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Density, range size and diet of the European Jay *Garrulus glandarius* in the Maremma Natural Park, Tuscany, Italy, in summer and autumn

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Transects of pinewoods in the Maremma Natural Park, Tuscany, Italy, showed unusually high densities of 347 to 676 (mean 484) Jays km^{-2} in July but much lower densities (similar to those in northern Europe) in October and November. The density in the alternative habitats, scrub and olive grove, changed in the opposite direction between seasons. The high numbers of Jays were associated with an abundance of cicadas *Cicada orni* in the pinewoods in July and of acorns in the scrub in autumn. Radio-tracking of four Jays showed ranges of 42.5 to 358.8 ha, which encompassed both scrub and pinewood in July but which were confined to scrub in autumn. Jays were seen to move from scrub to pinewood in large numbers at dawn in July and were observed to return at dusk. In autumn, individual birds were seen carrying acorns from scrub to pinewood, apparently to cache them there.

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Introduction

European Jays *Garrulus glandarius* are generally considered to live at low density in pairs on year-round territories in deciduous or mixed woodland (Bossema 1979, Coombs 1978, Goodwin 1986, Keve 1985). For example, a radio-tracking study in Sweden (Grahn 1990) showed a mean range size of 12.7 ha in the non-breeding season and 14.0 ha in the breeding period (75% isoclines), with estimated densities over five years of 8–13 birds km^{-2} (mean 11).

Preliminary observations in pinewoods in the Maremma Natural Park, Tuscany, Italy in July 1984, however, suggested that Jays occurred there at densities very much higher than those described for northern Europe. This suggested that ranges were much smaller and/or overlapped more in the Maremma than elsewhere, or that there was a different social system, e.g. with groups of Jays in each range as in some North American jay species. The very high density also suggested a very abundant food supply, since several studies have shown that density increases with increasing food supply (Davies and Houston 1984).

The aims of the present study were: (a) to measure the density of Jays in the Maremma Natural Park; (b) to measure range size; and (c) to investigate diet and food supply.

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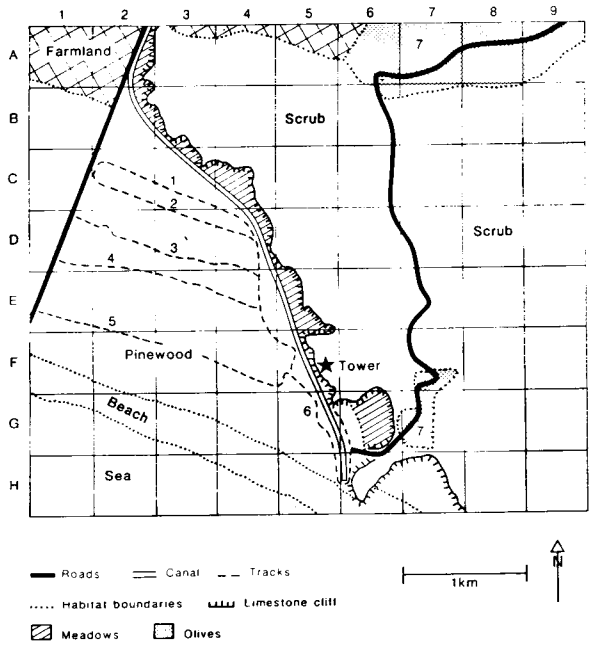

Fig. 1. The study area, showing the main habitat zones and the tracks and road used for transects (numbered 1 to 7).

Study area and methods

Study area

The study was carried out during July, October and November 1998 in the Maremma Natural Park on the coast of Tuscany, Italy (Fig. 1). The area is characterised by several distinct vegetation zones, bounded on the western edge by a beach with a belt of *Juniperus oxycedrus macrocarpa* on its landward side. A large part of the area is dominated by pine forest, mainly *Pinus pinea* with *Pinus pinaster* (mainly near the seaward side) with an understory of *Cistus* species, *Erica multiflora, Pistacia lentiscus, Myrtus communis, Juniperus oxycedrus macrocarpa* and *Juniperus phoenicea*. The study area is divided by a limestone escarpment, up to 135 m high, with a narrow irregular zone of grazed meadows at the base of the cliff and thick Mediterranean maquis scrub on the eastward, sloping side (Fig. 1). The scrub contains *Quercus ilex, Q. pubescens, Arbutus unedo, Phyllirea latifolia, Fraxinus ornatus, Erica multiflora, Pistacia lentiscus* and *Rosmarinus officinalis* (Bertani and Pasquali 1983, Nocentini and Piussi 1977). Some areas of scrub had earlier been cleared to create olive groves in the north and south ends of the scrub zone (Fig. 1).

Human activity was generally low within the Park during the study, with only occasional vehicles passing along the tracks in the pinewood (Fig. 1) and conducted parties of visitors on paths on the limestone ridge on three days each week. There was, however, frequent vehicle and pedestrian traffic on the road at the western edge of the study area and fairly regular vehicle passage on the road at the eastern side (Fig. 1).

