HUNTING RANGES AND HABITAT USE AND SELECTION OF URBAN-BREEDING MERLINS[1]

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Abstract. We studied hunting ranges and habitat requirements of 27 radio-tagged Merlins (*Falco columbarius*) breeding in Saskatoon, Saskatchewan from May to July, 1987–1990. Mean hunting range sizes of resident (hatched in the city) and immigrant (hatched outside the city) males were 6.3 ± 1.3 km² (2.2–13.7 km²) and 33.7 ± 12.1 km² (12.5–64.3 km²), respectively. Mean hunting range sizes of resident and immigrant females were 6.6 ± 3.4 km² (2.5–13.4 km²) and 8.6 ± 1.6 km² (0.6–17.5 km²), respectively. Spatial overlap in hunting ranges between neighboring Merlins ranged from 0 to 77.3%. Most immigrants frequently left the city to hunt and had less urban habitats in their ranges than did residents. Merlins that hunted exclusively within the city used habitats in relation to their availability. Resident and immigrant merlins that hunted both within and outside the city avoided hunting in agricultural habitats, which had relatively low prey abundance.

Key words: Merlin; Falco columbarius; Saskatoon; breeding; radio-tracking; hunting ranges, habitat use.

INTRODUCTION

Merlins (*Falco columbarius*) have been increasingly colonizing Canadian cities (Oliphant and Haug 1985, James et al. 1987, James 1988) in recent years. Although there have been studies of their habitat use in undisturbed areas and during winter in an urban area (Becker and Sieg 1987, Dickson 1988, Warkentin and Oliphant 1990), hunting ranges, habitat requirements, and spacing of urban-breeding Merlins are unreported. Here, we describe hunting range characteristics and habitat use of breeding Merlins in an urban population. Because few data are available on foraging differences among immigrant and resident birds in a population (but see Heredia et al. 1991), we also compare hunting habitats and ranges among resident and immigrant Merlins. We predicted that resident and immigrant Merlins would differ in their hunting habitats and ranges because of prior experience with different habitats.

METHODS

The research was conducted in the city of Saskatoon, Saskatchewan, Canada (52°07′N, 106°38′W), during May to July, 1987–1990. The study area is described by Sodhi et al. (1992).

Merlins first nested in Saskatoon in 1963, and since 1971, their numbers have increased steadily (Houston and Schmidt 1981, Oliphant and Haug 1985). Nesting density of Merlins was higher from 1987 through 1990 (19.7–24.6 pairs/100 km²) than anywhere else recorded (Sodhi et al. 1992).

Merlins were captured near their nests by using mist nets or dho-gaza nets (Clark 1981). Two tethered House Sparrows (*Passer domesticus*) or a tethered Great Horned Owl (*Bubo virginianus*) were used as lures. Merlins were radio-tagged because they ranged over large areas and focal individuals could not be followed otherwise. Model SM-1 (AVM Electronics, Livermore, Calif.) or model SS-1 (Biotrack, Dorset, U.K.), weighing 1.6% and 2.4% of male and female body mass, respectively, were attached dorsally to two tail feathers (*n* = 26) (Kenward 1978), or to legs (*n* = 4) by modification of the method of Grier (1970). The Merlins were not followed during the first day of radio-tagging, but were continuously monitored thereafter during the first and last four daylight hours (i.e., periods of maximum foraging activity; Sodhi, unpubl. data) on fair weather days. Radio-tagging had minimal effect on long-term behavior, reproductive output, and survival of the Merlins (Sodhi et al. 1991a).

We radio-tagged 33 Merlins (1987: two males, one female; 1988: five males, one female; 1989: five males, six females; and 1990: six males, four

females). Merlins were radio-tracked for 768 hr during the study. Because of transmitter failure, data from two males (1987) and one female (1990) were excluded from analyses. Because not all of the males were followed during the entire breeding cycle (e.g., a male captured and followed during the incubation period but whose transmitter failed during the nestling period), we monitored 12, 14, and 5 males during the incubation, nestling, and fledging periods, respectively. Females were followed during the fledging period only, when they began providing food for the young. Each Merlin was tracked for a total of 24 hr during the incubation period, 16 hr during the nestling period, and 16 hr during the fledging period. We adjusted observation days during the nestling and fledging periods so that all monitored Merlins of the same sex were followed when they had chicks of similar age (± 7 days). Nestling ages were determined based on an unpublished aging method we developed with wild Merlin nestlings.

