

The Systematic Study of Radio-tagged Raptors: II. Sociality and Dispersal.

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SUMMARY

The advantages of using radio-tracking for studying sociality and seasonal movements are put into context with previous techniques. Both phenomena are best studied with interval sampling. Analyses of static and dynamic interactions are discussed, followed by a description of field techniques developed to collect data on survival, dispersal and other movements. Finally, four examples use data from Northern Goshawk (*Accipiter gentilis*) and Common Buzzard (*Buteo buteo*) studies to illustrate how the methods can be applied and their importance for conservation.

INTRODUCTION

Kenward & Walls (this volume) discussed the advantages of radio-tracking over ringing in the study of raptor survival and showed how home range data can be analysed. This paper will look at the study of sociality in more detail, and describe how the mechanics of dispersal can be investigated. It starts, however, by discussing analysis of the data before describing its collection, to stress the need for planning.

Radio-tagging is an ideal technique for tracking animals continuously. Whilst this may be informative in the initial stages of a study, objective analysis can then be difficult (Macdonald, Ball & Hough 1980). When studying sociality, intermittent sampling has the following advantages over continuous monitoring: (i) independence of fixes can be maximised, (ii) more individuals can be studied simultaneously (see Kenward & Walls this volume), (iii) locations relative to other animals, which may not be seen when tracking only one animal, can be recorded for interaction analysis and (iv) disturbance by the observer can be reduced.

Ringing provides some essential information on the abundance and gross movements of many birds. However, there can be problems with bias in ringing studies, especially in the case of threatened species such as raptors, and ring recovery can be slow (Newton 1979; Kenward 1992). Whilst ringing is still essential, this paper will demonstrate how some questions may be answered more efficiently.

DATA ANALYSIS

Macdonald, Ball & Hough (1980) point out that the overlap in ranges of individuals, described by whichever model, gives an incomplete picture of the interaction between them. Many animals may use the same place but at different times. This is most easily seen across species, (for example lions and wildebeest may occupy the same ranges but will only interact very briefly). A good intraspecific example comes from Davies & Houston (1983) who showed how two Pied Wagtails (*Motacilla alba*) patrolled the same stretch of river bank but at different times. This was partly territorial and partly due to the renewal of their food. Macdonald, Ball & Hough (1980) therefore stressed the difference between static and dynamic interactions. A static interaction is the spatial overlap of one animal's home range on another's (as above). Conversely, a dynamic interaction is the relationship between movements of two or more animals, depending on whether they avoid or attract each other. In essence, a time dimension has been added.

The evaluation of the distance between animals at any given time can be complicated. Macdonald, Ball & Hough (1980) used the Ornstein-Uhlenbeck (O-U) diffusion process to simulate marginal distribution of the distances between two animals, and then tested whether the observed distances differed significantly from the prediction. Not only is this a complicated procedure, but it also has some dubious theoretical assumptions, which were questioned by the authors themselves. For example the O-U model assumes that an animal tends towards the centre of its range, which is often not true, as for example if a bird that nests on the edge of its range commutes long distances each day to a distant food source. Moreover, in testing for significant differences between each pair of animals, it assumes that the set of locations for each animal are independent data, yet again a dubious assumption. There are similar problems with all parametric home-range models. To check for dynamic interactions without any modelling, or assumptions of independence within the data set from each animal, the following method can be used (Kenward 1992, Kenward in press):

First the mean distance (D_o) between fixes observed in the same sampling round is calculated:

$$D_o = \frac{1}{n} \sum_{j=1}^n \sqrt{(x_{1j} - x_{2j})^2 + (y_{1j} - y_{2j})^2}$$

where n is the number of fix pairs and (x_{ij}, y_{ij}) are the coordinates of animal 1 at time j . Thus $x_{1j} - x_{2j}$ is the distance along the x -axis between individuals 1 and 2 at time j .

The expected mean distance (D_e), if locations are used at random with respect to the other animal, can be found by calculating the mean distance between each fix from one individual and all fixes from the other individual:

$$D_e = \frac{1}{n^2} \sum_{j=1}^n \sum_{k=1}^n \sqrt{(x_{1j} - x_{2k})^2 + (y_{1j} - y_{2k})^2}$$

where j and k are times, such that $x_{1,1} - x_{2,10}$ is the distance along the x -axis between individual 1 in its first position and individual 2 in its tenth.

The observed and expected distances are compared using Ivlev's index to give a coefficient of sociality:

$$S_c = (D_e - D_o) / (D_e + D_o)$$

which is symmetrical about 0, the result obtained if the animals move independently. Results from this index tend towards -1 if the observed distance is much greater than the expected distance, suggesting avoidance. A tendency towards +1 will result from the observed distances being closer than expected, suggesting some attraction. Since each pair of animals produces a single measure, there is no need to make any assumptions about independence within each set of fixes. Results are most consistent if D_o and D_e are the geometric means.

