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RECRUITMENT PATTERNS OF BLACKBIRDS *(TURDUS MERULA)* IN URBAN FRAGMENTED POPULATIONS

Esteban FERNÁNDEZ-JURICIC*[1] and José Luis TELLERÍA*

SUMMARY.—*Recruitment patterns of Blackbirds* (Turdus merula) *in urban fragmented populations.* The purpose of this paper is to study the effects of habitat fragmentation on Blackbird *Turdus merula* recruitment in 21 urban parks in the city of Madrid (Spain) during two consecutive breeding seasons (1997-98). We found that: (1) recruitment did not vary between years, showing high levels of spatial and temporal constancy; (2) recruitment was not affected by Blackbird density either within or among years; (3) fragment size accounted for a significant proportion of the variance of Blackbird recruitment; (4) after controlling for area effects, shrub cover in 1997 and shrub height in 1998 explained the remaining proportion of the variance of Blackbird recruitment; (5) human disturbance (rate of visitors and traffic load) and predator density (Magpie *Pica pica* and domestic cats) did not exert any significant influence on recruitment. Fragment size could be considered as the main indicator of the quantity of available habitat for reproduction, also decreasing human interference from park fringes and the levels of nest predation, whereas shrub cover and height could be regarded as factors of habitat quality, increasing the availability of nesting substrate and cover to rear and protect offspring.

RESUMEN.—*Patrones de reclutamiento de Mirlos Comunes (*Turdus merula*) en poblaciones urbanas fragmentadas.* El propósito de este trabajo es estudiar los efectos de la fragmentación sobre el reclutamiento de Mirlos Comunes *Turdus merula* en 21 parques urbanos de la ciudad de Madrid (España), durante dos temporadas reproductivas consecutivas. Se halló que: (1) el reclutamiento no varió entre años, mostrando altos niveles de constancia espacial y temporal; (2) la densidad de Mirlos Comunes no afectó el reclutamiento dentro ni entre años; (3) el área del fragmento explicó significativamente el reclutamiento en ambos años; (4) controlando el efecto del área, la cobertura de arbustos en 1997 y la altura de arbustos en 1998 explicaron de forma significativa la variabilidad remanente en el reclutamiento; (5) las molestias humanas (tasa de visitantes y tráfico automovilístico) y la densidad de depredadores (Urracas *Pica pica* y gatos domésticos) no ejercieron influencias significativas en el reclutamiento. El área de los parques urbanos podría considerarse como el principal indicador de la cantidad de hábitat disponible para la reproducción, disminuyendo además las interferencias de los bordes de los parques y los niveles de depredación de nidos, mientras que la cobertura y altura de arbustos serían factores de calidad del hábitat, aumentando la disponibilidad de substrato reproductivo y de cobertura para la crianza y protección de los pollos y juveniles.

INTRODUCTION

The effects of habitat fragmentation on the survival of populations is a prevalent concern in bird conservation (Rolstad, 1991; Saunders *et al.*, 1991; Wiens, 1994; Harris & Silva-Lopez, 1992; Andrén, 1994; Newton, 1995; Tellería & Santos, 1997). Despite an increasing knowledge at the scale of bird communities, there is little information on how this process affects individual species. Reproductive success is important in fragmented scenarios, since patches without recruitment could turn into population sinks, unable to maintain permanent populations (Pulliam, 1988; Dias, 1996). An array of factors that increase in intensity with the degree of fragmentation may affect reproductive outcome: lack of food and nesting places, disturbance levels, nest predation and nest parasitism (Harris, 1988; Yahner, 1988; Morrison *et al.*, 1992; Martin 1992, Nour *et al.* 1993, Riffell *et al.*, 1996; Donovan *et al.*, 1997). However, although many studies have evaluated the effects of nest predation on the ability of species to survive in fragments (see Andrén, 1995 for a review), few have assessed the effects of fragmentation on the reproductive ability of bird populations (see, howe-

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* Departamento de Biología Animal I. Facultad de Biología. Universidad Complutense de Madrid. E-28040 Madrid, España.

[1] E-mail: estebanf@eucmax.sim.ucm.es.

ver, Kurki & Lindén, 1995; Matthysen *et al.*, 1995; Robinson *et al.*, 1995).