When being followed, each Merlin was located every 3 min and its locations were plotted on a 1:50,000 map. Because excessive locations near the nests could bias our results (Haug and Oliphant 1990), we plotted locations of birds near nests only when they made hunting attempts. After releasing a radio-tagged Merlin, we checked location error of the radio-tag, by having one observer remain near the radio-tagged Merlin and another observer locate it from various distances. From 1 km, our radio location error averaged about 50 m. We visually located Merlins 25% of the time. The rest of the locations included in this paper were obtained when Merlins were ≤ 1 km (judging from radio signal strength) away from the observer. At each radio location, we also recorded time, whether the Merlin was perching or flying, and, if possible, the habitat being used. We calculated the hunting range sizes by employing the minimum convex polygon method (Mohr 1947), using all plotted locations of each Merlin.

We also used locations of Merlins taken at 30-min intervals to evaluate their habitat use and selection. We used a 30-min span between two consecutive locations because during this span, a Merlin could travel about 25 km, assuming an average flight speed of 50 km/hr (Warkentin and Oliphant 1990). This distance would cover all habitats in our study area, so these locations were considered statistically independent (see Kenward 1987, Widen 1989).

We delineated four habitats in each hunting range: (1) urban—human habitation in and outside the city except parks and cemeteries, (2) parks—parks and cemeteries both in and outside the city, (3) agricultural—cultivated areas, and (4) grasslands—areas with tame pastures and native grasses. We used aerial photographs taken in 1986 to develop a general habitat map of the study area. In July of each year of the study, we updated the habitat map. These yearly habitat maps were then used to calculate the areas of different habitat types in individual hunting ranges.

To assess habitat selection, we compared habitat availability with use (based on the number of radio locations in each habitat type). To determine habitat selection, we used Bonferroni's Z-tests if a significant difference between habitat availability and use was found using a chi-square test (Neu et al. 1974, Byers et al. 1984). We refer to a habitat being selected when used more often and avoided when used less often than expected by chance.

To determine whether Merlins frequent habitats with higher prey densities we estimated total number of all potential prey species in each habitat. Passerine counts at five randomly selected points within each habitat type were made in 1989 (Sodhi 1991a). Birds seen or heard within 25 m of each station were recorded for 4 min. Passerines were counted for 4 min because two 10-min preliminary counts in each habitat had revealed that passerine abundance tended to reach an asymptote in 4 min. Passerine counts were made once a month (May–July) within the first 4 hr of daylight in fair weather ($< 10\%$ cloud cover, < 15 km/hr wind speed). Different random points within each habitat were used each month. We calculated the mean number of passerines for each habitat following the method of Hutto et al. (1986). Because breeding Merlins in Saskatoon feed almost exclusively on passerines that weigh less than 100 g (Oliphant and McTaggart 1977, Sodhi et al. 1990), we only considered birds less than 100 g as potential prey species. We did not find passerine abundances recorded in each habitat to be significantly different among survey months (chi-square tests, df $= 2$, $P > 0.05$), so we pooled data from different months.

We refer to breeding Merlins hatched outside Saskatoon as immigrants and breeding Merlins hatched inside the city as residents (Newton 1988). We analyzed data of immigrant and res-
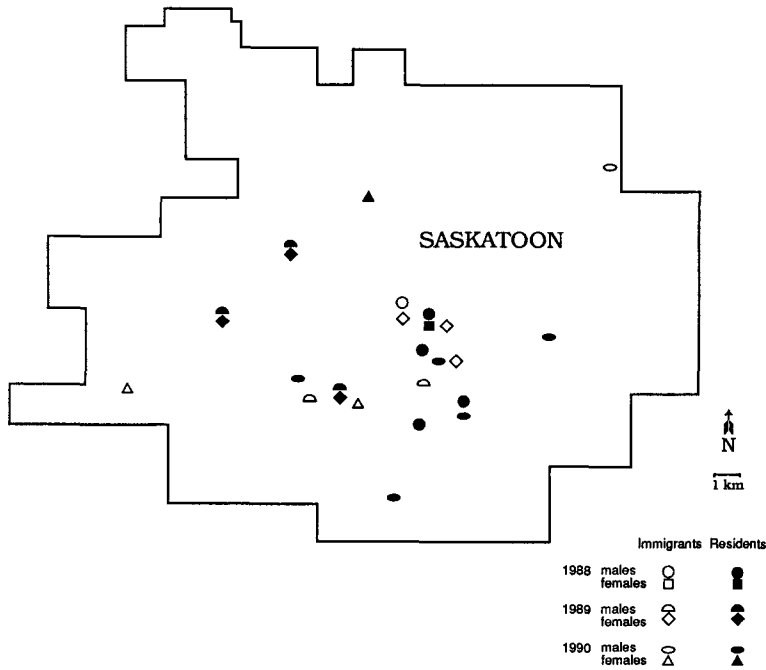
FIGURE 1.   Nest locations of radio-tracked resident and immigrant Merlins.

