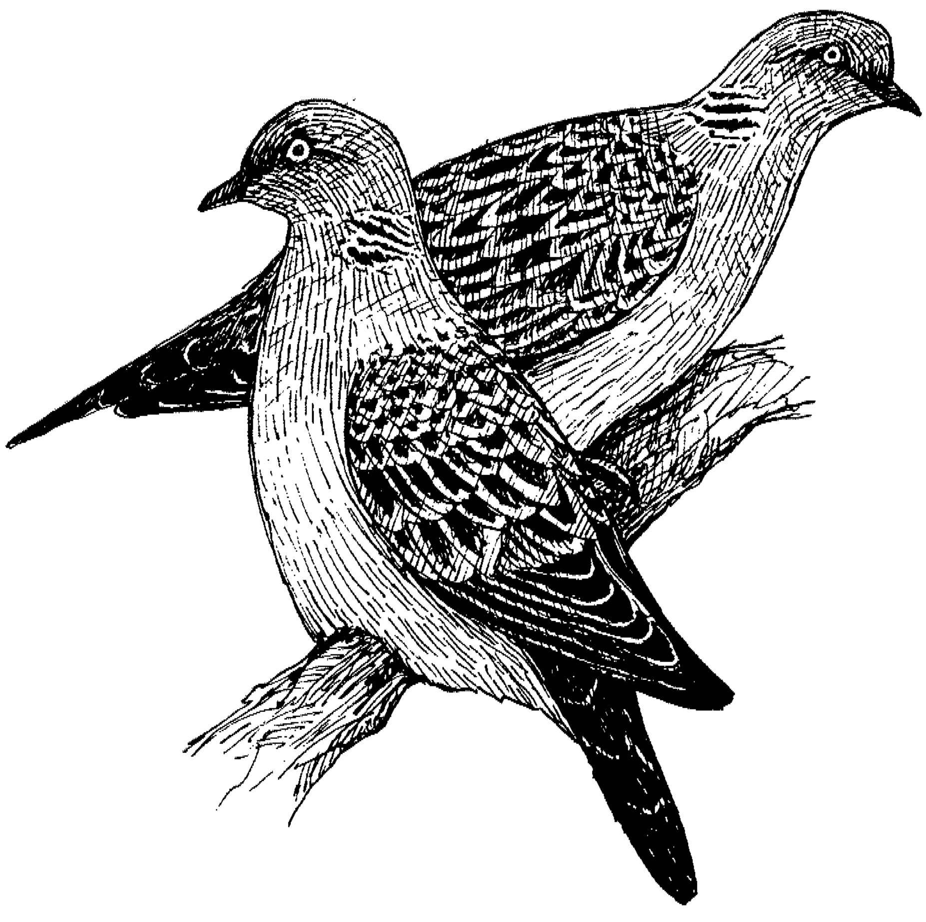
ENGLISH NATURE

The summer ecology and habitat use of the turtle dove

A pilot study

No. 219 - English Nature Research Reports



working today
for nature tomorrow

ENGLISH NATURE RESEARCH REPORTS
No 219

THE SUMMER ECOLOGY AND HABITAT USE OF THE TURTLE DOVE : A PILOT STUDY

John R. Calladine, Francis Buner & Nicholas J. Aebischer
The Game Conservancy Trust,
Fordingbridge,
Hampshire
SP6 1EF

A study funded by the Lowlands Team of English Nature and managed, on their behalf, by Phil Grice of the Birds Unit of the Uplands Team.

Further copies of this publication can be obtained from:

The Enquiry Service
English Nature
Northminster House
Peterborough
PE1 1UA

ISSN 0967-876X

CONTENTS

3.8 Ringing and the resighting of colour rings .....

SUMMARY

1. In Britain, the Turtle Dove (*Streptopelia turtur*) has recently experienced a dramatic population decrease (-72%) and range contraction (-25%), following a lengthy period of increase and expansion. Similar observations have been made elsewhere in Europe. Despite conservation concern over its current status, the ecology of the Turtle Dove is relatively little known. The aim of the present six-month pilot study, which was undertaken at two sites in East Anglia in 1996, was to assess the feasibility of a future, detailed investigation into the summer autecology and conservation needs of the Turtle Dove in England.

2. Census work, using constant-effort-search and transect methods, suggested that the degree of territory occupancy and/or the detectability of Turtle Doves declined from the commencement of the study (late May) at one site and from early July at the other.

3. The number of Turtle Doves seen and their behaviour were recorded on 3-km transects, which were walked at 2-hour intervals during the day every 2 weeks through the field season. Singing activity and the detectability of Turtle Doves was generally greatest in the early mornings. Both were reduced and variable during the remainder of the day. Therefore the most efficient time of day to census Turtle Doves is within 3 hours after sunrise, when, in the present study, over 60% of territory-holding males were detected.

4. The number of breeding attempts recorded for individual pairs was reduced compared to previous studies. In the present study, only 4 out of 28 pairs (14%) were thought to have laid a second, as opposed to a replacement, clutch. Earlier studies suggest that 2 or even 3 breeding attempts in a season were normal.

5. Seed remains in faeces were readily identifiable and their frequency of occurrence appeared to reflect availability within the foraging area. Natural supplies of food may have been scarce in the early summer and the diversity of seeds taken by Turtle Doves in 1996 was probably low when compared to previous studies.