Methods

Estimates of Jay density were based on transects on foot and by car along narrow tracks in the pinewoods and by car only on the road through the olive groves and scrub (Fig. 1), by recording every bird seen on known lengths of transect. The transects varied in length, from 0.72 km (Transect 6) to 1.68 km (Transect 5; Fig. 1) so the data were expressed as Jays seen per km. In autumn, transect 6 was included as part of each of the other transects. Most Jays were detected when 10–40 m ahead of the observer (mean 27.1 ± 1.2 m, $n = 119$), usually when the birds called and flew away. Most flew away from the track but any which landed again near the route were noted so as to avoid duplication. The transects took only 10–20 min, so that Jays detected in one part were very unlikely to have been encountered again later.

On some transects, the distance of each Jay or group of Jays from the transect line was estimated (within 10 m zones) and densities were calculated using the hazard rate model (Buckland 1985, Burnham et al. 1980), which uses information on the rate of decline in number of birds seen with increasing distance from the transect line. When groups of Jays (see below) were spread over more than one distance zone, the one containing the majority of the birds was used in the analysis. It was not possible to make such estimates in scrub areas, since visibility was very limited in the dense vegetation and the canopy was usually completely closed along road edges.

Two or more Jays were considered to be together (i.e. in a group) if they were in the same tree canopy or similarly-sized area (about 10 m across). Such groups usually flew away together in the same direction after detecting the observer.

Five Jays were trapped in mist nets strung between trees in the olive grove at the southern end of the study area (Fig. 1) and four (two in July and two in October) were fitted with small radio transmitters glued and tied to the base of the two central tail feathers (Kenward 1987). The radio-tagged birds were located each day, either while still at their roost site at dawn or by triangulation from two high points on the limestone ridge, and their positions within at least a 250×250 m grid (and usually within 125×125 m) were determined by approaching the birds closely or by triangulation every 15 min for periods of at least several hours. Successive fixes were considered to be independent, since the birds usually moved rapidly and continuously through the area during the day (Fig. 8). Range sizes were estimated by minimum convex polygon and harmonic mean analyses (Kenward 1987), using the Mcpaal suite of computer

Table 1. Number of Jays seen on transects (Fig. 1) made between 0900 and 1800 hours. N = no. of transects.

Transect (Fig. 1)	Mean number of Jays km^{-1} July			October–November		
	x̄	SE	N	x̄	SE	N
1	–			0.8	0.6	2
2	24.7	1.0	3	1.0	0.2	2
3	14.8	1.0	24	0.4	0.2	3
4	8.3	1.4	3	0.9	0.3	6
5	–			1.1	0.3	7
6	4.3	0.9	16	*		
1–6	11.4	1.1	46	0.9	0.2	20
7	2.4	0.6	10	7.7	1.7	14

* Transect 6 included as part of transects 1–5 in October–November.

software (M. Stuwe and C. E. Blohowiak, National Zoological Park, Smithsonian Institution). Harmonic mean analysis was also used to plot contours of range use and to define core areas containing 80% and 50% of the radio fixes.

Jays moving between the main sections of the study area, pinewood and scrub, were counted from high vantage points on the limestone cliff (Fig. 1), and the totals moving in each direction in each half-hour period were compared.

The Jays' diet was determined by direct observation of feeding birds, since it was not possible to collect faeces or regurgitated pellets for analysis. It was possible to make only preliminary assessments of the relative abundance of food in the pinewood, scrub and olive groves.

Results

Number of Jays seen on transects

In July, a mean of 11.4 Jays km^{-1} were seen on daytime transects (1–6; Fig. 1) of the pinewood (Table 1), with no significant change through the month. There was, however, significant variation between transects ($F = 29.52$, $p < 0.001$), with numbers decreasing from north to south (Table 1). The main habitat features which also varied were the proportion of large *Pinus pinea* and the amount of open space in the wood, both of which also decreased from north to south. On the main transect (3; Fig. 1), the number of birds seen before 0800 hours or after 2000 hours (3.5 ± 0.9 km^{-1}) was significantly lower than during the rest of the day (14.8 ± 1.0; $t = 8.49$, $p < 0.001$). Significantly fewer Jays per km were seen in olive groves than in the pinewoods (Table 1), (though differences in visibility between the two habitats may make such a comparison invalid).

In October and November, the number of Jays seen per km of pinewood transect was strikingly lower than in July (Table 1; $t = 9.54$, $p < 0.001$), with no significant change over the autumn period and no significant variation between transects ($F = 0.44$, $p = 0.776$). In contrast to July, more Jays were seen in olive groves than in the pinewoods (Table 1), and the number seen per km of olives was significantly higher in autumn than in July ($t = 2.94$, $p = 0.01$).

