetation cover), we intend to assess if Moustached Warbler males establish well defined territories and if they present a preference towards some habitat types.

2. Materials and Methods

The Pego-Oliva marsh is situated between Dénia, Oliva, Pego and Verger (38°52'21"N; 0°03'47"O). This wetland presents an elongated shape, parallel with the coastline, with an area of 1255 ha. The marsh originated from a bay that was filled due to clogging processes. It is a wetland with permanent water, although the water input varies seasonally. The water input has different origins: the Bullent and Racons rivers, torrents and subterranean aquifers. In addition, canal infrastructure communicates different areas of the marsh for agricultural purposes [19] [20]. The Pego-Oliva marsh is protected by different conservation figures. In 1994, it was declared Natural Park and included in the Ramsar agreement; later, it was included in the catalog of wetlands of the Valencian Community and in the Natura 2000 Network as a Site of Community Importance (SCI) and Special Protection Area (SPA).

We captured and marked 11 males of *A. melanopogon* during a reproductive season (7th of April to 17th of May 2009) using six 10 m long mist nets (60 m in

total) [21]. The sampling began at sunrise and had a duration of four hours, checking the nets every hour. We determined sex, age class, subcutaneous fat and molt state and took biometric data of each captured individual, following the criteria of Kaiser [22] and Svensson [23]. We equipped the captured individuals with radio emitters from Biotrack (single-celled PIP3) using a Rappole's leg-loop harness [24]. The weight of the harness and the emitter (0.5 g) represents about 3.8% of the mean body mass of this species (10 - 13 g) and, thus, does not hinder the marked individuals [25]. We tracked the location three times per day (morning, noon and evening) between 08/04/2009 and 17/05/2009 using a portable antenna (Lintec, flexible 3-element yagi) and a receptor (Biotrac Sika). Each emitter was programmed to a different frequency and corresponded to a different canal. The geolocation of the emitter consisted in synchronising the antennas and receptors using walkie-talkies (Talkabout T5622) to register the angle of origin of the signal (measured with a Silva compass) from two different reference points (registered with a Garmin eTrex GPS). From the coordinates of the reference points and the measured angles, we estimated the position of each individual (triangulation), with the help of the telemetric Locate III software [26] and the triangulation plug-in for QGIS. We assumed a precision of ±3 m [27].

For the locations, we divided the day into three time periods: morning (7:00-11:00 h), noon (11:00-16:00 h) and evening (16:00-21:00 h), giving enough time between measures so that tracking events can be considered random and independent from each other, thus avoiding an effect of autocorrelations between locations measured from an individual during the same day [28].

We estimated the home range of each individual with the QGIS software [29] and the AniMove plug-in. We used two methods of home range estimation: 1) the Minimum Convex Polygon (MCP) and 2) the Kernel Density Estimation (KDE) using 95% of the points and 50% of the points for the core area [27] [30] [31]. We also estimated the home range overlap of an individual as the proportion of its home range area that is shared with other individuals [32]. Finally, we used a Spearman correlation test to check if there is a significant correlation between the number of observations (n) and the size of the home range (if there is no correlation, we can assume we obtained enough data points).

As we distinguished three time periods during the day, we also analyzed if there was variation in home range size over the day. To do so we estimated the home range for each daytime period in each bird using the KDE method. Afterwards, we normalized the data by a logarithmic transformation and performed a one-way ANOVA of repeated measures. We discarded individual 9 because the number of registered points in two daily periods was too low.

As an approximation before the compositional analysis, we performed a Principal Component Analysis (PCA) to test for specific vegetation preferences. To infer habitat use (*i.e.* preference for specific vegetation types) inside the home range, we calculated the proportion of each habitat type in both the 95% and