ident Merlins separately (Fig. 1). Further, we analyzed habitat data separately for birds that hunted only within the city and birds that hunted both within and outside the city. When more than one bird was radio-tracked in each of the above categories, we used the aggregate method (Swanson et al. 1974) to calculate habitat availability and use. We report standard error with means.

RESULTS

DESCRIPTION OF HUNTING RANGES

Range-size data from different years were combined because we did not find a significant difference among years in the hunting range sizes of males during the incubation and nestling periods (Kruskal-Wallis ANOVA, df = 2, $P > 0.20$, two-tailed) and among females during the fledging period (1989 and 1990 compared; Mann-Whitney $U = 14$, df = 3, 6, $P > 0.20$, two-tailed).

Mean hunting range sizes of resident and immigrant males were 6.3 ± 1.3 km² (2.2–13.7 km²) and 33.7 ± 12.1 km² (12.5–64.3 km²), respectively, and were significantly different ($U = 46$, df = 4, 12, $P < 0.005$, one-tailed). Some males were followed during one breeding period only and this could have biased our hunting range size analyses. Data analyzed from two randomly se-

lected males, both of which were followed for at least a total of 40 hr showed that hunting range sizes reached asymptotes within 16 hr of observations in both males. This justifies our inclusion of males followed for only 16 or 24 hr in hunting range size analyses. Moreover, hunting range sizes did not differ among three breeding periods (incubation, nestling, and fledging) in resident (Kruskal-Wallis ANOVA, $H = 5.6$, df = 2, 0.05 $< P < 0.10$) or immigrant males ($H = 2.7$, df = 2, $P > 0.20$).

All immigrant males spent some time out of the city hunting, while eight of 12 resident males hunted only within the city. In 1988, two males nesting 0.8 km apart (one resident and the other an immigrant), were radio-tracked from the incubation to the fledging period. The immigrant male tended to hunt more frequently outside the city (51% vs. 34% for the resident male). In 1989, a resident and an immigrant male, nesting 0.8 km apart were radio-tracked during the incubation and the nestling periods. Again, the immigrant male tended to hunt more frequently outside the city (33% vs. 0% for the resident male).

Mean hunting range sizes of resident and immigrant females were 6.6 ± 3.4 km² (2.5–13.4 km²) and 8.6 ± 1.6 km² (0.6–17.5 km²), respectively, and were not significantly different ($U =$

TABLE 1. Habitat use and selection by breeding male Merlins in Saskatoon during the incubation period. Values for availability and use for each habitat were obtained using the aggregate method (Swanson et al. 1974). When habitat availability and use differed significantly, we used Bonferroni's Z-tests to determine habitat selection. A = avoided, S = selected, and E = used, but not significantly different from availability. A and S are significant at $P < 0.05$.

Habitat	Residents U[1] (n = 7)		Residents R[2] (n = 2)			Immigrants (n = 3)		
	Proportion available	Proportion used[3]	Proportion available	Proportion used	Habitat selected	Proportion available	Proportion used	Habitat selected
Urban	85.7	83.6	58.5	79.1	S	53.7	38.8	A
Parks	14.2	16.3	9.5	6.2	E	7.7	14.5	S
Agricultural	—	—	34.0	20.8	A	25.3	11.8	A
Grassland	—	—	16.0	14.7	E	13.1	34.7	S
Total area (km²)	12.3		7.0			93.2		
Total locations		336		96			144	

[1] Hunted only in urban habitat and parks.
[2] Hunted in all four habitats.
[3] Bonferroni's Z-test not applied because $\chi^2 = 1.0$, df = 1, $P > 0.20$.

14, df = 3, 8, $P > 0.20$, one-tailed). Seven of eight immigrant females left the city to hunt compared to only one of three resident females. Because neighboring resident and immigrant females within a year were not radio-tracked, we could not compare hunting times spent outside the city for females.