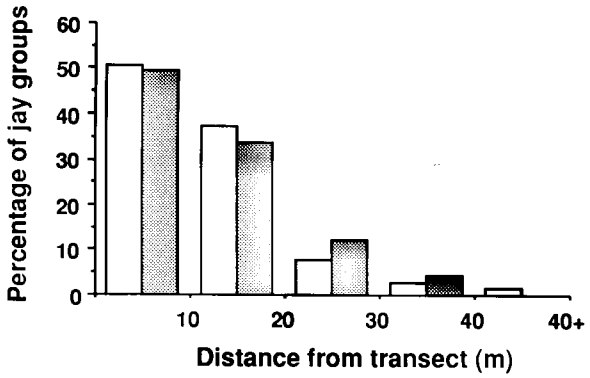

Fig. 2. The percentage of Jay groups (including single birds) in different distance zones outward from the pinewood transect lines, on transects made on foot (open columns) and by car (hatched). Sample sizes were 140 (on foot) and 133 (by car). There is no significant difference between the two distributions ($\chi^2 = 1.44$, $p > 0.05$).

Density

Most Jay groups seen in the pinewoods in July were within 10–20 m of the transect line (Fig. 2) and, since most were detected when still some distance ahead of the observer, it was unlikely that many within 10 m of the transect were undetected. There was no significant difference between transects carried out on foot and

Table 2. Estimates of Jay density (birds km^{-2}, using the Hazard Rate Model (Buckland 1985). Mean group size was 2.32 ± 0.15 in pinewoods and $1.29 \pm$ in olive groves.

Date	Transect	Length (km)	Groups seen	Density	SE
a) Pinewoods					
24 July	3	1.55	14	676	223
25 July	3	1.55	19	386	75
26 July	2+3+5	4.46	38	659	198
27 July	3	1.55	16	517	72
28 July	3+5	3.23	18	327	93
30 July	3+5	3.23	22	476	117
31 July	3+5	3.23	15	347	176
			Mean	484	54
b) Olive groves					
28 Oct	7	1.48	19	544	145
8 Nov	7	1.48	17	612	85
			Mean	584	34

No significant difference between the two mean values.

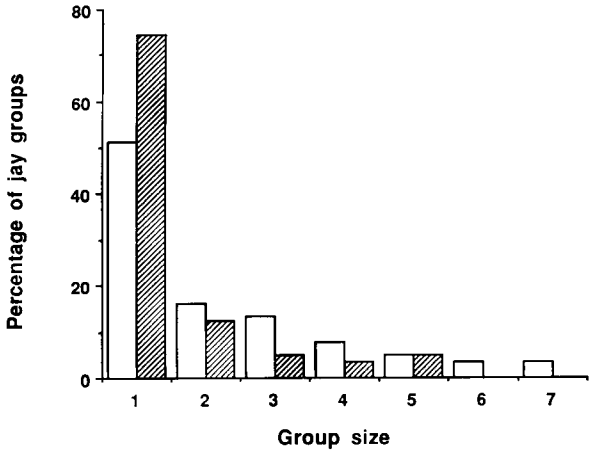

Fig. 3. The percentage of Jay groups of different size seen on pinewood transects made on foot (open columns) and by car (hatched). Sample sizes were 119 (on foot) and 121 (by car). The two distributions differ significantly ($\chi^2 = 15.69$, $p < 0.01$).

those by car (Fig. 2). A similar distribution was observed in transects of olive groves in October and November.

Density estimates based on these distributions, the number of groups encountered per km and mean group size (see below) suggested 327 to 676 Jays km^{-2} in pinewoods in July and 544 to 612 km^{-2} in the olive groves in October and November (Table 2). These estimates were not significantly different from cruder ones made by assuming that all the Jays within 10 m of the transect line were detected, i.e. that a band 20 m wide was swept. No estimates of density could be made in the dense scrub areas, where visibility was very limited.

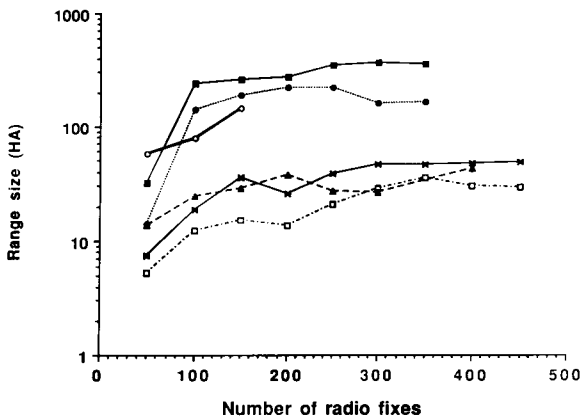

Fig. 4. Change in calculated range size in hectares (95% contour; harmonic mean analysis) with increasing number of fixes, added in chronological order. The lines represent: closed square, J1 (July); open circle J2 (July); open square, J3 (Oct); triangle, J3 (Nov); cross, J4 (Oct); closed circle, J4 (Nov).

Table 3. Estimates of the size of Jay ranges in July and in autumn.