This paper intends to determine which factors are correlated to the recruitment of Blackbirds (*Turdus merula*) in 21 urban parks of Madrid during two consecutive breeding seasons. Urban parks constitute a suitable scenario to study fragmentation effects on reproductive success since they can be regarded as isolated forest fragments in a matrix of buildings affected by similar ecological processes (habitat deterioration, edge effects, predation, etc.) to other fragmented habitats (Soulé *et al.*, 1988). Taking into account the peculiarity of these urban fragments, intensively used by pedestrians and managed by gardeners, our aims are fourfold. (a) To analyse the spatial and temporal consistency of the recruitment patterns found in this urban scenario. (b) As long as density is one of the main factors that could exert some influence on recruitment, as a regulatory mechanism of the number of new individuals in the population (O'Connor, 1985; Stacey & Taper, 1992; Stearns, 1992), we tested how recruitment could have been modified by Blackbird density. (c) To test how fragment size affects Blackbird recruitment, and (d) considering similar degrees of fragment area, to assess the relative contribution of habitat structure, predation, and human disturbance in determining Blackbirds reproductive output.

It may be expected that after controlling for density-dependent effects, Blackbird recruitment would decrease as park area decreases because of the increasing impact of negative environmental effects such as predation, low food availability or high human disturbance. Besides, we expect recruitment to increase with the structural complexity of vegetation, to decrease with predator density (by increasing egg and adult predation) and to dwindle with human disturbance (by reducing habitat suitability as a result of pedestrian levels and traffic load).

MATERIAL AND METHODS

The Blackbird is a common breeding bird in urban parks of Europe, where it exploits moist lawns as a source of earthworms and other invertebrates, the main food of nestlings (for a review see Cramp, 1992). It nests in shrubs and trees. Consequently, Blackbirds occur at high densities in landscapes with a mixture of green, moist grasslands and bushes. Sexing and aging of individuals can be reliably done by inspection of bills, legs and plumage coloration (Cramp, 1992).

During the spring-summer of 1997 and 1998 we sampled intensively 21 parks in the city of Madrid, Spain. These green plots are scattered over an urban matrix and their sizes range from 0.4 ha to 118 ha (Anonymous, 1997). To prevent the effects of Mediterranean drought on grassland patches, all parks are watered three days a week (four hours a day) throughout the year, keeping the main feeding substrate of Blackbirds during the critical summer period.

Besides area, we took into account the following three groups of variables which may have brought about changes in the reproductive success of Blackbirds.

Food and nest-site availability. We measured, across the whole area of small fragments and in 25 m radius circular plots located at 100 m intervals in large ones (Larsen & Bock, 1986), the amount of grass cover as an index of food availability and the average shrub height and shrub cover as indices of availability of potential nesting places (see Cramp, 1992).

Predator density. Magpies (*Pica pica*) are known to be predators of Blackbirds, particularly in urban settings (Møller, 1988; Groom, 1993). Therefore, Magpie abundance is expected to be negatively related to Blackbird recruitment. Domestic cats are another compelling predatory pressure for birds in urban environments (Baker & Graf, 1989). Density estimations of Magpies and cats were accomplished by means of line transects in the same spots in which Blackbirds were recorded (as described for estimations of Blackbird density, see below).

Human disturbance. Urban parks are important recreational areas; thus, the amount of human disturbance may constrain the reproductive success of Blackbirds because of its sensitivity to pedestrians (Fernández-Juricic & Tellería, 1999). Car traffic may also play a role on the reproduction of birds close to highways (Reijnen & Foppen, 1995). Therefore, the following protocol was set up to determine the amount of human disturbance (for a similar approach see Blair, 1996). For larger parks, in four randomly selected points a team of observers recorded simultaneously the number of pedestrians passing by in 3-min. intervals at morning and midday in the areas in which bird transects had been carried out. In small parks, a single observer was enough to cover the whole area. This procedure was repeated twice at each park with an interval of 25 days. Following a similar sampling procedure, we also recorded the number of moving cars during morning and afternoon (two measures with an interval of 20 days) in seven randomly located points in the perimeter of large parks and throughout the whole perimeter in small ones. Final figures were turned into rates per minute.