Although the calculations are straightforward, care must be exercised when collecting and analysing these data. When looking for dynamic interactions, animals must be found during every

sampling period. If only those distances between fixes taken within a given time period are used, there is a tendency to discard long distances because these tend to occur when there is a delay in finding one individual. This will result in a bias towards attraction, since only those fixes collected at the "same time" are used.

Dispersal in the Common Buzzard has previously been recorded by observation (Olsson 1958) as well as by ringing and wing-tagging (Picozzi & Wier 1976; Tubbs 1974). The data consist of observing general movement during certain seasons, or an absence of a wing-tagged bird. Ringing provides a natal area and a final position, usually for a dead specimen. Nothing can be said as to what has happened in between. Moreover, first year recoveries are a biased sample: they represent unsuccessful birds, which died. Thus Picozzi & Weir (1976) found that 69% of Buzzard recoveries were a result of shooting or poisoning, but is there really so much human impact on Buzzards? Picozzi & Weir (1976) also noted that only first year birds were found more than 100 km from their nest and most adult recoveries are found within 50 km. Was this because unsuccessful, dispersing birds were over-represented in the recoveries, or because juveniles really travelled further than adults? Continuous movement records, from radio-tracking, can answer these questions.

FIELD TECHNIQUES

Our present field techniques are described, both to show how a regime has been developed to permit quantitative analyses and to give some idea of the manpower involved. Although details are specific to Buzzards, the general procedures can be applied to all raptors.

After tagging birds shortly before or after fledging, all were monitored for survival twice a week for at least four weeks. The reason for this frequency was to try and identify causes of death, before the carcass decayed, during a period of presumed high mortality (Newton 1979). Deaths are likely because of the inexperience of the young, but there is also the possibility of adverse effects from harness tags. During this period in 1991 some broods were visited once a day. All members of the brood were found on each occasion, so dynamic interactions could be analysed. Birds were visited only once a day so that broods could be monitored at 13 nests. With a day in between, locations were likely to be independent.

Throughout the winter, birds were checked once a week for survival and location. In late October, after most dispersal, the local birds were found three times a day for a period of ten days to establish range characteristics. The stability of winter ranges, extrapolated from the ten-day track and weekly checks over two years, means that future mortality checks could be reduced to once a month. Lost birds were best sought for by air shortly after the dispersal period. At the end of February, checks were increased to twice a week to detect any returning dispersers, and because all birds tended to move about more in spring.

Initially it took 1.5-2 days to check every Buzzard through the dispersal period. Once they had settled down it was possible in one day, for those within 50 km. During the spring time, as the Buzzards started to move about more, monitoring took 1.5-2 days but was quite variable.

EXAMPLE 1: SOCIALITY OF WINTERING GOSHAWKS.

Between August 1976 and March 1977, 14 Goshawks were trapped and tagged on the Frötuna estate in central Sweden. Ten of the hawks were tracked for a period of at least ten days, the time in which range size reached a maximum for two Goshawks released in Britain (Kenward 1982).