Jay no.	Month	Range size (ha) by:		
		Minimum Convex Polygon	Harmonic Mean (95% contour)	N (fixes)
1	July	363.7	358.8	360
2	July	187.5*	146.6*	143
3	October	64.1	29.6	434
4	October	77.9	48.3	425
3	November	62.1	42.5	355
4	November	210.6	166.5	345

* range not fully revealed; insufficient fixes.

Group size

The most frequent encounter on transects in pinewoods in July was with a single Jay, more than 10 m from any

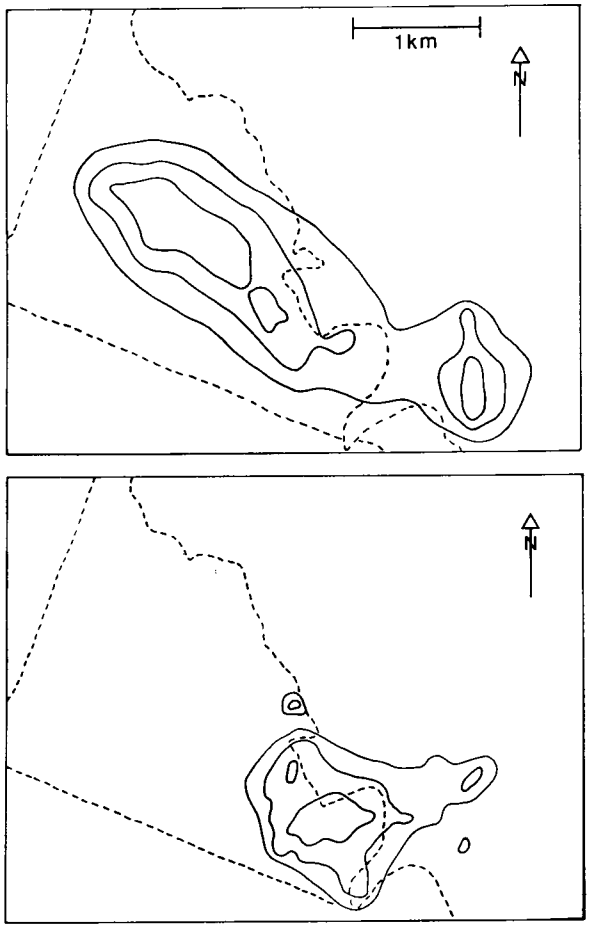

Fig. 5. Ranges of radio-tagged Jays in July (J1 upper; J2 lower) in the Maremma Natural Park, drawn by the Mcpaal harmonic mean analysis (see Methods). The contours are based on one or more centres of activity and comprise those which enclose the inner 50%, 80% and 95% of fixes. The dashed lines show habitat divisions.

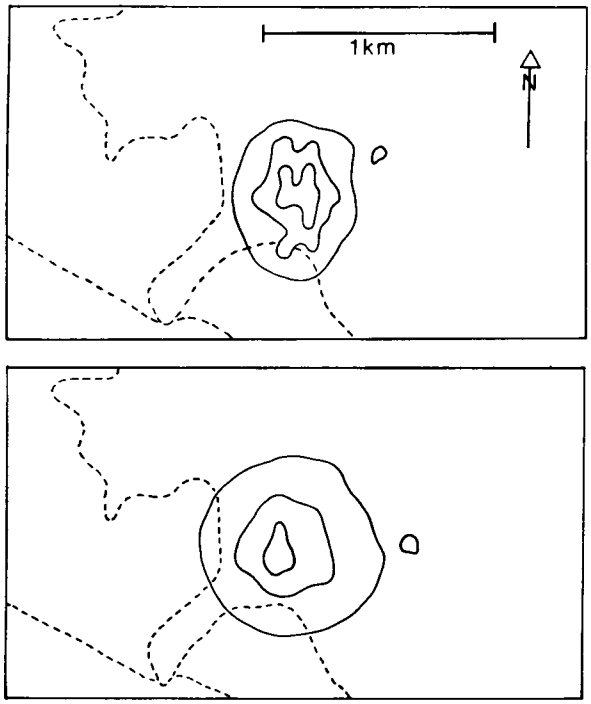

Fig. 6. Ranges of radio-tagged Jays in October (J3 upper; J4 lower). Map features as for Fig. 5, except that only the south-eastern portion of the study area is shown, on a larger scale.

others. This was significantly more often the case on transects made by car than on those made on foot (Fig. 3). However, most Jays seen were in groups of two or more (77% on walking transects and 51% on car transects), and up to seven birds were seen foraging together (Fig. 3). Juvenile birds were seen being fed by adults on several occasions and it is possible that most groups were pairs or family parties. A similar distribution of group sizes was observed in smaller samples on transects of the olive groves, but groups could not easily be counted in dense scrub areas.