6. The behaviour of individual Turtle Doves was successfully investigated via radio-telemetry, while colour-ringing was of limited use. In the present study, the movements of 4 tagged Turtle Doves were effectively monitored. Individual home range size was 94.0 - 460.2 ha. The sample size was too small for statistical analyses of habitat use but trends suggested that hedges, pasture and cereals were important.

7. Recommendations for future work include:-

a) The radio-tracking of at least 30 Turtle Doves per annum, which will: permit statistical analyses of habitat use and individual time budgets; increase the efficiency of nest finding and the location of roosts and feeding sites; permit nest monitoring with minimal disturbance.

b) An assessment of the feasibility of radio-tagging Turtle Dove pulli, to investigate the fledging process and post-fledging dispersal and survival.

c) A comparison of food availability and quality with food utilisation by Turtle Doves.

d) Calibration of the use of faecal remains to characterise the diet of Turtle Doves.

1. INTRODUCTION

1.1 The study species

The Turtle Dove (*Streptopelia turtur*) breeds over much of Europe (south of *c.* 55° - 60° N), west Asia and north Africa. It is a trans-Saharan migrant, with most spending the winter in the northern tropics and semi-arid Soudanian and savanna zones of Africa (Cramp 1985). The British Isles are at the northern edge of its breeding range, where the species is now largely restricted to southern, eastern and central England (Gibbons *et al.* 1993). Survey and census work organised by the British Trust for Ornithology (BTO) suggests a 72% decline in abundance since 1979 (Marchant *et al.* 1990, Marchant & Wilson 1996) and a 25% contraction in range between the periods 1968-1972 and 1988-1991 (Gibbons *et al.* 1993). The recent marked reduction followed a lengthy period of apparent increase and range expansion from at least the mid-19th century (Spencer 1965, Marchant *et al.* 1990). Some local declines were apparent from the 1950s (Goodwin 1989) but trends from census work suggest that the general increase continued up to 1978/79 (Marchant *et al.* 1990). A few local studies showed Turtle Dove abundance to vary in a manner similar to the national trend (eg Duckworth 1992, Miller 1992). The pattern of range expansion followed by recent declines has been repeated elsewhere in Europe, commencement of declines being noted from the 1950s onwards (Holzwarth 1971, Kraus 1972, Cederwall 1978, Hongell & Saari 1983, Bijlsma 1985, Yeatman-Berthelot & Jarry 1995). Overall, up to about 60% of the European population (for which trends are known) declined between 1970 and 1990, especially from the mid-1980s onwards, and particularly in western Europe (Tucker & Heath 1994).

The Turtle Dove has been surprisingly little studied in Britain, where the only ecological study was completed in the 1960s (Murton *et al.* 1964, Murton 1968). The requirements of the species are, therefore, little understood. Moreover, there is no information on its ecology in a modern agricultural environment, which has changed considerably since the 1960s (Grigg 1989). The factors causing the recent marked population decline, and the stages of its life-history at which such factors operate, are currently unknown.

1.2 Aims of the study

The present study, undertaken in 1996, was a six-month pilot project to assess the feasibility of studying the summer ecology of the Turtle Dove in England. The following objectives were addressed:-

1) Collection of basic information on behaviour, nest-site choice, breeding success and foraging and roosting locations.
2) The development of an optimal methodology for censusing the species.

3) Analysis of faecal samples to determine diet.

4) Assessment of trapping, marking and radio-tracking Turtle Doves and the potential contribution of these methods to monitoring habitat use and time-budgets of individual birds, and also, to achieving the other objectives of the project.

5) A review of relevant literature on the Turtle Dove.

The ultimate aim was to assess the feasibility of a future, detailed investigation into the summer autecology and conservation needs of the Turtle Dove in England.

1.3 Study sites

Two contrasting sites were selected, (1) Ixworth Thorpe, north-west Suffolk, and (2) Deeping St Nicholas, south Lincolnshire (Figure 1). The Ixworth Thorpe site (0°49' E, 52°20' N) consisted of mixed arable and pasture on gently undulating ground (between *c.* 23 m and 40 m above mean sea level) drained by a small, north-west flowing river, the Black Bourne. Most of the pasture was on the damper ground by the river. Small, semi-natural woodlands, recent plantations, isolated trees and hedges (of a variety of size and structure) were a feature of the landscape. Houses (including small villages), other buildings, gardens (some large and with trees and shrubs) and some rough ground and scrub (a conservation area, game cover and derelict land) also occurred. Neighbouring ground was generally similar but with fewer recent plantations and fewer hedges in some areas.

The Deeping St Nicholas site (0°13' W, 52°44' N) consisted of intensively farmed arable land within fenland. The extensive flat topography (*c.* 2 - 3 m above mean sea level) was interspersed with a few recent small plantations, buildings and gardens (including an 'extended' village), few hedges and an extensive network of drains and ditches. Many of the latter features were bordered by long, narrow strips of permanent grass.

A third site at Hockwold, south-west Norfolk (0°34'E, 52°27'N) was initially studied, however it was found impossible to commit sufficient time to three sites and so the Hockwold site was abandoned, although it would be highly suitable for future study.

2. METHODS

2.1 Field Observations

Field work at Ixworth Thorpe was undertaken by J.C., from 24 May - 10 September 1996, and at Deeping St Nicholas by F.B., from 21 May - 29 August 1996.