50% areas from the KDE (we excluded the MCP estimations as they are prone to overestimations of the home range) [33]. For the analysis of habitat use, we used a vegetation map, drawn from satellite images of the Pego-Oliva marsh 2009 obtained by the GeoEye-1 satellite. We distinguished 9 habitat types based on the vegetation: short reed (*Phragmites* sp.) (SR; with 47.7% of the total surface); tall reed (TR; 33.3%); bulrush (*Typha* sp.) (BR; 0.21%); rushes (*Juncus* sp.) (RS; 1.35%); pastureland (PL; 2.9%); reed and bulrush (RAB; 0.53%); reed and rushes (RAR; 6.19%); reed and pastureland (RAP; 1.3%) and unusable habitat for birds (no use; 11.1%). This classification of habitats was used to perform a compositional analysis [34]. We compared the available habitats with those habitats that are used by the individuals in two phases [35]. First, we selected a home range randomly from the study area (second-order selection from Johnson), which was used to estimate the available habitat. Second, the habitat used by individuals was estimated from the actual home ranges estimated from our radiotracking data (third-order selection from Johnson) [35]. Both available and used habitats were characterized following two criteria: habitat composition of a central range and the distribution of the points obtained by radio tracking [34] [36]. We classified the habitats according to their relative use: if a habitat was used more frequently than expected according to its availability we categorized it as preferred [34].

For the test of the general habitat selection, we used Wilks lambda analysis, to determine the randomness or non-randomness of the birds' distribution. We estimated the differences of use between the different habitat pairs using the log-ratio coefficient $d_i = \ln(x_u/x_{ai}) - \ln(x_u/x_{aj})$ [34], where x_u is the used proportion and x_a is the available proportion for each analyzed habitat unit (*i*) and a reference habitat (*j*). In some cases of available but not used habitat units, we replaced the x_u value with 0.01 and 0.000001. As a result, we obtained 11 tables (one for each individual) with nine rows and nine columns (one for each habitat type). Each of these tables represented the habitat preference of each individual. Afterwards, we calculated the mean and standard error of each element and the relation between the mean. The standard error (t) served as a measure of the deviation from randomness, indicating preference if the values were positive and far from 0 [34]. All statistical analyses were carried out using the R software [37] and the adehabitat package [38].

3. Results

We obtained a total of 417 geographic locations of the 11 Moustached Warblers, with a mean of 37.9 observations per individual (Table 1), ranging from 7 (individual 9) to 63 (individual 6) observations. We did not observe a significant correlation between the number of observations and the size of the home range (Spearman correlation test, $\rho = -0.546$, p-value = 0.083, for KDE 95%, and $\rho = -0.561$, p = 0.073, for KDE 50%). The mean home range size using the KDE method and considering 95% of the points was 17.5 ± 4.5 ha (Figure 2), ranging
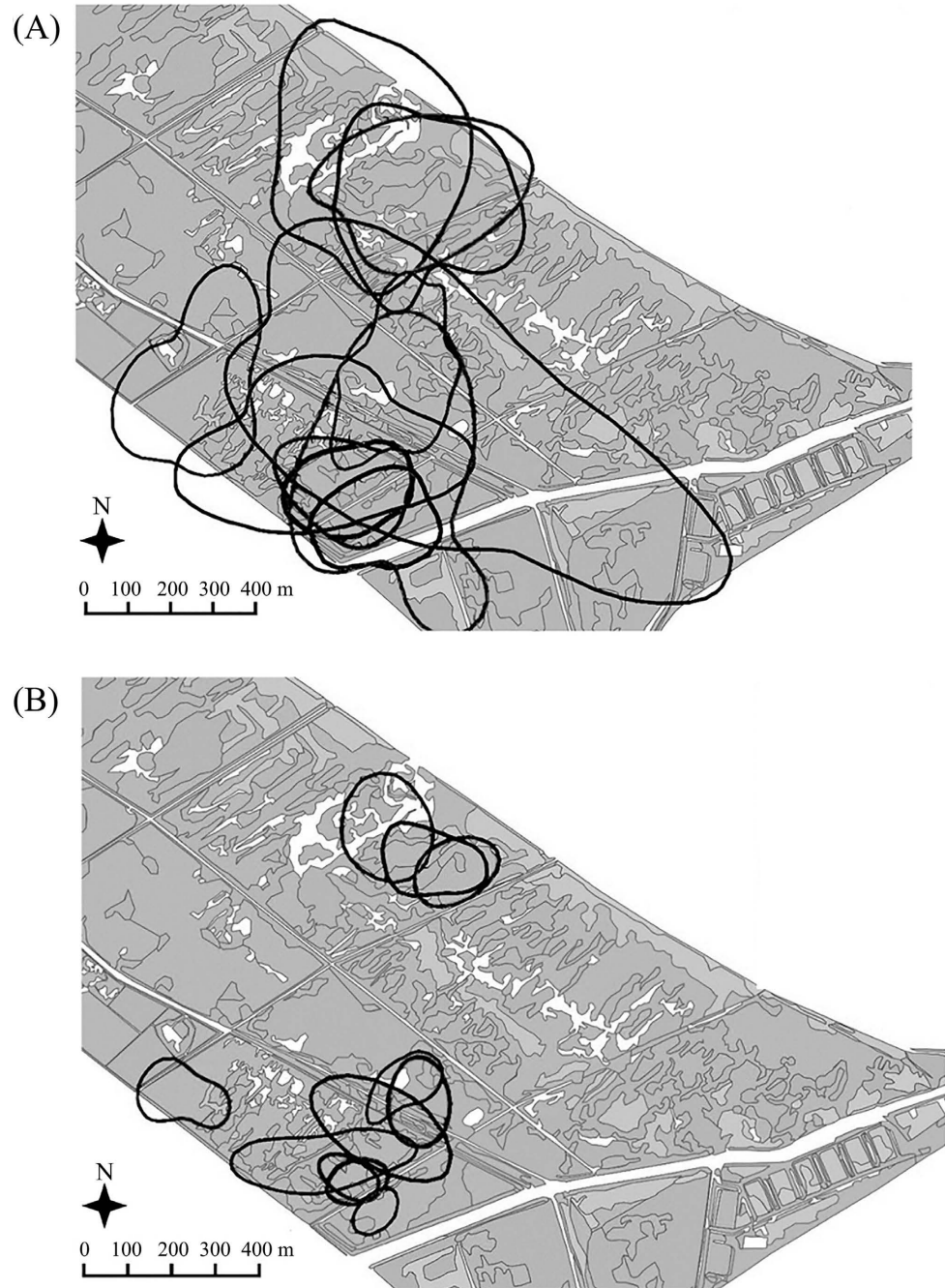
Figure 2. Representation of the KDE 95% (A) and KDE 50% (B) areas of the 11 marked males of *A. melanopogon* in the study area.