Blackbird density was estimated by visiting 4-5 times each park per year in the morning (from 0700 to 1030) between April and September. We recorded the number of individuals seen and vocalizing in 100 × 50 m fixed line transects in large parks (Seber, 1982). In small parks birds were detected by thorough searching. Final figures were expressed as number of birds/10 ha (for a similar approach see Tellería & Santos, 1994; 1997).

Recruitment was assessed as the proportion of juveniles to adult males at the beginning of the summer, just after the end of the reproductive period. This estimation of recruitment could be regarded as juvenile recruitment. We obtained such figures by repeated counts of young individuals and adult males in each park until mid August. Our estimates of Blackbird recruitment were based on males instead of females, since male territoriality is an important factor regulating the stability and age structure of Blackbird populations (Cramp, 1992; Hatchwell, 1996a; 1996b; Cresswell, 1997; 1998). Moreover, the detection of females varied excessively in both years (Table 1) since males were relatively more easily detected than females (mean proportion of male to females: 2.44 in 1997 and 3.24 in 1998). A lower and more variable female detection rate can arise as a consequence of several factors: (1) while males are feeding earlier broods, females might be re-nesting, (2) after the breeding season males and females tend to occupy different areas, and (3) after young individuals fledge, more females than males migrate because males are more aggressive and territorial (see Cramp, 1992). We first studied recruitment rates including males and females, but no clear pattern was evident from such data in relation to our hypotheses.

TABLE 1

Mean proportion of male to female Blackbirds (*Turdus merula*) detected at 21 urban parks of Madrid (Spain) during two consecutive breeding seasons. *[Proporción media de machos en relación a hembras de Mirlos Comunes* (Turdus merula) *detectados en 21 parques de Madrid (España) durante dos temporadas reproductivas consecutivas.]*

Park	*1997*	*1998*
Joan Miró	3.0	2.0
Emir	2.0	1.0
Plaza Toros	2.0	2.0
Picasso	2.0	3.0
Concha Piquer	3.0	2.0
Descubrimiento	2.0	2.0
Breogán	4.0	3.0
España	1.5	4.0
Eva Perón	2.0	2.0
Santander	3.0	5.3
Olof Palme	2.0	3.0
Arganzuelas	3.5	1.7
Cerro Almodóvar	3.3	8.0
Aluche	2.0	5.5
Fuente del Berro	3.3	4.7
Roma	2.0	1.7
Complutense	2.0	4.5
Moro	1.9	2.5
Emperatriz de Austria	2.0	3.3
Oeste	2.3	4.4
Retiro	2.3	2.4

By no means was our juvenile recruitment estimation precise aimed at obtaining figures of Blackbird recruitment instead; it was intended to be a rough indicator of how reproductive output could vary in fragmented landscapes. It was also based on the feasibility to discriminate adult males from juveniles and on their high rates of detection in the field (Cramp, 1992). The ratio focused on the last breeding stage of young individuals (fledging-juveniles), setting aside the influence of mortality factors during the incubation and fledging periods.

Mean juvenile recruitment values were compared between years with a t-test for paired samples. To analyse the spatial and temporal concordance of estimations in both years we correlated both measures with a Pearson product moment correlation. The analysis of the inter-annual recruitment variability was carried out by correlating the residuals of a regression between 1997 and 1998 recruitment to variables related to habitat structure, human disturbance and predator density. Pearson product moment correlations were employed to explore the relationship between recruitment and two density estimations: overall density and density of males. We used a linear regression analysis to assess the effects of park area on Blackbird recruitment. The residuals of this latter regression (Blackbird recruitment controlled for fragment size effects) were used to assess the effects of habitat structure, human disturbance and predator density. Significant associations between these variables and recruitment were assessed with Pearson product moment correlations. After determining variables showing significant correlation, we performed a stepwise multiple regression analysis. This analysis is not only predictive but also serves to establish functional relationships between dependent and independent variables after controlling for their covariation (StatSoft, 1996). Since the outcome of the addition or deletion of variables can be different, we performed forward and backward stepwise procedures in order to ensure the robustness of the results (Nicholls, 1989). The forward selection procedure consists in adding variables one at a time until the addition of further variables does not significantly increase the R^2 value. The backward selection method takes all the predictor variables and then gets rid of those whose removal does not appreciably lower the R^2 (Nicholls, 1989). We finally selected the set of independent variables that yielded the highest R^2 values and therefore accounted for most of the variance in recruitment. Some variables were log-transformed to meet normality and homogeneity of variance requirements.