2.1.1 Territory Mapping

An area of *c.* 560 ha at Ixworth Thorpe was surveyed eight times (25-26 May, 1-3 June, 17-18 June, 6-8 July, 22-23 July, 5-6 August, 21-22 August and 31 August - 1 September) using Common Bird Census (CBC) methodology (Bibby *et al.* 1993), recording and mapping all encounters with Turtle Doves and their behaviour. Types of behaviour recorded included singing, displaying, flying, feeding, drinking, nest building and copulating. Feeding sites were also described (Section 2.14). The surveys were carried out on foot, walking along hedges and across fields so to cover all ground and maximise the chances of seeing detectable Turtle Doves. Incubating birds sitting tight on nests were unlikely to have been detected by such an approach. Following a general impression that Turtle Doves were more detectable in the early mornings, derived from pilot fieldwork (see Section 2.1.2), all such surveys were undertaken between 04.30 and 10.00; 2-3 days were therefore required to cover the whole area. In addition to the 'systematic' survey, supplementary observations were made while carrying out other fieldwork (eg. nest finding/monitoring, radio tracking). In general, supplementary observations were spread throughout the daylight hours and evenly over the study area. A breakdown of habitats covered by the survey is given in Table 1.

The numbers of individual Turtle Doves and singing Turtle Doves seen or heard during systematic surveys were used to assess variation in singing frequency, territory occupancy and/or individual detectability through the season. Data from the systematic surveys, combined with the supplementary observations, were used to produce territory maps. Maps were produced covering two-week periods through the season, in addition to a combined map for the whole season. In accordance with CBC methodology (Bibby *et al.* 1992), a territory was identified by observations of nests, nest-building, singing birds, display flights, recently fledged young or a combination of these criteria. Head-bowing (a display by males directed towards females) was not included as a territory indicator as it was frequently observed at feeding and loafing/roosting sites. The chosen criteria had to be observed at least twice at the same site, or in close proximity to it, for a territory to be recognised. On some maps covering two-week periods, just one such observation was included as a territory indicator, but only if there was another such observation outwith the two-week period. The two-week period maps were used to indicate territory occupancy/detectability through the season.

At Deeping St Nicholas, Turtle Doves were, in general, more sparsely distributed than at Ixworth Thorpe. In order to increase the sample of individuals and territories surveyed, a much more extensive area (*c.* 7000 ha.) was used as a study site at Deeping St Nicholas. Consequently a survey identical to that undertaken at Ixworth Thorpe was not possible at Deeping St Nicholas. At the latter site, a route which passed close to most hedges, plantations and scrub was cycled each month and all Turtle Doves were recorded as above. All singing and displaying Turtle Doves and even birds seen in or close to suitable nesting habitat (hedges, bushes etc.) were recorded as potential territories. A breakdown of habitats in the study area at Deeping St Nicholas is given in Table 2.

2.1.2 Daily and seasonal variation in singing frequency and individual detectability

To determine temporal variations in singing frequency and individual detectability of Turtle Doves, a transect *c.* 3 km long was walked at each site at two-hourly intervals throughout the daylight hours, starting at 05.00, on one day approximately every two weeks (Figures 2 & 3). At Deeping St Nicholas these transects were carried out on 5 June, 18 June, 2 July, 20 July, 7 August and 21 August and at Ixworth Thorpe on 30 May, 11 June, 25 June, 16 July, 1 August and 14 August. Each transect took approximately 1 hour to walk. All encounters with Turtle Doves were recorded as for the territory mapping (section 2.1.1). The latter data, comprising sightings of singing males and total individuals, were $\log_{10}(x+1)$-transformed prior to statistical analysis to normalise the distribution and standardise the variance of the residuals. A three-way analysis of variance was carried out to assess the effects of site, date and time, and their interactions. The sightings data were also expressed as ratios compared to the number of territories apparently occupied on each date (singing males) or twice the number of territories (all individuals) to indicate detectability, and analyzed in the same way after $\log_{10}(x+1)$-transformation. This approach permitted an optimal methodology for surveying Turtle Doves to be developed; suitable periods and times of day were identified when a high proportion (or all) of (potential) territory holders were singing or otherwise behaving territorially, and their detectability was consistent (preferably consistently high) at those times and/or periods.

2.1.3 Nest finding and monitoring

Much time and effort was put into finding nests. The latter involved watching birds and following them to their nests or more usually 'cold searching' of suitable habitat (hedges, scrub, young plantations etc.) in areas where birds were seen behaving territorially. In addition, radiotelemetry enabled the nests of tagged birds to be located (Section 2.3). Nest sites were described including location, height above ground level, species and size of the tree or shrub holding the nest and distance from the main trunk and/or edge of the shrub. Distances were measured to the nearest 0.1 m and heights were measured from the base of the tree or shrub. Once found, and when accessible, nests were visited every 3-4 days to monitor their outcome, a mirror on the end of a long stick being used to examine the contents of nests above head height. Rates of hatching and fledging success were determined from daily rates (measured from the finding of each nest to their final outcome) which were extrapolated to include the complete incubation and chick-rearing periods respectively (Mayfield 1975).

2.1.4 Feeding sites

During all field observations, sites where Turtle Doves were seen on the ground were recorded and described. It was occasionally not possible to be certain whether the birds were actually feeding because either a clear view could not be obtained or their presence was not detected until they had been flushed from the ground. The plant species present in an area *c.* 1 m^2 centred on where the dove(s) was thought to be feeding, the approximate ground cover provided by each species (where cover > 5%), which species were in seed or flower and the general height of vegetation were recorded. The presence of fallen seed on the ground and other features were also noted when appropriate.