from 5.6 ha (individual 5) to 58.8 ha (individual 10). Comparing the values of the KDE 95% and the MCP (23.3 ± 4.8 ha), we did not observe significant differences (t-test for paired samples, t = 1.021; df = 10; p-value = 0.33). The values for the core areas (KDE 50%) (Table 1, Figure 2) were more similar between individuals, with a mean of 2.8 ± 0.5 ha and ranging from 0.9 ha to 5.3 ha. Home range overlap (Table 1) was 77.8% ± 5.7% for KDE 95% and 70.3% ± 8.7% for KDE 50%, reaching in some cases a total (100%) overlap (Figure 2).

Table 1. Number of observations (n), home rang size (MCP, KDE 95% and KDE 50%), home range overlap (KDE 95% and KDE 50%) and observation period for each monitored individual.

Individual	n	Home range size (ha)			Overlap (%)		Observation period
		MCP (ha)	KDE 95%	KDE 50%	KDE 95%	KDE 50%	
1	44	12.9	9.6	2.5	5.2	0.0	12/04/09-28/04/09
2	45	34.8	22.6	4.3	55.8	34.9	09/04/09-07/05/09
3	47	9.5	5.6	1.2	100.0	92.2	09/04/09-26/04/09
4	22	8.8	6.3	1.2	100.0	100.0	09/04/09-17/04/09
5	57	9.7	5.6	0.9	99.2	7.8	09/04/09-03/05/09
6	63	9.9	9.7	1.9	100.0	80.0	09/04/09-03/05/09
7	54	58.5	16.1	3.3	91.3	94.2	08/04/09-02/05/09
8	47	35.7	14.2	2.4	92.3	64.8	08/04/09-02/05/09
9	7	4.5	20.0	4.8	84.6	47.9	08/04/09-11/04/09
10	16	30.9	58.8	5.3	44.0	58.5	08/04/09-15/04/09
11	15	23.3	23.9	2.5	83.7	85.6	18/04/09-03/05/09
Mean	37.9	21.7 ± 4.9	17.5 ± 4.5	2.8 ± 0.5	77.8 ± 5.7	60.5 ± 8.5	

We did not find significant differences in home range sizes over daytime periods (ANOVA for repeated measures, p = 0.410, for KDE 95%; and p = 0.294, for KDE 50%), although we observed a slight increase in home ranges during noon.