Range size

When range size, taken as the area enclosed by the 95% contour in harmonic mean analysis (Kenward 1987), was plotted in relation to the number of radio fixes, in increments of consecutive sets of 50, three of the four radio-tagged Jays' ranges reached asymptotic values after 200–350 fixes (Fig. 4). The range of J2, however, with only 143 fixes, was not completely described, although the trend of increase in size with number of fixes was similar to those for J1 and for J4 in November (Fig. 4).

Range sizes estimated by the minimum convex polygon method (Kenward 1987) were consistently larger than those based on the area within the 95% harmonic mean contour (Table 3), presumably because of the disproportionate effect of a small number of outlying

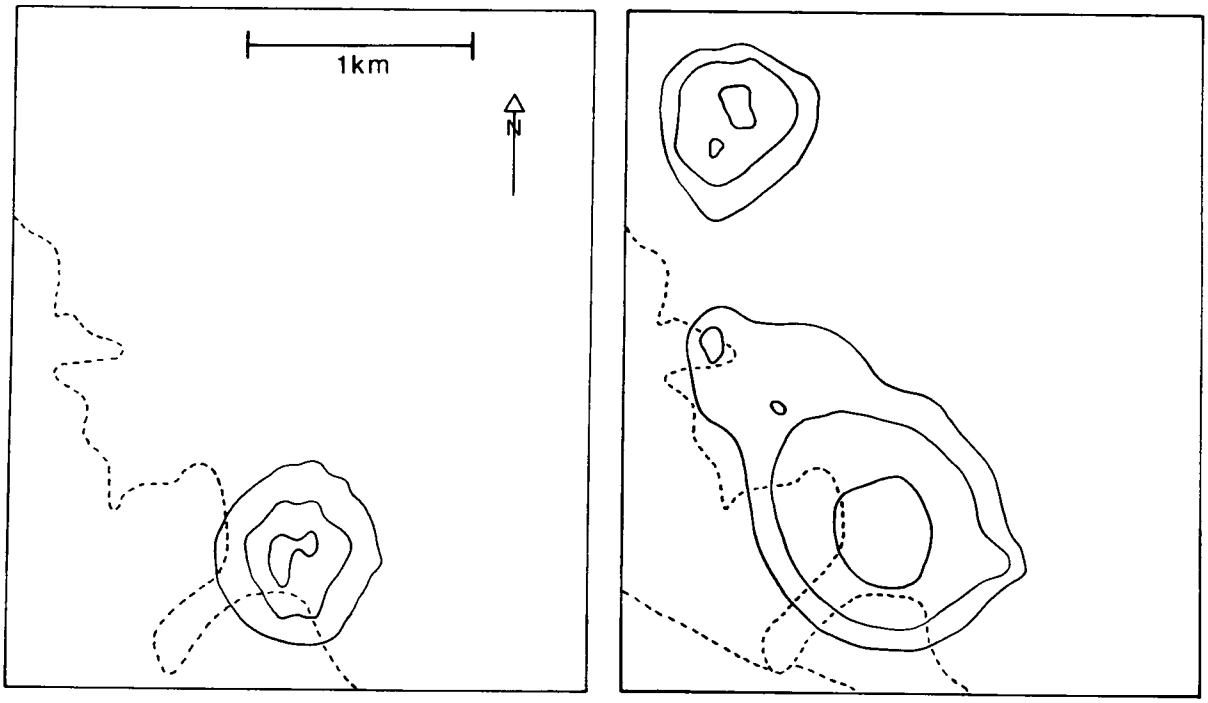

Fig. 7. Ranges of radio-tagged Jays in November (J3 left; J4 right). Map features as Fig. 6.

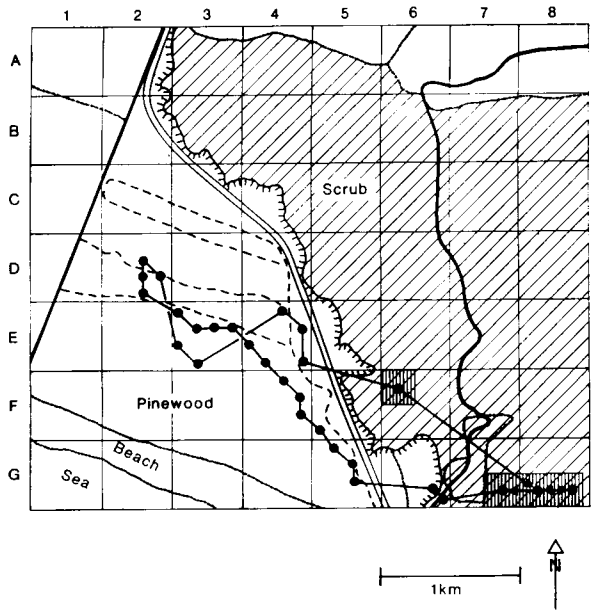

Fig. 8. The sequence of successive locations of J1 on 31 July 1988, determined by radio tracking. Dots show locations within 125 × 125 m grid squares and hatched areas show locations only within 250 × 250 m squares. Map features as in Fig. 1.

fixes on the former. Range sizes measured in October and November were considerably smaller than that of J1 in July, but J4 greatly increased its range size between October and November (Table 3).