2.1.5 Faecal samples

Faecal samples were collected opportunistically when they were seen deposited by Turtle Doves or produced during handling. In addition, samples were collected from nests from which young had fledged or otherwise disappeared. Samples were air-dried and stored in sealed plastic bags until analysis. The dried samples were softened by soaking in water for 18 hours and then sieved through 180-micron aperture gauze to discard small, unidentifiable and soft constituents. The remainder was examined under a binocular microscope and identified with reference to Flood & Gates (1986). Approximately 25 - 100% of faeces in each nest was examined, the dry weight of the examined proportions ranged from 9 - 22 g. The entire sample from individual birds was examined. The proportion of each seed type within each faecal sample was estimated, to the nearest 5%, by examining the evenly spread, sieved samples over a grid of 1-cm squares.

2.2 Trapping and marking Turtle Doves

2.2.1 Catching methods

Two methods of catching adult Turtle Doves were employed successfully, both at known feeding sites. At Deeping St Nicholas, mist nets were positioned inside large, dark grain-stores (where the doors were kept open) and caught 20 birds during 29 - 30 June and 7 July.

At Ixworth Thorpe a clap net was used to catch 4 adult Turtle Doves on 5 July. The birds were attracted to a small amount (*c.* 5 - 6 handfuls) of wheat grain placed at a known 'feeding' site

(site no. 3 in Section 3.6). The grain was used to attract birds to the relatively small catching area of the net and was put out three days prior to the first (and successful) catching attempt. A similar amount of grain was put out at another 'open' site which should have been visible to Turtle Doves from at least two occupied territories. No birds had been seen on the ground at this site previously and, despite the apparent visibility of the grain, no birds were seen to feed.

Tape-luring, using a recording of Turtle Dove song, proved unsuccessful at attracting birds, even when played directly beneath singing males. Similarly, placing mist nets by nests and attempting to flush birds in the latter stages of incubation (n = 2) or early stages of brooding (n = 1) proved unsuccessful; the birds easily avoided the nets. In no instance where the latter was tried was the nest subsequently deserted.

2.2.2 Ringing and colour-ringing

Most adults caught and all accessible chicks were fitted with individually numbered metal BTO rings and colour rings, except for those adults fitted with radio transmitters, which received only metal rings (in accordance with conditions of the licence granted to fit unconventional marks). The colour rings used were commercially available 'Cobex' overlapping rings (from A. C. Hughes Ltd.), 5.0 mm tall with 5.5 mm internal diameter. Most individuals were given unique combinations of three colour rings plus the metal ring. Two colour rings fitted comfortably on one leg, but because of the Turtle Dove's relatively short tarsi, the third colour ring had to be filed to *c.*_ of original height (with coarse emery-cloth or a fine angle-grinder) for it to accompany the metal ring on the same leg. Birds were aged and sexed using Baker (1993), weighed to the nearest gramme using 200-g Pesola spring-balances and the maximum wing chord measured to the nearest mm using a stopped rule. Wings of pulli were measured to the tip of the growing feathers, any downy extension being ignored. Biometrics are given in Appendices 1 and 2 for possible future use but are not considered in the present report.

2.2.3 Radio transmitters

Four adult Turtle Doves from each study site were fitted, under licence, with 'Biotrack TW4' radio transmitters (at Deeping St Nicholas on 29 June and at Ixworth Thorpe on 5 July). Each weighed *c.* 2.5 g, less than 2% of the body weight of an adult Turtle Dove. They were attached to the base of the upper side of the two central tail feathers. The procedure for their attachment was as follows:-

1. The two central tail feathers were carefully separated, any feather tracts being pushed aside to expose the quills.
2. Any down was removed from the basal part of the feathers using fine scissors.
3. The base of the feathers and quills were degreased with acetone using cotton buds.

4. When the attachment area was dry it was sprayed with superglue activator.

5. Superglue was placed onto the underside of the transmitter.

6. The transmitter was placed about 10 mm away from the point of feather implantation and held until the glue set (*c.* 10 seconds). The transmitters used had a groove to aid attachment to one feather quill, the other feather quill was glued to the transmitter's battery section.

7. The transmitter was further secured by tying with dental floss, threaded either side of the quill of the feather attached to the groove of the transmitter, and tied around the 'waist' of the transmitter. The knot was secured with a spot of superglue. A coarse needle was essential for threading the dental floss.

Turtle Doves have relatively long and stiff upper tail coverts. Attachment of the transmitter closer to the point of feather implantation would prevent the upper tail coverts from lying flat over the tail and would probably impair the bird's ability to preen the tail coverts to lie either side of the transmitter. When attached, the antenna of the transmitters extended *c.* 140 mm beyond the tip of the tail.