Regarding the proportions of the different habitat types within the home ranges, all the habitat types were present in the KDE 95% areas (Figure 3); SR (44.9 [28 - 68] %) and TR (29.7 [52 - 13] %) were the most frequent habitat types, but we can also remark RAB and PL with values up to 10% and 6%, respectively. In the core (KDE 50%) areas (Figure 3), we only recorded four of the nine habitat types, mainly SR (55.6 [71.5 - 29.6] %) and TR (33.6 [59.4 - 20.1] %). In addition, a certain proportion of unusable habitat was always present in both KDE 95% and KDE 50% areas, with values up to 50% in some cases. According to the PCA results (Figure 4), the two habitats with the highest weight explaining the variance were SR and TR, which explained 92.8% of the variation between individuals of KDE 95% areas, and 99.3% of the variation of KDE 50% areas.

The comparison between the available and used vegetation (Table 2) showed a non-random use of vegetation by the Moustached Warbled (Wilks Lambda test; $\lambda = 0.000003$, p < 0.001). The habitat types SR, TR, BR and unusable habitat were the most dominant ones, in comparison to RAR, RS, RAP, PL and RAB. The four dominant habitat types did not show significant differences in use between them. According to the compositional analysis, the different vegetation types can be ordered by preference from high to low as followed: unusable, SR, TR, BR, RS, RAB, RAP, RAR and PL.
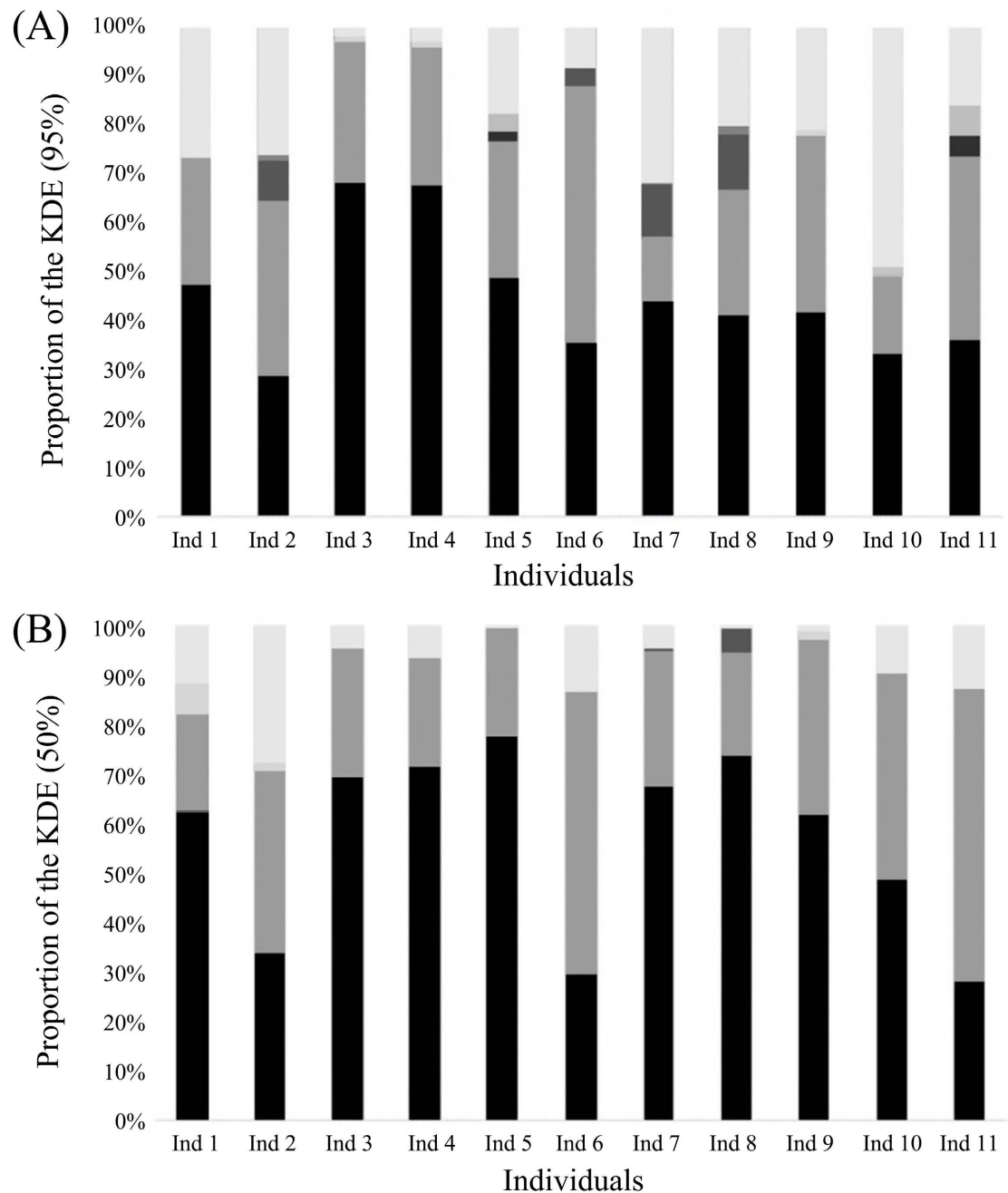
Figure 3. Proportion of the different habitat types within the KDE 95% (A) and KDE 50% (B) areas of the 11 marked males of *A. melanopogon*. The vegetation types: short reed (SR, ▇); reed and pastureland (RAP, ▇); reed and rushes (RAR, ▇); rushes (RS, ▇); tall reed (TR, ▇); pastureland (PL, ▇); reed and bulrush (RAB, ▇); bulrush (BR, ▇) and unusable habitat for the birds (no use, ▇).