J1 in July had a long narrow range extending over 4 km from a centre of activity in the scrub area to a second, larger one in the pinewood (Fig. 5a). J2's range, although incompletely revealed by the radio fixes, also extended over both habitats with a centre of activity in both (Fig. 5b). Both J3 and J4 in October and J3 in November had compact ranges, each with a single centre of activity confined to the scrub and olive zone (Figs 6a, 6b, 7a) but J4 greatly extended its range to the north-west in November and established a separate minor range (Fig. 7b) with rapid travel between the two areas. The whole range, however, was confined to the scrub and olive area.

In both periods of study, the two radio-tagged Jays tracked at the same time had very large overlap between ranges (Figs 5, 6 and 7), even though they were rarely in the same place at the same time and so did not seem to be in the same group.

To interpret the density estimates (above), it is important to know whether Jays avoided or were attracted to the pinewood tracks used as transect lines (Fig. 1). Of the 38 125 × 125 m grid squares where J1 was recorded, 42.1% contained a section of track compared with 27.1% of the 229 such squares in the pinewood as a whole ($\chi^2 = 3.56$, $p > 0.05$). J2 could be located usually only within 250 × 250 m grid squares; of the six which were used, half contained a section of track, the same proportion as in the whole pinewood (52 squares). There was thus no significant association between the Jays' occurrence and that of tracks. The somewhat higher proportion of track squares in J1's range may be related to most of the range falling in a part of the wood where tracks were particularly common (Figs 1 and 5a).

Movements during the day

In July, both of the radio-tagged Jays were found consistently at dawn and dusk in the scrub zone on a high ridge in the south-east of the study area, where they apparently roosted at night. They moved into the pinewood for the greater part of each day and returned to the scrub in the evening. J1's return journey was made by longer movements and by a more northerly route than its morning one (Fig. 8); more limited data on J2 suggested that it behaved similarly. In contrast, the daily movements of J3 and J4 in October and November were confined to the scrub and olive areas, with no radio fixes in the pinewood, apart from visits by J3 to a small patch of pines near the beach in the south-east of the study area.

Counts of Jays moving across the limestone ridge which divided the two main habitat blocks (Fig. 1) showed a pronounced passage from scrub to pinewood in the morning between 0600 hours and 0730 hours (Fig. 9a) and a return movement between 1900 hours and 2030 hours (Fig. 9b). Very few birds moved in the opposite direction to the main passage during either period. In spite of this large passage, observations in the pinewood before 0600 hours and after 2030 hours showed that some Jays apparently remained in the wood overnight and daytime transects through the scrub likewise showed that not all birds had travelled to the

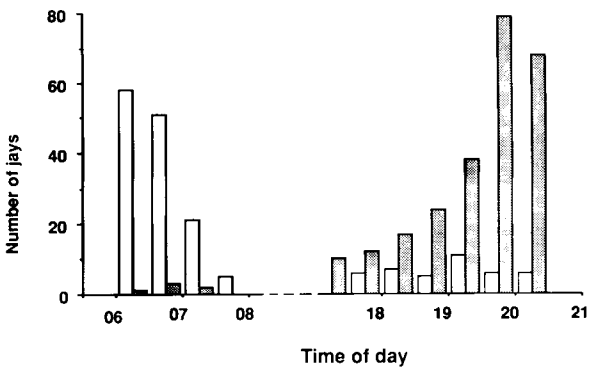

Fig. 9. Number of Jays seen moving from scrub to pinewood (open columns) and from pinewood to scrub (hatched columns) in 30 min periods at different times of day in July. Observations were made from a tower on the limestone ridge (Fig. 1). The time of sunrise varied from 0552 hours to 0606 hours and the time of sunset from 1851 hours to 1837 hours over the period of observation.

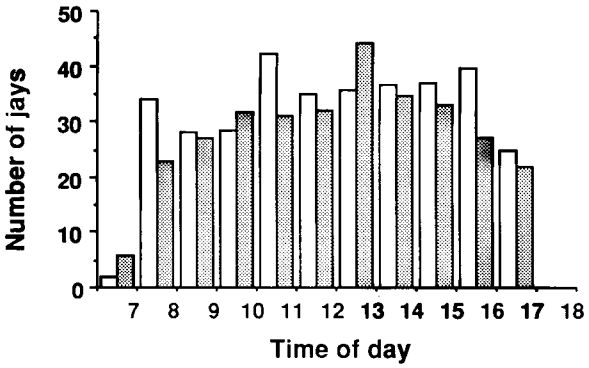

Fig. 10. Number of Jays seen moving from scrub to pinewood (open columns) and from pinewood to scrub (hatched colums) in one-hour periods at different times of day in October and November 1988. Observations were made from the same point as in July (Fig. 9). The time of sunrise varied from 0645 hours to 0702 hours and the time of sunset from 1742 hours to 1657 hours during the period of observation.

pinewood. In contrast to July, observations from the same vantage point in October and November showed a steady passage of Jays, roughly equally in both directions, throughout the day (Fig. 10). More of those moving from scrub to pinewood made long flights than did those moving in the opposite direction (85.4% of 733; 20.6% of 669 respectively).

