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CHARACTERISTICS OF SAND MARTIN *RIPARIA RIPARIA* COLONIES IN ARTIFICIAL RIVER WALLS

CARACTERÍSTICAS DE LAS COLONIAS DE AVIÓN ZAPADOR *RIPARIA RIPARIA* EN SUSTRATOS ARTIFICIALES

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SUMMARY.—Artificial structures play a significant role as optional breeding places for the sand martin. However, it is virtually unknown which factors determine habitat selection in these artificial sites and to what extent the species selects the same key features that it would in its natural habitat. We compared 16 variables from artificial walls with pipes in channelled rivers between walls holding ($N = 56$) or not holding ($N = 50$) a sand martin breeding colony. The presence of colonies was negatively associated with the distance of the breeding wall from the water and positively associated with flooding risk. Bibliographic data were used as a reference for the characteristics of natural breeding habitat. The sand martin selected similar key factors in artificial habitats as when breeding in a natural setting. These factors could probably be linked to limiting predator access to the colony and the occurrence of periodical rinsing episodes that may minimise parasite loads in nesting cavities.

RESUMEN.—Algunas estructuras artificiales constituyen un lugar de cría alternativo para el avión zapador. No obstante, se desconoce cuáles son los factores que explican la presencia de colonias en este tipo de hábitats artificiales y hasta qué punto son seleccionadas las mismas características que en el hábitat natural. Se comparó el valor de 16 variables en muros con tubos en tramos de río canalizados, en zonas con ($N = 56$) y sin ($N = 50$) colonias. La presencia de colonias estuvo negativamente correlacionada con la distancia al agua desde la pared donde se localizaba la colonia y positivamente correlacionada con el riesgo de inundación. Por otro lado, la bibliografía se empleó para determinar hasta qué punto la especie criaba en condiciones semejantes a cuando nidifica en un hábitat natural. Observamos que los aviones zapadores tienden a seleccionar características similares. Esto podría estar ligado a minimizar el acceso de predadores al nido y garantizar, mediante inundación, la limpieza de las cavidades que acogen el nido para minimizar la presencia de parásitos.

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INTRODUCTION

The identification of factors determining habitat selection is a priority when constructing conservation policies (Poulin *et al.*, 2002; Mildenstein *et al.*, 2005; Tanneberger *et al.*, 2009; Onorato *et al.*, 2011). Artificial habitats can be of key importance for several animal species (Moore and Robinson, 2004; Seaman, 2007; Murgui, 2009), including some that are of high conservation concern (Negro and Hiraldo, 1993; Goodman *et al.*, 2005). Artificial habitats are also likely to become increasingly important as natural habitat is lost or deteriorates. Understanding which habitat features are selected by animals when breeding is hence of great relevance in this scenario.

Breeding in artificial structures, such as holes in walls and bridges, or even in nest-boxes, is common among riparian birds (Cramp, 1988). The use of artificial breeding substrates is also documented in cavity-nesting bird species, such as the Eurasian kingfisher *Alcedo atthis* (Wechsler, 2007) and the sand martin *Riparia riparia* (Hollom, 1943; Malher, 2003). However, whereas there are multiple habitat selection studies for several riparian species breeding in natural habitat (e.g., Peris *et al.*, 1991; Peris and Rodríguez, 1996; Vilches *et al.*, 2012), they are virtually lacking where artificial breeding substrates are used.

The sand martin is a widespread Holarctic songbird that nests in colonies. These are usually situated in sandy banks, where the birds excavate holes in which to build their nests (Cramp, 1988). The colonies are normally placed close to water bodies. The species has also been reported to nest in artificial structures such as gravel or sand deposits, as well as within drainage pipes in walls channelling water bodies (Cramp, 1988). Although nesting in such structures is relatively rare compared to the use of natural habitat (typically river banks), it has been recorded since at least the first half of the 20th century (Hollom, 1943; Malher, 2003). This behaviour has allowed the sand martin to colonise new areas where the species had seldom or never bred before (Etxezarreta, 2010). This is an important development in some regions where such artificial structures are the only existing breeding habitat for the species (Etxezarreta, 2010). The occupation of these artificial sites has even been accompanied by a moderate decrease of population numbers in breeding colonies using natural sites (Tucker and Heath, 2004). Although artificial structures play a significant role in the conservation of this species in several European regions (Malher, 2003; Heneberg, 2006; Fasol, 2007; Etxezarreta, 2010), there is still a remarkable lack of knowledge of which factors determine habitat selection in these artificial sites and on the extent to which the species selects the same features that it would in a natural habitat.