The comparison of the available vegetation in the KDE 95% with KDE 50% areas (Table 2) also showed a non-random use of the vegetation (Wilks Lambda test; $\lambda = 0.0004$, p < 0.001). In this case, SR and TR were the most dominant habitats, selected over PL, RS, RAR and RAP, with BR the least selected habitat. The dominant vegetation types did not show significant differences in use between them. The unusable habitat had in this case less preference for use than SR
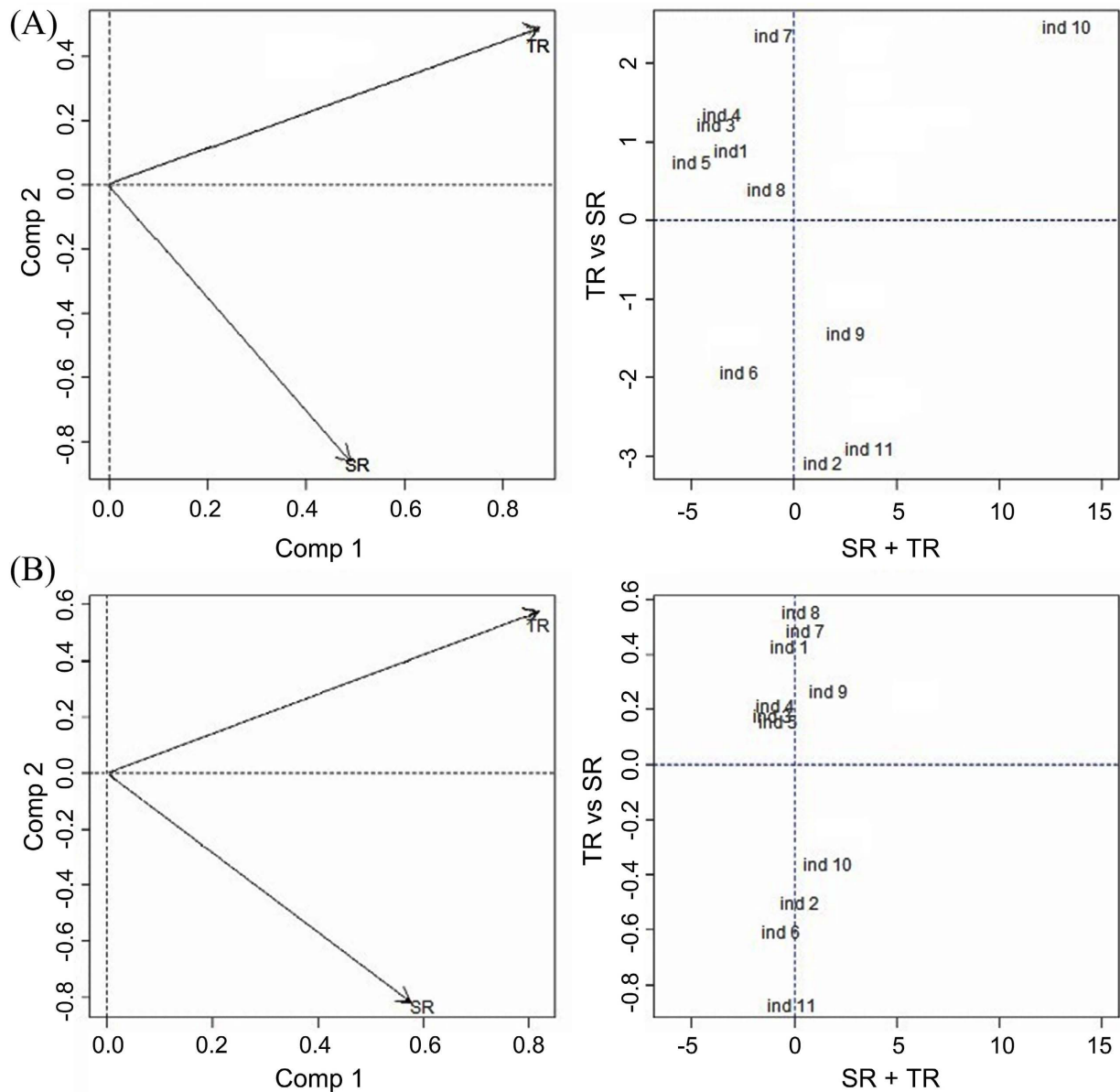
Figure 4. Results of the principal component analysis with the used habitat types for the KDE 95% (A) and the KDE 50% (B). Vegetation types: short reed (SR) and tall reed (TR). The individuals 1, 3, 4, 5, 7 and 8 in **Figure 3(A)** are grouped selecting SR over TR, although in **Figure 3(B)** all individuals are aligned on the SR + TR axis, using SR and TR similarly.