HUNTING RANGE OVERLAPS

Preliminary analyses revealed that birds nesting more than 2 km from each other had no spatial overlaps in hunting ranges. We therefore calculated spatial overlaps among radio-tracked birds nesting within 2 km of each other. For males, mean overlap in hunting ranges was 11.88 ± 6.3% (0–77.3%), 11.4 ± 4.3% (0–36.4%), and 10.6 ± 4.1% (0–46.4%) during the incubation, nestling, and fledging period, respectively. Mean overlap in ranges of resident with other resident and (or) immigrant males was 15.7 ± 8.2% (0–77.3%), 12.2 ± 5.3% (0–36.4%), and 12.2 ± 4.6% (0–46.4%) during the incubation, nestling, and fledging period, respectively. Mean overlap in ranges of immigrant males with other immigrant and (or) resident males was 0.1 ± 0.1% (0–0.3%), 9.1 ± 9.2% (0–18.3%), and 2.1 ± 2.1% (0–4.2%) during the incubation, nestling, and fledging period, respectively. Sample sizes were only sufficient to test differences in spatial overlap during the incubation period between immigrant and resident males, when overlap in ranges did not differ significantly ($U = 19.5$, df = 3, 9, $P > 0.20$, two-tailed).

Mean overlap in hunting ranges for females during the fledging period was 29.6 ± 4.4% (15.7–45.1%). Overlap was slightly larger for resident

TABLE 2. Habitat use and selection by breeding male Merlins in Saskatoon during the nestling period. Values for proportion of habitats available and use were obtained using the aggregate method. Habitat selection was determined using Bonferroni's Z-tests when habitat availability and use differed significantly. For abbreviations see Table 1. A and S are significant at $P < 0.05$.

Habitat	Residents U[1] (n = 7)		Residents R[2] (n = 3)			Immigrants (n = 4)		
	Proportion available	Proportion used[3]	Proportion available	Proportion used	Habitat selected	Proportion available	Proportion used	Habitat selected
Urban	84.1	78.7	61.7	56.8	E	48.5	41.5	E
Parks	15.8	21.3	5.2	10.9	E	11.6	11.8	E
Agriculture	—	—	28.2	17.2	A	42.2	17.7	A
Grassland	—	—	7.1	14.1	S	14.5	44.4	S
Total area (km²)	26.3		26.1			63.4		
Total locations		224		96			128	

[1] Hunted only in urban habitat and parks.
[2] Hunted in all four habitats.
[3] Bonferroni's Z-test not applied because $\chi^2 = 2.7$, df = 1, $P > 0.10$.

TABLE 3. Habitat use by breeding male Merlins in Saskatoon during the fledging period. When more than one bird was radiotracked in each of the categories, the aggregate method was used to calculate proportion of habitat availability and use.

| Habitat | Residents | | | | Immigrants | |
| | U[1] ($n = 2$) | | R[2] ($n = 2$) | | ($n = 1$) | |
	Proportion available	Proportion used[3]	Proportion available	Proportion used[4]	Proportion available	Proportion used[4]
Urban	83.7	82.2	77.2	67.2	84.0	78.1
Parks	16.3	17.8	4.9	18.7	0.1	6.2
Agricultural	—	—	8.0	12.5	11.7	6.2
Grassland	—	—	19.8	15.6	4.2	9.5
Total area (km²)	8.3		20.9		9.4	
Total locations		64		64		32

[1] Hunted only in urban habitat and parks.
[2] Hunted in all four habitats.
[3] Bonferroni's Z-test not applied because $\chi^2 = 0.1$, df = 1, $P > 0.20$.
[4] Chi-square test not attempted because <5 expected radio locations in >20% of habitats.

females (32.9 ± 8.5%, 20.8–45.1%) than for immigrant females (27.9 ± 6.5%, 15.7–37.8%). Our estimates of spatial overlaps for both males and females are conservative, because each year not all neighboring individuals were radio-tracked.

HABITAT USE AND SELECTION

Merlins that hunted only within the city used habitats in relation to their availability (Tables 1–4). Immigrant Merlins had proportionally less urban habitat in their ranges than residents, except during the fledging period (Tables 3, 4). Merlins that hunted both within and outside the city generally avoided agricultural habitat and selected the urban, parks, and grassland habitats (Tables 1–4). Male Merlins that hunted only within the city did not use habitats differently during different breeding periods. However, males

that hunted both within and outside the city showed some differences in habitat use and selection during different breeding periods (Tables 1–3).