RESULTS

Although juvenile recruitment of Blackbirds was slightly higher in 1998 than in 1997, no statistical differences were detected between the two years (mean 1997 = 0.643, mean 1998 = 0.685, $t_{20} = -1.247$, $P = 0.227$). Recruitment in both years was highly correlated, with 65% of recruitment estimations for each park lying in the 95% confidence interval (Fig. 1). There were no significant relationships between the

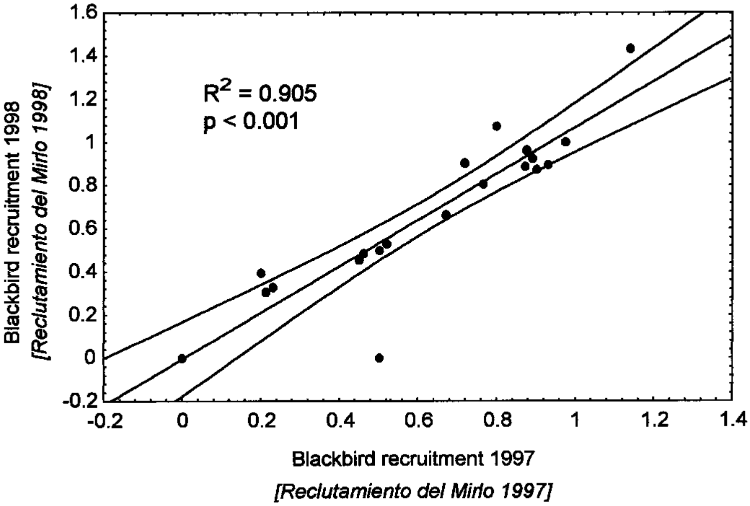

FIG. 1.—Spatial and temporal constancy of Blackbird (*Turdus merula*) recruitment patterns in 21 urban parks of Madrid (Spain). The graph shows the correlation between 1998 and 1997 recruitment values for each park with the 95% confidence intervals for such correlation.

[Constancia espacial y temporal del reclutamiento del Mirlo Común (Turdus merula) *en 21 parques urbanos de Madrid (España). Se muestra la correlación entre los valores de reclutamiento de 1998 y 1997 y su intervalo de confianza al 95%.]*