and TR, but more than the other habitat types. According to the compositional analysis, the different vegetation types can be ordered by preference from high to low as followed: SR, TR, unusable, RAB, RAP, RAR, RS, PL and BR.

Finally, the comparison between the available hábitats in the KDE 95% areas and the location points from the radio tracking (Table 2) also showed a non-random use of the different habitat types (Wilks Lambda test; $\lambda < 0.001$, $p < 0.001$). In this case, SR and TR are dominant over PL and RS, and BR and unusable areas the least used habitats. According to the analysis, the different vegetation types can be ordered by preference from high to low as followed: RAR, TR, ST, RAB, RAP, RS, PL and unusable.

Table 2. Compositional analysis comparing the total available vegetation with the used vegetation in the KDE 95% areas and the KDE 50% areas and comparing the total vegetation of both KDE areas. We extracted the differences between means from the log-ratio coefficient register and analysed them with a one-way t-test for paired samples (with df = 7). Significance is indicated by asterisks: p-value < 0.01 (*). Vegetation types: Short Reed (SR); Tall Reed (TR); Bulrush (BR); Rushes (RS); Pastureland (PL); Reed and Bulrush (RAB); Reed and Rushes (RAR); Reed and Pastureland (RAP) and unusable habitat for the birds (no use).

KDE 95%	No use	RAB	PL	RAP	RS	RAR	BR	TR	SR
SR	−0.459	7.574*	5.224*	5.476*	5.066*	3.722*	0.678	1.330	0.000
TR	−1.000	6.636*	5.034*	5.348*	4.627*	3.603*	0.205	0.000	
BR	−0.758	4.962*	3.508*	3.563*	3.994*	2.916*	0.000		
RAR	−4.342*	−0.252	0.165	−0.029	−0.646	0.000			
RS	−6.478*	0.123	0.567	0.301	0.000				
RAP	−5.573*	−0.286	0.938	0.000					
PL	−5.704*	−0.629	0.000						
RAB	−8.748*	0.000							
No use	0.000								

KDE 50%	No use	RAB	PL	RAP	RS	RAR	BR	TR	SR
SR	2.184*	1.145	2.444*	2.015*	2.429*	2.287*	3.053*	0.612	0.000
TR	2.213*	1.016	2.378*	1.911*	2.363*	2.166*	2.928*	0.000	
BR	−2.301*	−2.307*	−0.520	−1.014	−0.592	−0.636	0.000		
RAR	−1.480	−1.563	0.233	−0.222	0.261	0.000			
RS	−1.942*	−1.770	0.062	−0.400	0.000				
RAP	−1.408	−1.235	1.289	0.000					
PL	−2.074*	−1.804	0.000						
RAB	−0.164	0.000							
No use	0.000								