The mean number of potential prey species was 1.5 ± 0.4, 2.7 ± 0.3, 3.7 ± 0.6, and 4.5 ± 0.8 in agricultural, grassland, parks, and urban habitat, respectively ($H = 13.8$, df = 3, $P < 0.02$, two-tailed). Multiple comparisons (Siegel and Castellan 1988:213–214) revealed that the park and urban habitats had significantly more passerines than did the agricultural habitat ($P < 0.05$).

DISCUSSION

Becker and Sieg (1987) calculated the mean hunting range size of male Merlins during the nestling period in Montana to be 23.3 ± 4.6 km² (12.6–

TABLE 4. Habitat use and selection by breeding female Merlins in Saskatoon during the fledging period. When more than one bird was radio-tracked in each of the categories, the aggregate method was used to calculate proportion of habitat available and used. Habitat selection was determined by using Bonferroni's Z-tests. For abbreviations, see Table 1. A and S are significant at $P < 0.05$.

| Habitat | Residents | | | | Immigrants | | | | |
| | U[1] ($n = 2$) | | R[2] ($n = 1$) | | U[1] ($n = 1$) | | R[2] ($n = 7$) | | |
	Proportion available	Proportion used[3]	Proportion available	Proportion used[4]	Proportion available	Proportion used[5]	Proportion available	Proportion used	Habitat selected
Urban	87.8	85.9	35.4	18.5	76.6	84.4	33.9	48.4	S
Parks	12.1	14.1	4.4	0.0	23.4	15.6	8.0	11.7	E
Agricultural	—	—	52.2	65.9	—	—	57.5	27.6	A
Grassland	—	—	8.0	15.6	—	—	29.0	28.5	E
Total area (km²)	7.2		22.6		3.4		136.8		
Total locations		64		32		32		224	

[1] Hunted only in urban habitat and parks.
[2] Hunted in all four habitats.
[3] Bonferroni's Z-test not applied because $\chi^2 = 0.1$, df = 1, $P > 0.20$.
[4] Chi-square test not attempted because <5 expected radio locations in >20% habitats.
[5] Bonferroni's Z-test not applied because $\chi^2 = 0.6$, df = 1, $P > 0.20$.

28.1 km², $n = 3$) (Merlin nesting density 3.8 pairs/
100 km²). Range sizes recorded for Merlins by
Becker and Sieg (1987) were larger than those
recorded by us. In Saskatoon, we found the mean
range size of 14 radio-tracked males during the
nestling period to be 8.2 ± 2.7 km² (1.3–41.5
km²). Warkentin and Oliphant (1990) found mean
hunting range size of adult (five females, one
male) and juvenile (one female, two males) win-
tering Merlins in Saskatoon to be 19.6 ± 5.8 and
17.9 ± 3.4 km², respectively. The mean range
size for all breeding Merlins in Saskatoon was
11.1 ± 13.4 km² ($n = 27$), slightly smaller than
that for wintering Merlins. It has been suggested
that range sizes are inversely correlated with the
population density (Krebs 1971, Schoener and
Schoener 1982), but they could also be affected
by factors such as prey abundance (Village 1982).

Our estimates of spatial overlap between
neighboring radio-tracked Merlins ranged from
0 to 77.3%, but these values may be conserva-
tive. Several factors may influence whether
breeding Merlins have overlapping, rather than
mutually exclusive, hunting ranges in Saskatoon.
Because their nesting density within the city is
high, territory defense costs may likewise be high.
Their prey base is abundant and relatively stable
(Sodhi 1991a), so there may be reduced benefits
in exclusively defending hunting ranges. Further,
Merlin feed on mobile prey, which alter behavior
in response to the presence of Merlins (Sodhi et
al. 1990; Sodhi 1991b, 1991c) and, therefore
would be hard to defend. Overlapping their hunt-
ing ranges may offer relatively more foraging ar-
eas for Merlins. This also may be beneficial for
Merlins as they rely mostly on surprise while
hunting (Sodhi et al. 1991b). These factors may
make defense of exclusive hunting ranges a sub-
optimal choice (Brown 1964, Brown and Orians
1970, Davies 1980).

Immigrant Merlins generally had relatively less
urban habitat in their ranges, and most immi-
grants left the city to hunt. Immigrant males also
spent more time hunting outside the city than
resident males. It is possible that immigrants had
prior experience with out-of-city habitats which
influenced their use of such habitats during the
breeding season (Hilden 1965, Klopfer and
Granzhorn 1985). Generally, Merlins avoided
hunting in agricultural habitat possibly because
this habitat had lower prey abundance than other
habitat types. Similar results have been reported
in other studies of raptors (Sylven 1978, Craig
et al. 1986, Preston 1990).

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