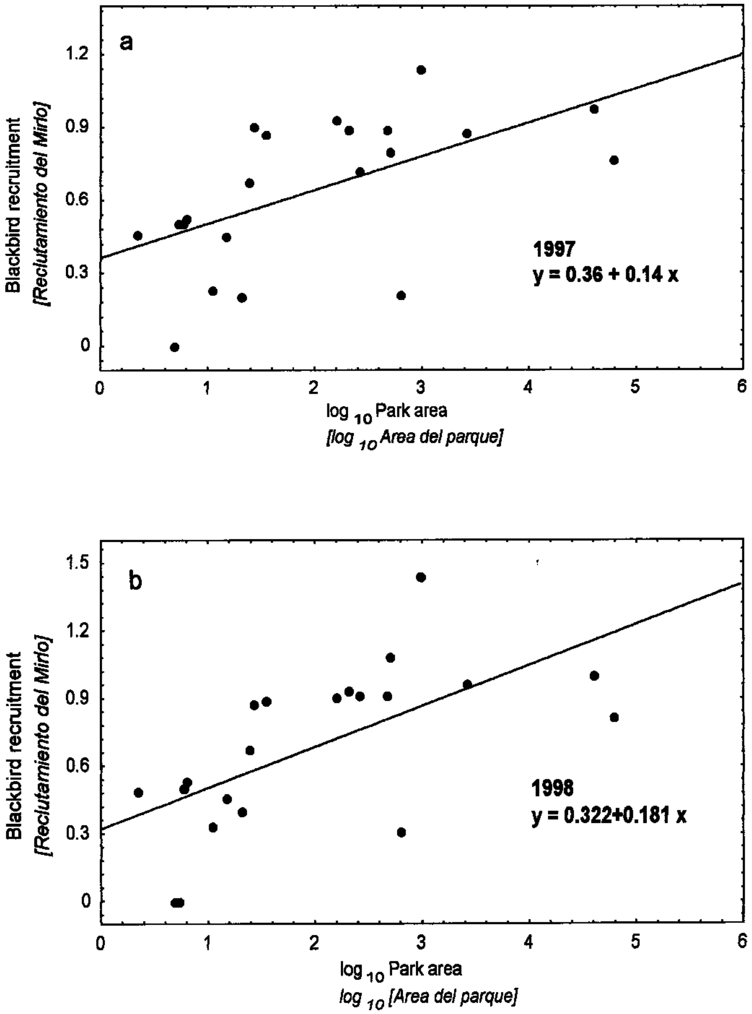

FIG. 2.—Relationship between Blackbird (*Turdus merula*) recruitment and patch area (ha) in 21 urban parks of the city of Madrid (Spain) in two consecutive breeding seasons, 1997 (a) and 1998 (b). In both years the linear regression models yielded significant relationships (1997, $F_{1,19} = 9.12$, $R^2 = 0.29$, $P < 0.01$; 1998, $F_{1,19} = 12.14$, $P < 0.01$, $R^2 = 0.36$).

[Relación entre el reclutamiento de Mirlos Comunes (Turdus merula) *y el tamaño (ha) de 21 parques urbanos en Madrid (España) durante dos temporadas reproductivas consecutivas, 1997 (a) y 1998 (b). En ambos años los modelos de regresión fueron significativos (1997,* $F_{1,19} = 9.12$, $R^2 = 0.29$, $P < 0.01$; *1998,* $F_{1,19} = 12.14$, $P < 0.01$, $R^2 = 0.36$).*]*

residuals of the regression relating the recruitment in both years and any of the following variables: variability of density between years ($R^2 = 0.085$, $P = 0.721$), $\log_{10}$ park area ($R^2 = 0.044$, $P = 0.854$), grass cover ($R^2 = 0.352$, $P = 0.128$), $\log_{10}$ shrub cover ($R^2 = -0.119$, $P = 0.618$), $\log_{10}$ shrub height ($R^2 = 0.189$, $P = 0.424$); and pedestrian rate ($R^2 = -0.388$, $P = 0.090$), car traffic ($R^2 = -0.118$, $P = 0.621$), Magpie density ($R^2 = -0.242$, $P = 0.304$) and cat density ($R^2 = -0.047$, $P = 0.835$) variability between 1997 and 1998.

In neither year did Blackbird recruitment correlate with population density estimations: overall density (1997, $R^2 = 0.3507$, $P = 0.101$;

1998, $R^2 = 0.2985$, $P = 0.167$) and male density (1997, $R^2 = 0.269$, $P = 0.117$; 1998, $R^2 = 0.372$, $P = 0.1$), nor did 1998 recruitment correlate with 1997 density ($R^2 = 0.278$, $P = 0.36$).

Park area significantly accounted for Blackbird recruitment in both years (Fig. 2). The amount of variability explained was nearly 30 and 36% in 1997 and 1998, respectively.

After controlling for the effect of park area, two of the seven studied factors were significantly related to recruitment in 1997 and 1998 (Table 2): shrub cover and shrub height. Both human disturbance (people and traffic load) and predator density (Magpies and cats) were not associated with recruitment residuals (Table 2). Stepwise multiple regression analysis yielded significant models in both years. Significant variables were shrub cover in 1997 ($y = 0.547 + 0.683x$) and shrub height in 1998 ($y = -0.216 + 0.022x$). Forward and backword stepwise procedures confirmed the same results in 1997 (Table 3) and 1998 (Table 4).