Riparian cavity-nesting bird species may breed close to the water not only because of the presence of river banks but also because the presence of water below the nests may be beneficial through reducing predator access (Garrison, 1999), limiting vegetation growth on walls, and/or reducing parasite loads in nests via periodic flooding episodes (Szép and Møller, 2000), these last especially in autumn and winter, when the nest tunnels are vacant. Thus, having water below nests would also be selected under artificial conditions.

The aim of this work is to determine habitat selection at a microscale level of sand martins breeding in colonies placed in artificial structures, as well as to test whether the species selects the same features as in natural breeding habitat. We collected data in northern Iberia, where the species has a distribution conditioned by artificial structures: drainage pipes in the walls of channelled rivers. Data from such colonies were compared to data reported in the literature for colonies located in natural structures.

MATERIAL AND METHODS

The study was carried out in northern Spain, within the Cantabrian basins of Basque rivers (see Etxezarreta, 2010 for details). All rivers in the region are short (18-78 km long), highly branched, with relatively steep gradients and large flow rates resulting from the oceanic climate. Such rivers lack suitable banks for the sand martin to nest but it has colonised the region by occupying artificial structures (Etxezarreta, 2010). In particular, it breeds in drainage pipes of walls in areas where the river has been channelled (fig. 1). The mean diameter of the pipes was 9.6 ± 2.8 cm in active colonies, similar to the diameter of natural nesting-cavities (González and Villarino, 1997).

During the breeding season of 2008, both the breeding colonies and a set of other similar (but unoccupied) artificial river walls were visited to measure 16 variables that could determine habitat selection at a microscale level (table 1). Hereafter, we refer to walls where the species was nesting ($n = 56$) as “positive” points, and empty walls that presumably could host sand martin colonies ($n = 50$) are termed as “negative” points. To select the non-occupied points we mapped all the artificial walls with pipes suitable to host the studied species. Thereafter, 50 of these walls were randomly selected for the

FIG. 1.—An example of an artificial wall housing a sand martin colony (town of Elgoibar, Gipuzkoa). Drainage pipes accommodated nests (one pipe has been highlighted with an arrow).
[Ejemplo de un muro artificial con una colonia de aviones zapadores (municipio de Elgoibar, Gipuzkoa). Los nidos se situaron en tubos de drenaje (se señala uno con una flecha).]

analyses. Walls with tall vegetation cover that hence were very unlikely to host a colony (Garrison, 1999) were *a priori* discounted and thus not included as negative points. Solitary nests were absent. Some sampling points (n = 33) situated in river zones likely to host a single colony were considered as separate points (colonies) if the "colony" was situated in more than one wall.

In a first, exploratory approach, we compared the original raw data (variables) between positive and negative points using

TABLE 1

Variables measured at each sampling site (i.e. active colonies or places that could potentially house sand martin colonies). Overall, we considered 12 continuous variables and 4 categorical variables. *[Variables medidas en cada uno de los puntos de muestreo (colonias de cría o puntos –muros– que podrían albergar una colonia). En conjunto, se consideraron 12 variables continuas y 4 categóricas.]*

Variable	Code	Unit/Category
Wall orientation	WLO	degree [°]
Wall height	WLH	m
Height of nearest pipe above water	PIPPRO	m
Height of furthest pipe above water	PIPDIS	m
Wall length	WLL	m
Distance from wall to water	WALWAT	m
River width (water)	RWW	m
River width (all)	RWA	m
River slope	RSL	%
Rocks on river[1]	RRO	%
Tree cover over river[2]	RTR	%
Vegetation cover on the wall	WLV	%
Nest availability	NESTA	1 (0-2 pipes/25 m-long wall), 2 (3-5), 3 (5-10), 4 (>10)
Water below nests	NESTW	1 (water), 2 (water and solid), 3 (solid)
Flooding probability[3]	NESTF	1 (low), 2 (moderate), 3 (high), 4 (very high)
Ecological quality[4]	ECO	1 (bad), 2 (deficient), 3 (moderate), 4 (good), 5 (very good)

[1] Percentage of emergent rocks for the river stretch located in front of a colony.