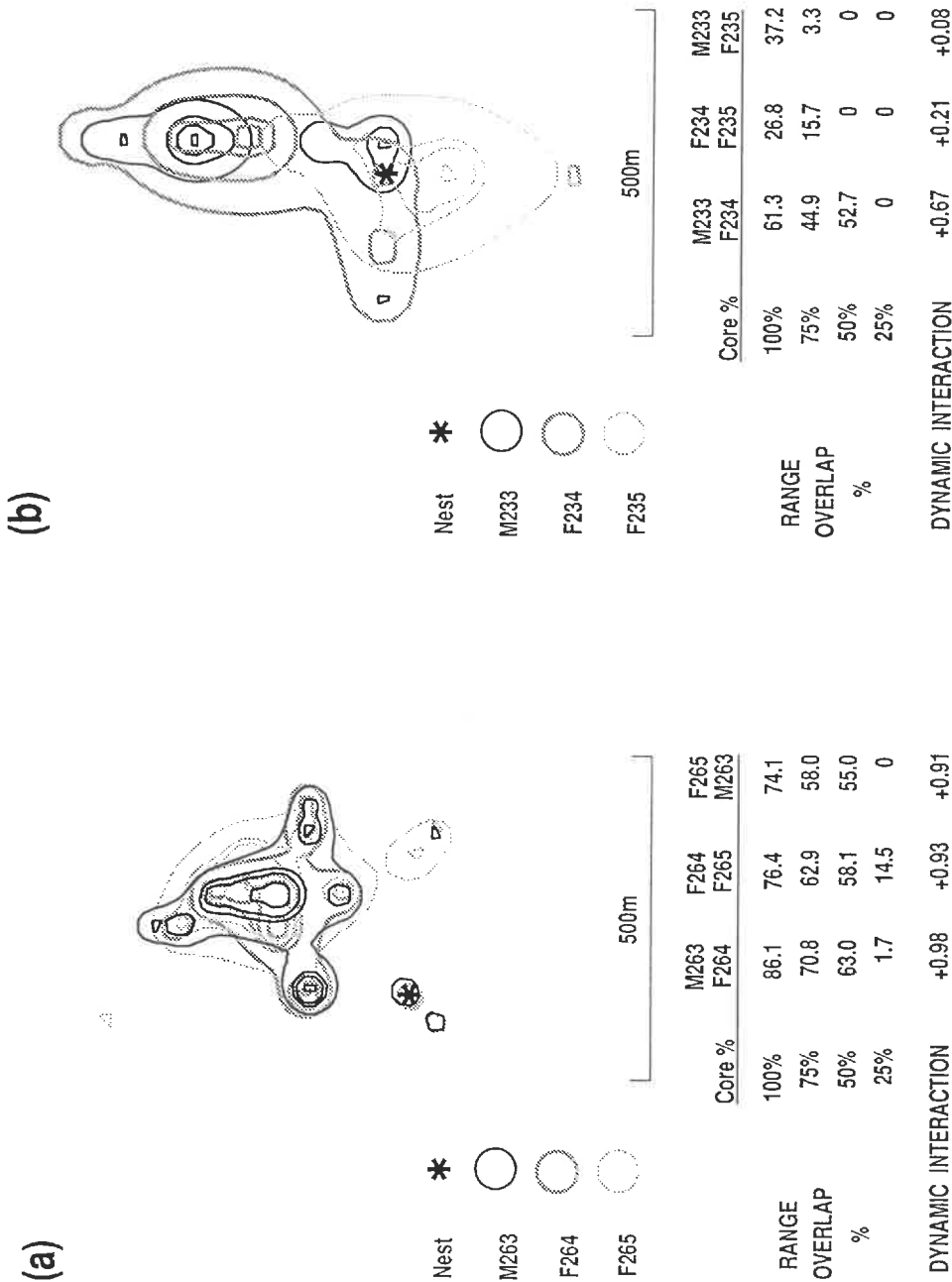
Five males tracked during this period overlapped each other extensively, particularly around some Pheasant (*Phasianus colchicus*) feeding areas. The average percentage overlaps for each pair, calculated by three methods for the outlines which contained 100% and 50% of the locations, are shown in Table 1 (see also Fig. 2 and discussion in Kenward & Walls, this volume). The static interaction is high, even when only the most dense 50% of fixes are used, except when using cluster analysis. These overlaps tell us nothing of any temporal separation that may be expected from the territorial behaviour most raptors exhibit around their nest (Newton 1979).

The dynamic interactions shown in the last column are consistently neutral, indicating that the hawks neither avoided nor attracted each other. There appears to be no relationship between the

Figure 1 The ranges of six young Goshawks, in two broods, around their nests. The harmonic mean contours are for 25%, 50%, 75% and 100% cores.



Figure 2 Theranges of six young Buzzards, in two broods, around their nest. The harmonic mean contours are for 25 %, 50 %, 75 % and 100 % cores.



amount of static overlap and the index of dynamic interaction (S_c). Hawks JM3 and YM5 overlapped quite extensively throughout all cores (even the 50% cluster) and yet their S_c score shows that they tended, if anything, to avoid each other. The static overlap is therefore due to another factor besides sociality, most likely the abundance of pheasants which provide a suitable food source. However, there is no consistent evidence that the hawks avoided each other, and therefore no hint of territoriality.

Table 1 The average overlap of five male Goshawks compared with the coefficient of sociality. The percentage overlap is shown for outlines containing all the radio locations and the densest 50%, calculated (a) as polygons peeled towards the harmonic mean centre (b) by cluster analysis and (c) by harmonic mean contouring.