DISCUSSION

Our results must be interpreted with care, since we did not ring juvenile Blackbirds and cannot assess the rate of juvenile dispersal from suburban or countryside areas. However, even though a previous study in Switzerland concludes that urban parks are sink habitats (Ribaut, 1964), other studies (Hatchwell, 1996a; 1996b) suggest that the factors influencing Blackbird reproductive success operate at finer scales than simple habitat classifications (such as urban or woodland habitats). Indeed, Blackbird nesting success within urban parks could reach high values depending on more specific factors such as human disturbance (Osborne & Osborne, 1980) or habitat complexity

TABLE 2

Pearson product moment correlations between 1997 and 1998 Blackbird (*Turdus merula*) recruitment estimations (after controlling for area effects) and habitat quality, human disturbance and predator density in 21 urban parks in Madrid (Spain). Significance: $P < 0.05$ (*).

[Correlaciones de Pearson entre las estimaciones del reclutamiento de Mirlos Comunes (Turdus merula) *de 1997 y 1998 (después de controlar por los efectos del tamaño del fragmento) en relación a la calidad del hábitat, las molestias humanas y la densidad de depredadores.]*

	Correlation coefficient	*P*	Signif. *
	1997		
grass cover *[cobertura de césped]*	0.014	0.952	ns
$\log_{10}$ shrub cover *[$\log_{10}$ cobertura de arbustos]*	0.552	0.012	*
$\log_{10}$ shrub height *[$\log_{10}$ altura de arbustos]*	0.550	0.022	*
$\log_{10}$ pedestrian rate *[$\log_{10}$ tasa de visitantes]*	-0.121	0.610	ns
car traffic *[tráfico automovilístico]*	0.135	0.570	ns
Magpie density *[densidad de Urracas]*	0.112	0.639	ns
cat density *[densidad de gatos]*	0.189	0.423	ns
	1998		
grass cover *[cobertura de césped]*	0.091	0.443	ns
$\log_{10}$ shrub cover *[$\log_{10}$ cobertura de arbustos]*	0.285	0.028	*
$\log_{10}$ shrub height *[$\log_{10}$ altura de arbustos]*	0.643	0.002	*
$\log_{10}$ pedestrian rate *[$\log_{10}$ tasa de visitantes]*	-0.077	0.747	ns
car traffic *[tráfico automovilístico]*	0.208	0.377	ns
Magpie density *[densidad de Urracas]*	-0.008	0.973	ns
cat density *[densidad de gatos]*	0.323	0.164	ns

TABLE 3

Forward and backward stepwise multiple regression analysis of juvenile Blackbird recruitment in 1997 on vegetation structure (shrub cover and height) after controlling for the effects of area in 21 urban parks in Madrid (Spain). Significance: $P < 0.05$ (*).
[Regresiones múltiples por pasos de la dependencia del reclutamiento de Mirlos Comunes jóvenes en 1997 de la estructura de la vegetación (cobertura y altura de arbustos), después de controlar por el efecto del área en 21 parques urbanos de Madrid (España).]

Forward stepwise method ($F_{1,18} = 5.807$, $P < 0.05$)

Factor included in the model *[factor incluido en el modelo]*	Paso *[step]*	R^2	*P*
$\log_{10}$ shrub cover *[$\log_{10}$ cobertura de arbustos]*	1	0.244	0.026 *

Backward stepwise method ($F_{1,19} = 5.897$, $P < 0.05$)

Factor excluded from the model *[factor excluido del modelo]*	R^2	*P*
$\log_{10}$ shrub height *[$\log_{10}$ altura de arbustos]*	0.293	0.398 (ns)
Factor included in the model *[factor incluido en el modelo]*		
$\log_{10}$ shrub cover *[$\log_{10}$ cobertura de arbustos]*	0.237	0.025 *

TABLE 4

Forward and backward stepwise multiple regression analysis of juvenile Blackbird recruitment in 1998 on vegetation structure (shrub cover and height) after controlling for the effects of area in 21 urban parks in Madrid (Spain). Significance: $P < 0.05$ (*)
[Regresiones múltiples por pasos de la dependencia del reclutamiento de Mirlos Comunes jóvenes en 1998 de la estructura de la vegetación (cobertura y altura de arbustos), después de controlar por el efecto del área en 21 parques urbanos de Madrid (España).]