[2] Percentage of tree cover over the river stretch located in front of a colony.

[3] According to the map of flooding risk in Gipuzkoa (www.uragentzia.euskadi.net), we determined the proportion (<25%, 25-50%, 50-75%, >75%) of nests/potential nests (pipes) likely to be inundated at least once in a normal hydrological year.

[4] Obtained from the web site of the Water Basque Agency, Basque Government (www.uragentzia.euskadi.net).

TABLE 2

Mean values (±SE), median and first and third quartiles for the 16 variables considered, and the corresponding statistical tests. Variables with (*) are those in which raw data were normally distributed. In these cases we used *t*-tests for comparisons and in the rest we used *U*-tests. Significant values, in bold. *[Medias (±SE), medianas y primer y tercer cuartiles para cada una de las 16 variables, así como las correspondientes pruebas estadísticas. El (*) indica las variables que se ajustaron a la distribución normal. En este caso se empleó un test de* t, *mientras que en las variables que no se ajustaron a esta distribución se empleó un test de U. En negrita se indican los valores significativos.]*

Variable	**Negative** **$n = 50$**	**Positive** **$n = 56$**	**Statistics**	***p***
WLO*	190.8 ± 14.5 181.5 (105.0-291.8)	193.2 ± 13.3 200.0 (103.5-278.0)	$t_{104} = 0.122$	0.903
WLH*	4.9 ± 0.2 5.0 (4.0-6.1)	5.0 ± 0.2 5.0 (4.4-5.7)	$t_{104} = 0.142$	0.888
PIPPRO	2.1 ± 0.4 1.1 (0.8-2.1)	1.4 ± 0.1 1.3 (1.0-1.5)	$U = 1358.5$	0.791
PIPDIS*	4.7 ± 0.6 4.0 (2.9-6.0)	3.7 ± 0.2 4.0 (2.5-4.5)	$t_{104} = 1.634$	0.105
WLL*	145.4 ± 21.1 101.5 (45.8-202.8)	133.3 ± 18.1 82.0 (35.8-176.3)	$t_{104} = 0.437$	0.663
WALWAT	2.3 ± 0.6 0.5 (0.0-3.0)	0.6 ± 0.2 0.0 (0.0-0.5)	$U = 971.0$	**0.003**
RWW*	21.3 ± 2.3 16.5 (10.0-28.3)	24.4 ± 1.6 24.5 (14.5-31.0)	$t_{104} = 1.153$	0.252
RWA*	28.3 ± 2.8 21.5 (15.0-35.8)	32.3 ± 1.8 31.0 (22.3-45.8)	$t_{104} = 1.217$	0.226
RSL	0.8 ± 0.1 0.6 (0.5-1.0)	0.8 ± 0.1 0.8 (0.5-1.0)	$U = 1305.0$	0.529
RRO*	0.17 ± 0.03 0.10 (0.00-0.25)	0.22 ± 0.02 0.15 (0.10-0.30)	$t_{104} = 1.459$	0.148
RTR*	0.12 ± 0.01 0.10 (0.05-0.20)	0.11 ± 0.1 0.10 (0.05-0.15)	$t_{104} = 0.817$	0.416
WLV	0.00 ± 0.00 0.00 (0.00-0.00)	0.00 ± 0.00 0.00 (0.00-0.00)	$U = 1237.0$	0.088
NESTA	3.3 ± 0.1 4.0 (3.0-4.0)	3.5 ± 0.1 4.0 (3.0-4.0)	$U = 1341.0$	0.678
NESTW	1.5 ± 0.1 1.5 (1.0-2.0)	1.2 ± 0.1 1.0 (1.0-1.5)	$U = 1057.0$	**0.013**
NESTF	3.0 ± 0.1 3.0 (3.0-3.3)	3.6 ± 0.1 4.0 (3.0-4.0)	$U = 723.0$	**<0.001**
ECO	1.9 ± 0.2 1.0 (1.0-3.0)	1.7 ± 0.1 1.0 (1.0-2.0)	$U = 1257.0$	0.312

t-tests (where the data fitted a normal distribution; K-S test, $p > 0.05$) or non-parametric *U*-tests (where the data did not fit a normal distribution). Secondly, in order to identify whether the species selected some characteristics to occupy a particular wall, and to predict which variables determine the presence of a sand martin colony, we conducted a stepwise (forward) logistic regression with presence of a colony as a binary response variable and habitat-related variables as predictors. Categorical variables (NDEN, NBEL, NFLO, RQT) were introduced as such into the model and the rest were standardised by their mean and variance (SD) to ensure that each predictor was on the same scale. Statistical procedures were run with SPSS 18.0; means are given ± SE.