2.3 Radio-tracking and monitoring marked birds

2.3.1 <u>Radio-tracking</u>

For recording purposes, each radio-tagged individual was referred to by its frequency (a 3-digit number) and sex (M/F). Radio-tagged individuals were tracked using 'Telonics' receivers and hand-held three-element Yagi antennae. 'Fixes' of tagged birds were determined from approximate triangulation in the field, based on strength and direction of signals received. The majority of fixes were confirmed visually, and hence the remainder, which could not be confirmed (eg. birds in dense cover or cases in which confirmation would disturb or otherwise influence the behaviour of the bird) were considered accurate and reliable. Based on a few days of pilot radio-tracking, the following protocol for recording fixes was developed and used at Ixworth Thorpe: days were grouped into 5-day periods and were also split into 3-hour intervals covering all daylight hours and short periods of darkness before dawn and after dusk (ie 04 - 07, 07 - 10, 10 - 13, ..., 19 - 22 hours). Within each 5-day period a minimum of 3 fixes within each 3-hour interval, for all 5 days combined, was attempted for each tagged individual. Such a schedule permitted time to search for missing birds and also to continue other field observations. Normally more than three fixes were obtained in each 3-hour/5-day unit but in *c.* 20% of cases this was not achieved. At Deeping St Nicholas, a more opportunistic approach to radio-tracking was employed, mostly because much time was spent searching for three individuals which went 'missing' soon after tagging.

The locations of all fixes were plotted onto digitised maps of the appropriate study site. The latter were prepared using the MapInfo Professional 4.0 desk-top mapping program (MapInfo Corp. 1992) and included the habitat and crop types listed in Tables 1 and 2. Home ranges were evaluated using minimum convex polygons (MCPs) drawn around the plotted fixes corresponding to the breeding periods relevant to each individual Turtle Dove (pre-laying, incubation, chick-rearing and post-failing), and around the fixes for the entire period for which each bird was monitored (Kenward 1987). The area of the MCPs, and the proportions of each habitat within them, were determined using the above mapping program. Habitat utilisation by the tagged Turtle Doves was investigated at two levels. First, the proportional area of habitats contained within the MCPs was compared with that available in the entire study site. Second, the proportions of habitats within a 50-m radius of all fixes combined were compared to those available within the relevant MCP. The choice of a 50-m radius was partly arbitrary but is thought to be representative of the actual habitats being utilised, rather than simply being flown over, by a Turtle Dove at the time of any one radio-location. Compositional analysis was used to compare proportional habitat utilisation to the proportions of habitats available, at both levels (Aebischer *et al.* 1993). In order to avoid habitat comparisons containing large numbers of unused habitat types, which could bias the statistical analysis, the number of habitat types were reduced to the following 5 broad types: 1) all cereal crops, 2) all non-cereal arable crops, 3) all grassland (pasture, set-aside and rough grass combined), 4) all hedges, scrub, plantations and other woodland combined, and 5) all other habitats (villages, buildings etc.) combined.

At each fix, the behaviour of the individual was recorded as perched (including roosting/loafing but not near the nest), feeding, drinking, at the nest, singing, displaying or nest building. If the mate was present, this was also recorded. The latter observation could only be confirmed when both members of the pair were tagged but was also recorded when visual observations suggested the presence of an untagged mate. Data on individual time budgets were thus collected.

2.3.2 Colour rings

Turtle Doves were opportunistically checked for colour rings during all field work. The feasibility of using colour rings to determine individual range size and site and mate fidelity (between nesting attempts and seasons) could therefore be assessed.

3 RESULTS

3.1 Territory mapping

A maximum of 23 Turtle Dove territories were identified at Ixworth Thorpe, which suggested a territory density of 4.1 per km^2 (Figure 4). Not all territories were detected throughout the season implying that some males could have moved territories. A maximum of 20 were detected in any one two-week period and only in the earliest such period (25 May - 7 June). The latter figure corresponded to a territory density of 3.6 per km^2. The number of territories detected declined significantly through the season at a rate of 2.73 territories per two-week period (R^2=0.95, $F_{1,7}$ = 136.447, P<0.0001) (Figure 5). Territories were not necessarily detected in consecutive two-week periods (Table 3) but there was a tendency for nests and eggs to be found in, and for young to fledge from, territories that were detected more frequently (Table 4, linear-by-linear association test, P < 0.01).

In the order of 33 territories were identified at Deeping St Nicholas (Figure 6), implying a territory density of *c.* 0.5 per km^2. The survey methodology for the extensive area at Deeping St Nicholas was not directly comparable with that at Ixworth Thorpe (see Discussion). A core area of 8 territories (within *c.* 3 km^2), close to the transect route at Deeping St Nicholas (Figure 3), was monitored frequently enough to suggest that the seasonal decline was dissimilar to that at Ixworth Thorpe; territory occupancy remained constant during June and then declined during July and August at a rate of 1.96 territories per two-week period (R^2=0.98, $F_{1,3}$=91.56, P=0.01) (Figure 5).

3.2 Daily and seasonal variation in singing activity

The daily pattern of singing behaviour remained the same through the season (no significant time/date interaction); there were no significant interactions of site with either date or time of day, implying that singing activity varied in a similar manner at both sites (Table 5). Singing activity varied significantly with date, time of day and between study sites (Table 5). The peak of singing activity was in the early morning (Figures 7-16). At Ixworth Thorpe, the 05.00 transect invariably detected the greatest number of singing Turtle Doves, while the same was true in 5 out of 6 occasions at Deeping St Nicholas (Figures 7 & 8). On the sixth occasion, the maximum number of singing individuals was heard during the 07.00 transect. The efficiency of detecting singing Turtle Doves, expressed as a ratio of the number of singing birds to the number of apparently occupied territories on the transect, did not differ significantly between sites but there were significant effects of both date and time (Table 6). An average of *c.* 60% of territorial males (assuming only male Turtle Doves sing, Cramp 1985) were detected during the 05.00 transect (Figures 10 & 12). Observations at both sites indicated that singing activity declined from the early morning and remained at a low level through the day, with generally less than 30% of the potential maximum (that is the number of apparently occupied territories which could be detected from the transect on each date) heard during most transects. A small resurgence in singing activity towards the evening was also suggested. Singing activity, from the transect data, also declined through the field season (Figures 13 & 14). Analyses of variance of the number of Turtle Doves heard singing during each transect, and the ratios of numbers singing to apparently occupied territories, (the dependent variables) with date and time, for each site, confirmed the visible trends from Figures 7 - 16 (Tables 7 - 10). The seasonal decline in singing activity accorded with the seasonal decline in territorial activity detected by the more extensive surveys at Ixworth Thorpe and Deeping St Nicholas (Section 3.1).