Forward stepwise method ($F_{1,18} = 7.813$, $P < 0.05$)

Factor included in the model *[factor incluido en el modelo]*	Paso *[step]*	R^2	*P*
$\log_{10}$ shrub height *[$\log_{10}$ altura de arbustos]*	1	0.303	0.012 *

Backward stepwise method ($F_{1,19} = 4.711$, $P < 0.05$)

Factor excluded from the model *[factor excluido del modelo]*	R^2	*P*
$\log_{10}$ shrub cover *[$\log_{10}$ cobertura de arbustos]*	0.206	0.427 (ns)
Factor included in the model *[factor incluido en el modelo]*		
$\log_{10}$ shrub height *[$\log_{10}$ altura de arbustos]*	0.199	0.043 *

(Fernández-Juricic, unpublished information). Therefore, we consider our juvenile recruitment results as indicative of general trends in the outcome of breeding activities within these urban parks.

Blackbird juvenile recruitment in urban parks of Madrid was similar among fragments and between years, and this pattern was not related to park area, the main predictor of fragment reproductive quality. Thus, the pattern found in small parks with low reproductive success could be as predictable as that in large parks with higher recruitment. Such continuity in environmental conditions could have meaningful implications at the population level: the persistence of high ranking individuals in high quality territories, of juvenile dispersal from high to low reward habitats (Hatchwell *et al.*, 1996b), and of the spatial age-structure of urban populations, with large areas as sources of potential breeding individuals to other kinds of habitats (Snow, 1958).

Fragmentation, by virtue of an area effect, modified Blackbird recruitment, fragment size being an indicator of the quantity of available habitat for reproduction or attraction of juvenile immigrants from other populations. A similar pattern of high proportion of juveniles in large parks could have been brought about by high adult mortality in large parks. However, this appears not to be the case since male density increased in large urban parks (1997, $R^2 = 0.6767$, $P < 0.001$; 1998, $R^2 = 0.5142$, $P < 0.05$), which suggests that survival may be rather high in large fragments.

Blackbirds in small parks of Madrid seem to suffer similar patterns of habitat deterioration and increasing interference from peripheral areas as populations of passerines in forest fragments (Matthysen *et al.*, 1995; Robinson *et al.*, 1995). This size effect upon recruitment showed a logarithmic pattern, increasing its potential in parks below 10 ha (Fig. 2). Such small parks may be subject to increasing effects of predation (Møller, 1988; Groom, 1993) as well as to lower amounts of feeding and nesting substrata and higher disturbance levels from peripheral areas (Wilcove, 1985; Møller, 1991). Social processes may also be affected in small parks. Blackbird territoriality could be enhanced due to the low availability of suitable places, increasing the effects of interference competition upon conspecific presence (Cresswell, 1997; 1998), and restraining feeding rates as a consequence of increasing impact of visitors per unit area (Fernández-Juricic & Tellería, 1999). Therefore, park area itself may be a valuable resource, independently of the habitat suitability of parks. Blackbirds from large parks, for instance, would make use of a higher availability of alternative places to avoid interference or to reach a given threshold of absolute availability of breeding resources.

Controlling for area effects, we found habitat quality factors related to the availability of nesting substrates to exert a positive influence on Blackbird reproductive output. The more complex the shrub cover and height, the higher the availability of cover to protect offspring from the effects of predation (Møller, 1988; Groom 1993). At the level of our study, we found that the density of predators (Magpies and cats) did not affect Blackbird recruitment, nor did the amount of human disturbance. However, such variables may override other processes at the individual level, such as nesting in more intricate substrates to avoid Magpie approaches (Møller, 1988) or increasing the rate of vigilance and thereby decreasing food consumption upon human approaches (Fernández-Juricic & Tellería, 1999). Indeed, that Blackbird reproductive output rested on the amount of protective cover places some value on how predation and disturbance could be indirectly reduced by the benefits of habitat complexity.

Our results support the pervasive effects of very small green fragments in urban areas on the ability of Blackbirds to breed. If these results are representative of the way other species strive for survival in small parklands, we must beware of the meaning of parks below a given size as «wildlife islands» in urban landscapes. The relationships found here do not necessarily mean causal mechanisms. Indeed they only suggest that in the context of an urban environment, where the human presence prevails, the reproductive success of Blackbirds could be meaningfully modified by the area of the park and the availability of nesting substrates.

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