RESULTS

From 16 variables, three (WALWAT, NESTW, NESTF) were detected to differ between positive and negative points (table 2).

The stepwise logistic regression included two variables (NESTF, WALWAT) that were useful predictors between positive and negative sampling points (Model: $\chi^2 = 32.882$, $df = 4$, $p < 0.001$; NESTF, Wald's $\chi^2 = 19.196$, $df = 3$, $p < 0.001$; WALWAT, Wald's $\chi^2 = 4.005$, $df = 1$, $p = 0.045$; Intercept, $\chi^2 = 11.062$, $df = 1$, $p = 0.001$). The colonies tended to be close to water and where the possibility of seasonal rinsing was high. The percentage of sampling points correctly classified by this function was 72.6%.

DISCUSSION

The sand martin in the Cantabrian basins of Basque rivers only nests in artificial structures, typically the drainage pipes of walls in channelled rivers (Etxezarreta, 2010). Adaptation to this new habitat reflects the sand martin's capacity to occupy artificial cavities where no suitable natural habitat exists (Suvorov *et al.*, 2011).

The probability of colony occurrence was higher for artificial sites with water below and a high flooding risk. The logistic regression revealed that both variables predicted wall occupancy by a colony in our study area with high probability (72.6%). However, there was still a significant amount of non-explained variation, which may involve such variables as thermal features and parasite load. Such variables should be explored in any future analysis.

The selection for proximity of breeding walls to water is not unexpected; it has indeed been reported in studies carried out in natural habitats, with colonies situated in river banks (e.g., Silver and Griffin, 2009). In these cases, flooding risk is directly related to erosion and a bank that does not become eroded can collapse within only 2-3 years, hence allowing vegetation to grow, predators to enter and nests to be destroyed, which can cause a serious decrease in breeding success (Garrison, 1999) or promote the abandonment of a colony (Freer, 1979). Although artificial colonies in a containment wall are not subject to the same risk of collapse as earth banks, they too can be overgrown and thus become more accessible to predators if there is no water below the nests. The presence of vegetation on a breeding wall (or bank) is considered to be one of the main causes of abandonment (Heneberg, 2007).

Flooding is considered to have a positive impact on the sand martins' breeding success, because it allows the hole to be cleaned (Szép and Møller, 2000; Bengtsson and Olsson, 2002). As in natural sites, nests in artificial walls are also constructed with vegetation (moss, roots and stems) as well as materials of animal origin (duck feathers) (Cramp, 1988; Etxezarreta, 2010), which are prone to house ectoparasites. Thus, by building nests in areas that have a high likelihood of flooding between breeding seasons, colonies in artificial walls will also benefit from such periodic cleaning (Garrison, 1999; Szép and Møller, 2000).

Natural breeding banks have been shown to require a vertical height of not less than three metres in order to minimise predator access (Silver and Griffin, 2009). In our colonies the height of breeding nuclei ("points") ranged from 2.0 to 8.5 m (mean 3.0 m), as has been reported in natural colonies (Sieber, 1980). We did not test for the effect of wall slope on the occurrence of sand martin colonies in our study but nearly all the walls were vertical.

In contrast to other works (González and Villarino, 1997), orientation did not vary between "positive" and "negative" breeding points in our study area, indicating that particular orientations were not selected for. This is the only non-significant variable for which there was previous evidence of relevance in the literature.

Riparian habitats, river banks in particular, are among the most deteriorated ecosystems in the world due to channelling or urbanisation. As a consequence, attempts to recover this habitat for species nesting in cavities, such as kingfishers (Wechsler, 2007) or sand martins (Heneberg *et al*., 2006; Gulickx *et al*., 2007), have been carried out. Therefore, to facilitate the creation of sand martin colonies, a channelling wall should be vertical, directly above water and offer adequate drainage pipes or holes of 8-10 cm in diameter. However, future research should investigate whether these artificial structures allow these birds to achieve similar breeding rates as occur in nature, or whether productivity is reduced or enhanced in such circumstances.

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