3.3 Daily and seasonal variation in the detection of Turtle Doves

The total number of Turtle Doves present in the course of the season varied differently between the two sites, as indicated by a significant interaction between date and site (Table 5). No significant interactions were noted with respect to time of day, and the effect of time of day itself was not significant (Table 5). The latter implied that either Turtle Doves may tend to remain within a relatively small area for most of the day or that rates of movement to and away from a site, within a day, are similar. The efficiency of detecting all Turtle Doves, expressed as a ratio of the number of registrations to twice the number of apparently occupied territories on the transects, differed significantly between sites, and also varied differently, in the course of the season and diurnally, between the two sites. The general trends for the detection of all Turtle Doves were similar to those for singing individuals (Figures 17-26) but it should be noted that data for all birds included those singing, therefore the two data sets were not independent. At Deeping St Nicholas, up to 40 Turtle Doves were seen feeding at a grain-store, included in the transect. Turtle Doves spent much time loafing on the roof of the grain-store or in nearby trees. A marked reduction in the number of Turtle Doves seen at Deeping St Nicholas occurred after the store was emptied in mid-July (Figure 24). At Deeping St Nicholas, the number of registrations during transects frequently exceeded the number of resident birds, that is twice the number of apparently occupied territories (Figure 22). The latter implied that many feeding birds were not territory holders in the immediate vicinity. No such large feeding or gathering sites occurred close to the transects at Ixworth Thorpe which is likely to have been a causal factor of the significant differences in the number and variation of Turtle Dove registrations between sites. Analysis of variance of the number of Turtle Doves detected during each transect (the dependent variable) with date and time, for each site, confirmed the absence of a significant effect of time of day, in contrast to the analysis confined to singing activity (Tables 11 - 14). The low numbers recorded at Deeping St Nicholas on 18 June are difficult to explain; there was virtually no variation in weather conditions between days on which transects were counted.

Behaviour, other than singing, which was recorded during transects is summarised in Appendix 3. During fieldwork it was apparent that many Turtle Doves were disturbed by the presence of an observer or were only seen after having been flushed. Therefore, the latter data were considered to be an unreliable representation of true Turtle Dove behaviour.

3.4 Nest Sites

A summary of 31 nest-site descriptions is given in Table 15. The majority of nests were in Hawthorn (*Crataegus monogyna*) (20 out of 31, 65%), others were found in Elder (*Sambucus nigra*), Norway spruce (*Picea abies*), Sycamore (*Acer pseudoplatanus*), Blackthorn (*Prunus spinosa*), Apple (*Malus sylvestris* var.) and Wych Elm (*Ulmus glabra*). All nests were 1.3 - 3.5 m above the ground (median height 2.2 m) and tended to be situated among the outer branches of the tree or shrubs (20 out of 31, 65%, were within 1 m of the outer edge of the foliage). The trees and shrubs used for nesting were in hedges, scrub or small plantations, or were isolated bushes. The locations of nest sites are shown in Figures 27 and 28.

3.5 Breeding success

A summary of the results of nest monitoring is given in Table 16. All known complete clutches contained 2 eggs. At two nests where clutch initiation dates were known, the time to hatching was 15 days. At eight nests where hatching and fledging dates were known, the fledging period was 15.0 days (s.e. 0.5, range 13 - 17 days). Young Turtle Doves were seen close to nine monitored nests for at least three days after fledging.

Only three nests at the egg stage were found at Ixworth Thorpe, all of which failed to hatch. Six young from four nests were known to fledge successfully. All, with the exception of two young from one nest, were detected only when newly fledged. No recently fledged young were seen at sites where nesting Turtle Doves were not suspected (see Discussion). Four out of a potential 23 territories (17%) fledged young.

At Deeping St Nicholas, 8 out of 28 eggs from 14 nests failed to hatch during 177 observation-days. Assuming an incubation period of 15 days (Table 16), a hatching success (number of eggs hatched/number of eggs laid) of 66% was suggested (after Mayfield 1975). Seven out of 29 chicks from 16 nests failed to fledge during 178 observation-days. Assuming a rearing period of 15 days (Table 16) a fledging success (number of young fledged/number of eggs hatched) of 65% was suggested. Four pairs of nests which were in close proximity but not contemporarily active may have belonged to the same pairs; one individual, a radio-tagged male, was certainly double-brooded (nest nos. 12 & 17, Table 16). At Deeping St Nicholas, 13 out of a potential 33 territories (39%) fledged young. The figures for the two sites were not directly comparable, however (see Discussion). The precise cause of breeding failure is known for only two nests; one clutch was taken by a Jay (*Garrulus glandarius*) and one partial brood loss was due to observer disturbance (a 12-day-old chick fell from its nest). Predation was the likely cause of failure of two other nests.