Habitat use

In July, the two radio-tagged Jays changed from scrub to pinewood habitat between 0630 hours and 0830 hours, had 80–100% of their radio fixes in pinewood till 1730 hours and then changed back to scrub by 2030 hours (Fig. 11). The timing of these changes corresponded well with that of the passage of large number of other Jays (Fig. 9). In October and November the two radio-tagged Jays did not use the main pinewood (although many others did so) but they visited olive groves throughout the day. J3 used olive trees in two separate (morning and afternoon) periods, returning to the scrub in the middle of the day (Fig. 12a) while J4 had 50–70% of its radio fixes in olives throughout the day (Fig. 12b).

Diet, foraging behaviour and food supply

It was not possible to observe Jays in the dense scrub but those seen in olive groves and pinewoods in July were feeding almost exclusively on cicadas *Cicada orni*. The birds foraged by flying to a perch, usually on a branch but sometimes on a tree trunk or on the ground. From here, they looked around in all directions with

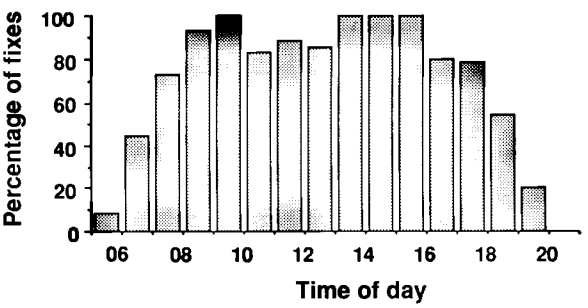

Fig. 11. The percentages of locations of radio-tagged Jays J1 and J2 which were in pinewood at different times of day in July 1988. Sunrise and sunset times as in Fig. 9.

considerable turning of the head and neck, before pouncing on a cicada or moving on to a new perch. Occasionally a cicada, disturbed as the Jay moved, was pursued in the air.

In October and November, Jays were seen foraging in oaks (mainly *Quercus ilex*) growing among the scrub. Of 166 birds close enough to the observer to see what they were carrying while flying from the scrub to the pinewoods, 78.9% had one or more acorns in their beaks. In contrast, of 86 Jays moving in the opposite direction, only two (2.3%) were carrying acorns. Two birds flying from the scrub were seen to be carrying fruits of the strawberry tree *Arbutus unedo*. A few

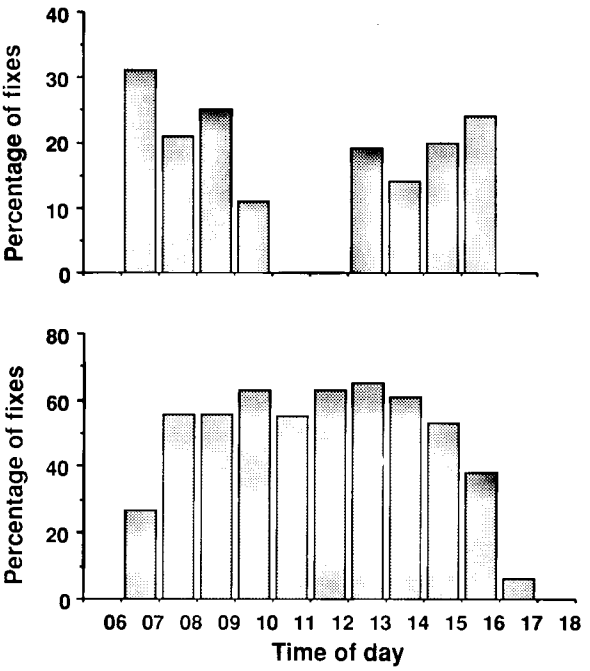

Fig. 12. The percentage of locations of radio-tagged Jays J3 (upper panel) and J4 (lower panel) which were in olive groves at different times of day in October and November 1988. Sunrise and sunset times as in Fig. 10.

observations were made of Jays apparently caching food and there was evidence, from shells and other remains as well as direct observation, that Jays were also consuming acorns immediately. Some birds were seen catching insects (e.g. Odonata), both in the air and on the ground and one Jay was seen eating grass seeds.

It was possible to make only provisional and indirect assessments of food supply and how it varied between habitats. There was a considerable volume of cicada song throughout the Park, especially in July each year, but the noise was loudest in the pinewoods, somewhat lower in olive groves and lowest in the scrub, but no equipment for precise sound measurement was available. The persistence of shed larval exoskeletons on the ground or clinging to tree trunks or other vegetation gave some indication of the number of cicadas which had emerged in each habitat, although the complexity of the vegetation made quantitative measurement very difficult. Preliminary observations showed up to 15 exoskeletons on individual pine trunks and around five m^{-2} on open areas in pinewood. Olive trees had up to four skins on them but fewer than one m^{-2} on the ground between them. Few exoskeletons were found in dense macchia scrub.