KDE 95% vs KDE 50%	No use	RAB	PL	RAP	RS	RAR	BR	TR	SR
SR	41.440*	1.141	2.448*	1.580	2.426*	−0.052	4.816*	−0.479	0.000
TR	47.446*	1.198	2.497*	1.580	2.479*	−0.006	4.561*	0.000	
BR	3.730*	−3.558*	−1.343	−3.011*	−1.870*	−2.638*	0.000		
RAR	8.040*	0.601	1.722	0.945	1.734	0.000			
RS	6.231*	−1.770	0.062	−0.976	0.000				
RAP	9.199*	−0.689	1.629	0.000					
PL	5.657*	−1.804	0.000						
RAB	12.808*	0.000							
No use	0.000								

4. Discussion

Arbeiter & Tegetmeyer [27] found that home ranges of a congeneric species (*A. paludicola*) increased with observation time, thus indicating insufficient time effort for home range estimations. In our case, home range size did not correlate

with the number of observations and, therefore, it can be considered sufficient. Our home range size estimations indicate that the Moustached Warbler does not move large distances during its daily routines, but we found an important variation between individuals. This variation could be explained by food availability [39]. Previous studies showed that *A. melanopogon* has a more restricted diet than other species of the genus, feeding mainly on Collembola, Ephemeroptera, Odonata, Hemiptera, Lepidoptera, Trichoptera, Diptera, Himenoptera, Coleoptera, Araneidae, Isopoda and Gasteropoda [40]. Thus, home range sizes could vary according to the availability of the different prey types [41] [42] [43]. As an alternative explanation, the Moustached Warbler may compete on the trophic level with other species of the genus, like *A. scirpaceus* [44] which may lead to home range adjustments associated with the presence of competitors. Furthermore, the diet of the Moustached Warbler changes seasonally [45] and, therefore, individuals may increase their home range during periods of food shortage until they find higher quality habitats.

Another potential explanation for the individual variation in home range size is that home ranges of the Moustached Warbler are established based on the age of the individuals because younger individuals are expelled by dominant adults. The existence of subordinate individuals could indicate that intraspecific competition is more important than previously thought, but as we were not able to measure the age of the individuals, we could not test this hypothesis [46]. However, we found that the overlap between the home ranges of the different individuals was high in both the KDE 95% and KDE 50% areas with 77.8% and 70%, respectively. Other studies classified species with a home range overlap of approximately 50% as not territorial [27]. Therefore, as our overlaps are about 20% higher, we can make the same assumption for the Moustached Warbler.

Although we did not find differences in home range size between different daytime periods, other animals showing high territorial behavior, like the Common Shrew (*Sorex araneus*), vary their home range depending on the location of resources even daily [47]. In the case of the Moustached Warbler, even if we did not observe significant changes in home range size over the day, individuals may change the location of the home range depending on where they find different resources.

Home ranges of *A. melanopogon* are dominated by short and tall reeds, followed by moderate proportions of bulrush and rushes. Vegetation height must play a fundamental role in habitat selection of *A. melanopogon*. The compositional analysis suggests that individuals prefer short reed areas; however, considering the locations from the radio tracking, the species seems to have also a remarked preference for tall reeds and mixed areas (reeds with rushes). From a management perspective, our results suggest that *A. melanopogon* would be favored by maintaining different vegetation structures in nesting and feeding areas based on vegetation height [48] [49]. Keeping vegetation heights and species diverse might increase habitat suitability for different arthropod species that are

part of the Moustached Warbler's diet [40].

Vegetation covers about 80% of the KDE 95% areas and about 91% of the KDE 50% areas; in both cases, it is mainly formed by short reed, which was preferred over the tall reed areas. This indicates that the Moustached Warbler prefers areas with dense and well-structured marsh vegetation, where it can move through [50]. Finally, it is worth mentioning that all analyzed areas had a relevant proportion of unusable habitat, despite we never found the birds in these areas. They may use the border to the vegetation to catch their prey, given that, because of the effect of the ecotones, these areas present more insects than inside the dense vegetation [51].

In conclusion, the high overlap of the home ranges indicates a non-territorial behaviour of the Moustached Warbler in our study area. We did not detect that individuals vary the size of their home ranges, but they may change the location based on resource availability. A heterogeneous and stratified vegetation might have a positive effect on habitat suitability for the Moustached Warbler.

Acknowledgements

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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