Hawks	Core%	(a) Peeled polygons		(b) Cluster analysis		(c) Contours (H_c)		S_c
		100	50	100	50	100	50	
YM6 & JM3		61	62	61	5	81	53	+0.02
YM6 & YM5		67	52	67	1	78	67	-0.02
YM6 & JM10		62	60	62	0	74	26	+0.08
YM6 & JM11		54	63	54	0	80	47	0.00
JM3 & YM5		64	38	64	43	83	63	-0.03
JM3 & JM10		37	57	37	31	69	50	+0.01
JM3 & JM11		73	82	73	9	79	81	+0.03
YM5 & JM10		58	12	58	10	76	22	+0.01
YM5 & JM11		62	35	62	19	81	51	+0.12
JM10 & JM11		27	54	27	17	68	67	-0.01
Average		57	52	57	14	77	53	+0.002

EXAMPLE 2: SOCIALITY OF POST-FLEDGING GOSHAWKS.

Radio tags were fitted to a total of 187 young Goshawks, from 130 broods found on Gotland (Sweden), between 1980 and 1984. Figure 1 shows the ranges of two broods aged between 65 and 90 days around their nest. The harmonic mean contours represent 100%, 75%, 50% and 25% cores. Fixes found within 50m of the nest were excluded, but the nest is still within the 50% contour of every range. This could be due to a resource, such as food which is dropped at the nest by the parent, providing the necessary focus.

In the first nest, two birds (F339 & M340) are cohesive, but both static and dynamic interaction analyses showed that the other bird (M341) moved independently. In the second brood, M332 had little contact with F331, but was often together with F330, which was sometimes with F331. These results show that some of the birds were associating with each other away from the nest, whereas others were not. Only two nests have been used here, to simplify the explanation. The variability between nests shows that interpretation of such small samples is impossible. However when more nests were examined, with at least two pairs of observations before 65 days, S_c averaged +0.59 for 13 male-female sets, +0.73 for 7 female-female sets and +0.69 for 10 male-male sets. As the young hawks got older, however, they became less cohesive (Mann-Whitney U-tests, $P<0.025$) and male-male sets became less cohesive than female-female sets ($P<0.009$) but males showed no tendency to avoid females (Kenward, Marcström & Karlbom in press).

EXAMPLE 3: SOCIALITY OF POST-FLEDGING BUZZARDS.

In 1990 and 1991, radio-tags were fitted to 58 young Common Buzzards from 38 broods found in a 7km x 20km strip of E.Dorset, England. In 1991, 14 young Buzzards, 65-90 days old, were located once a day for ten days. The resulting harmonic mean contours of two broods' ranges are shown in Figure 2. Unlike Goshawks, activity is not centred around the nest, which lies on or beyond the 75% contours. However core overlaps were very extensive, especially at nest (a).

The coefficients of sociality between individuals at nest (a) are very high suggesting a very strong cohesion between all of them. In this particular case there also seems to be some correlation between the static and dynamic overlap except when using the 25% cores. The second brood had two cohesive hawks (M233 & F234) and a third (F235) which was fairly neutral. Again there was some correlation between core overlap and the dynamic interaction coefficients, but not at 100%. As in the Goshawks, having only two nests makes interpretation impossible.

EXAMPLE 4: BUZZARD DISPERSAL

The value of radiotracking many individuals is also shown by results from the 58 Buzzards tagged in Southern England. Of 46 Buzzards that survived the postfledging period, and whose radios were still working, two thirds dispersed to set up a winter range elsewhere. The dispersal period was short: 18 of 30 dispersers left within three weeks from mid-August to mid-September. This one-way dispersal occurred at the same time as exploratory journeys which took several individuals up to 20 km from the nest. This may be the "local wanderings" described by Picozzi & Weir (1976). but it is far easier to quantify these movements when the positions of all birds are definitely known, rather than having to rely on sighting an individual or assuming it to have gone.

During the spring of 1991, those birds that had remained within a kilometre of their nest suddenly became far more exploratory. One was found over 40 km away despite the average winter range being only 1.4 km in diameter. Simultaneously, five out of eight of those that had dispersed, and spent the winter within a similarly small range, returned to their natal area. Two others returned later. One of these hawks had disappeared without trace during the dispersal period, despite two aerial searches covering more than 100 km from its nest. The hawk not found back at its nest site had not dispersed far and could have returned within an hour, missing detection by the twice-weekly check. Unfortunately only one of those birds had a back-pack tag and could therefore be tracked beyond the spring. This bird then disappeared until spring 1992, when it returned once again. A similar pattern is now emerging among the 1991 cohort. It seems, therefore, that philopatry may explain why first year birds were found further from their natal area.

It may be that these are not representative years but, having followed 23 individuals throughout each year, comparisons are possible between years. If further tracking proves Buzzards to be truly philopatric, and they end up breeding near their natal area, then they may be better aided in returning to distant unpopulated areas by re-introduction programmes than by a *laissez-faire* approach based mainly on protecting established populations.

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