In contrast, the other major food, acorns, occurred only in the scrub areas, since oak trees did not occur in the pinewoods. It was not possible, however, to make any assessment of the abundance of acorns.

Large insects, other than cicadas, occurred in all the habitat types, but large scarab beetles (*Geotrupes spiniger, Trypcopris pyrenaeus, Sericotrupes niger* and *Thorectes intermedius*) were noticeably abundant on the ground in the scrub and olive groves in October and November.

Discussion

The abundance of Jays in the Maremma pinewoods in July was clearly much greater than would be expected in northern European woodlands. The overall encounter rate of more than 11 Jays per km (and up to a mean of 25 on one transect) was very much greater than would be predicted from Swedish studies (Grahn 1990). The overall density in the pinewoods estimated from the transect data was also very much higher than in the Swedish study area. Sample sizes, however, were considerably smaller than those considered desirable by Burnham et al. (1980), so the density values for the Maremma should be considered approximate. The Maremma values might be overestimates if the same birds were counted more than once or if the Jays tended to concentrate along the tracks used as transect lines. Efforts were made to avoid counting Jays more than once and neither of the birds radio-tracked in July showed a significant attraction to tracks. Although this evidence is inadequate, any such tendencies would be offset by any birds which avoided the tracks after an earlier disturbance and by any which were not detected by the observer. It is thus likely that the high July density was a real phenomenon.

The rate of encounter with Jays in the pinewoods in the autumn (Table 1) was more similar to that which would be expected in Sweden (from density data in Grahn 1990), but by then the density had increased in the olive groves and probably also in the scrub zone (although this could not be surveyed). This suggests that the same Jays stayed in the Park, but moved habitat between seasons.

There was no evidence of territorial behaviour, either in July or in the autumn, since the two Jays which were radio-tagged in each period had very considerable overlaps between their ranges even though they did not appear to associate together. It should be emphasised, however, that the status of the radio-tagged Jays was not known and it is possible that non-territorial birds had been caught selectively. Grahn (1990) also suggested that Jays in his Swedish study area did not defend exclusive territories outside the breeding season and became more tolerant of intruders. However, his birds remained within small ranges with none of the very extensive ranging found in the admittedly small sample of Jays in the Maremma.

The dramatic change in habitat use, from pinewoods in July to scrub and olive groves in autumn was clearly associated with a change in diet from cicades to acorns (and possibly other fruits and seeds), following an obvious peak in abundance of cicadas in midsummer together with their disappearance and the ripening of the acorns in autumn. Although no Jays were radio-tracked over the transition period, the dramatic seasonal decrease in the frequency with which Jays were encountered in the pinewood (Table 1) makes it very likely that individuals must move their ranges from summer to autumn; whole-year ranges are thus likely to be much larger than those indicated in Table 3.

In addition to these seasonal shifts, there were pronounced daily movements between habitats. In July the majority of the Jays spent the day in the pinewoods, where cicadas seemed to be most abundant and where the large open-canopied pines may have provided the best opportunities for capture. The mobility of cicadas, which could respond to the presence of the Jays by flying away, may have created the need for large ranges in July, so that the birds could move continually into new undisturbed areas. However, it is less clear why the birds did not spend the night there also, instead of making the journey to a high ridge in the scrub zone, with its possibly risky crossing of an open area below the limestone cliff. It is possible that the dense thorny scrub provided particularly secure roosting sites but there may also have been food, such as beetles, which were available there at dawn and dusk (Pigozzi 1987).

In autumn, the regular movements of Jays between the scrub and the pinewoods, carrying acorns only in

one direction, suggests that the birds might have been caching the food among the pines, since such storage of acorns has been described in other areas (Chettleburgh 1952, Schuster 1950, Turcek and Kelso 1968) and Jays have been observed to transport acorns up to 18 km from an oakwood (Wadewitz 1976). The similarity in rate of passage in both directions suggests that the same birds were making repeated return journeys. However, the two Jays radio-tagged in October showed that not all of the local population made such movements, but that some were visiting the olive groves instead. These individuals may have been caching acorns among the olive trees, but they may also have been foraging, possibly on beetles or other insects.

The diversity of habitats in the Maremma, with an abundant insect food in summer and a supply of acorns which, as well as being eaten immediately in autumn, could be cached and recovered throughout the rest of the year (as has been observed elsewhere by Bossema (1968, 1979), Chettleburgh (1955), Owen (in Goodwin 1986) and Swanberg (1969)), may well be the reason why the area supports such a high density of Jays. It would be of great interest to investigate the density, range and social organisation of this population during the breeding period.

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