3.6 Feeding sites

All sites where Turtle Doves were seen feeding at Ixworth Thorpe are described (Table 17) and their locations are shown in Figure 29. All sites had either very short vegetation (ie 10 cm or less), were very sparsely vegetated (less than 20% cover) or contained grain fallen from the standing crop. Relatively few feeding birds were seen in May, June and July. Two sites (#3 and #9, Figure 29) were totally unvegetated and no seeds (or potential animal prey) were visible. Turtle Doves were once seen taking mineral grit intended for stock (site #6). Grain fallen from standing barley (a short and sparse crop compared to that in neighbouring cereal fields - site #7) was regularly taken from 28 July to 14 August. A field of disced wheat stubble (site #16) was used daily from 10 August to 5 September (the last Turtle Dove sighting in the area), with up to 23 birds present at any one time.

At Deeping St Nicholas, the majority of Turtle Doves seen feeding were at four purposely maintained feeding sites (supplied with wheat grain, rape and grass seed and linseed), or at four grain-stores (taking spilled grain from around them or actually eating grain inside (two large open stores))(Figure 30). The maintained feeding sites were attended frequently, with up to 18 individuals present at any one time, until 20 July (when the first rape fields were cut). Over 40 Turtle Doves were seen at the grain-stores on occasions. Other sites where Turtle Doves were seen feeding at Deeping St Nicholas include harvested rape fields (1 - 10 individuals in 8 fields between 28 July and 27 August), sugar beet (1 - 6 individuals in three fields, 23-24 May), a harvested pea field (1 on 21 July) and several set-aside fields, field margins, weedy and grass areas (Figure 30).

3.7 Analysis of faecal samples

The fractions of faecal samples which could be examined after sieving consisted almost entirely of the remains of seeds (Tables 18 and 19). Wheat (*Triticum aestivum* var.) was a major component of all samples, with a *Brassica* species (most likely rape) and chickweed (*Stellaria media*) present in the majority. Annual nettle (*Urtica urens*), creeping buttercup (*Ranunculus repens*) and linseed (*Linum usitatissimum*) comprised 10% or more of the remains of one or two samples each. Other seeds and grit constituted very small components of a few samples. The remains of a single fly (Diptera species) and a weevil (Curculionidae) were found in a sample from an adult collected at Ixworth Thorpe.

Remains in faeces collected from nests presumably reflected diet during the latter stages of chick rearing; young are fed exclusively on crop milk for the first *c.* 5 days, and then also other foods until *c.* 9 days post-hatching, after which crop milk is not given (Cramp 1985). Accordingly, the date of the 10th day after hatching for each nest from which samples were taken is given in Tables 18 and 19, that being the approximate date when the faeces were likely to have been produced. The sample size was too small for a meaningful analysis of temporal variations in diet, however, wheat and chickweed seeds appeared to be taken throughout the sampling period. *Brassica* seeds may have increased in importance through the period and other seeds (*Urtica, Ranunculus* and *Linum*) may have been more important in the early part of the sampling period.

3.8 Ringing and the resighting of colour rings

Twenty adult and 18 pulli were ringed at Deeping St Nicholas and 4 and 2 respectively at Ixworth Thorpe. Full details are provided in Appendices 1 and 2. Despite regular searching, only one colour ringed individual was subsequently seen at Deeping St Nicholas, at Worth's Farm on 20 July. At Ixworth Thorpe, one was seen at site 7 (Table 17, Figure 29) on 2 August and one at site 16 on 27 August (note that only two young birds were colour ringed at that site). On all three occasions, only one lower colour ring could be seen. Relatively few immature Turtle Doves were seen at Ixworth Thorpe (1 - 5 were seen during August and September). At Deeping St Nicholas up to *c.* 10 immatures were seen from mid-July onwards.

3.9 Radio-tracking

Four adult Turtle Doves caught at Worth's Farm, Deeping St Nicholas, were fitted with radio transmitters on 29 June (Appendix 1). Three individuals were located only infrequently within the first week after attachment, and not at all afterwards:-

#208F 4 July (23.45), 5 July (23.10) and 6 July (12.30) at Poplar Farm (2.4km N of Worth's Farm).

#241M 1 July (18.30) Vine House Farm (1.6 km S of Worth's Farm)
2 July (18.45) Goose Hill Farm (1.2 km S of Worth's Farm)
4 July (23.00) Lock's Farm (5.2 km NE of Worth's Farm)
6 July (10.30) Lock's Farm (5.2 km NE of Worth's Farm)
6 July (17.35 - 18.30) Worth's Farm
6 July (22.15) Four Ashes (6.3 km NE of Worth's Farm)

#248F 1 July (18.30) Goose Hill Farm (1.2 km S of Worth's Farm)

The remaining individual (#268M) successfully reared two broods (nest nos. 12 & 17, Table 16) and was frequently located until 8 August when it lost its transmitter (fell off).

Four adult Turtle Doves, caught at Ixworth Thorpe on 5 July (Appendix 2), were fitted with radio transmitters. Receiving equipment was not available until 10 July by which time #260M had moulted the feathers to which the transmitter was attached (the transmitter was found in a small wood *c.* 300 m south of the trapping site still attached to a tail feather). The other three individuals were regularly located until their departure from the area (or radio failure): #202M until 3 September, #220F until 5 August and #230M until 28 August. Individuals #220F and #230M were a mated pair. All three tagged birds incubated clutches which failed to hatch (#202M, nest no. 10, Table 16) or otherwise failed soon after hatching (#220F and #230M, nest no. 9, Table 16).

3.9.1 Individual time-budgets

Time-budgets of radio-tagged individuals are summarised within breeding periods (Tables 20 - 23) and within 5-day periods (Appendices 4 - 10).

3.9.1.1 *Pre-laying* (Table 20)

During pre-laying, the 3 monitored individuals divided their time between loafing, at and away from the nest site, and feeding. The tagged pair (#220F and #230M) tended to feed during the late morning and afternoon and *c.* 66% of their time was spent together. Turtle Dove #202M, a male, had a tendency to feed throughout the day and was seen less frequently with a mate compared to the other two individuals. The mate of the latter was not tagged so that the proportion of time spent with the mate was probably underestimated. Note that #268M was already incubating when radio-tracking commenced.

3.9.1.2 *Incubation* (Table 21)

Over 90% of incubation during the daylight hours was carried out by the males. Both tagged males at Ixworth Thorpe spent relatively little time feeding (5 - 10% of fixes), and feeding tended to occur within 3-4 hours after dawn and before dusk. The few occasions the Deeping St Nicholas male (#268M) was seen feeding during both of its incubation periods were also in the early morning or evening. The single tagged female (#220F at Ixworth Thorpe) fed and loafed (away from the nest) through most of the day. She was always at the nest from late evening to early morning, changing over at the nest when the male returned from feeding in the morning or leaving to feed in the evening. Both members of the pair (#220F and #230M) tended to be at the nest during the night, as was male #202M. Therefore, it was not possible to ascertain which sex incubated during darkness. Male #230M spent two nights away from the nest and at Deeping St Nicholas #268M was frequently absent, hence the female is presumably able to incubate through the night.

3.9.1.3 *Chick-rearing* (Table 22)

Unfortunately relatively little information was collected during chick-rearing (the birds at Ixworth Thorpe failed). At Deeping St Nicholas #268M apparently spent little time at the nest. Over 25% of fixes during chick-rearing recorded the individual singing and/or displaying. The latter individual commenced incubating a second clutch almost immediately after the first brood fledged. Whether the same female was the partner for both clutches was not known with any certainty.

3.9.1.4 *Post-failing* (Table 23)

The female at Ixworth Thorpe either left the area or its transmitter failed two days after the failure of the breeding attempt. The two males remained and were detectable for 24 and 25 days after failing respectively. Both males continued to concentrate their feeding in the early morning and in the evenings. The remainder of the day was spent perched near their feeding sites, usually with other Turtle Doves.

3.9.2 Individual ranges and habitat-use

The location of fixes from radio-tracking and MCPs which represented individual home-ranges are shown in Figures 31 - 34. Individual home-ranges for the entire monitoring period ranged from 94.0 - 460.2 ha, with a mean of 318.6 ha (Table 24). The sample size was too small to suggest whether such ranges, and their variation between breeding periods, were typical. A comparison of the summed areas of 50-m radius around each fix (Table 25) to the MCPs showed that only 7 - 12% of the latter was used by the tagged Turtle Doves.

Analysis of variance of the logratios of habitat proportions within MCPs showed no significant variation between breeding periods (Wilk's $\Lambda = 0.085$, $P = 0.748$). Therefore all periods were combined and total home-ranges were used in subsequent analyses. The sample size (4 individuals) was too small for statistical comparison of habitat use and availability but ranking matrices based on logratio-differences showed trends of relative habitat use (Tables 26 & 27). The habitat proportions used to create the ranking matrices are given in Table 28. Proportional habitat use within MCP home-ranges compared to the proportions available within the study sites was ranked in descending order of relative use: grass > other > cereal > other arable > hedges and woods. In contrast, when habitat use within 50-m buffers of radio-locations was compared to the proportions available within the MCP home-ranges, habitat rankings were: hedges and woods > cereal > grass > other arable > other.

4. <u>DISCUSSION</u>

4.1 The efficiency of detecting Turtle Doves

4.1.1 <u>Daily and seasonal variations</u>

Transect data from both study sites indicated a marked diurnal variation in singing activity. The maximum (*c.* 60% of the potential maximum) occurred in the early mornings (within 2-3 hours after sunrise) and relatively few birds were heard (usually <30% of the potential maximum) during the remainder of the day. The latter trend was consistent through the season. A similar, though less marked, trend was apparent for the total numbers of Turtle Dove registrations during transect surveys at Ixworth Thorpe but not at Deeping St Nicholas. At the latter site, up to 40 Turtle Doves were seen at an artificial feeding site included in the transect. Turtle Doves spent much time loafing on the roof of the grain-store or in nearby trees; similar behaviour was recorded for radio-tracked individuals at Ixworth Thorpe. Birds at, and close to, the grain-store, and flying to and from it, were recorded throughout the day. No such large feeding or gathering sites occurred close to the transects at Ixworth Thorpe. At the latter site, the majority of Turtle Doves recorded during transects were probably local territory holders (but see Section 4.1.3), whereas at Deeping St Nicholas, birds from a much wider range could have been recorded when they visited the grain-store. Radio-tracked individuals, tagged at the grain-store, were found up to 6.3 km away, and some probably travelled further (Section 4.3.2). Differences in the origins of birds recorded during transects could therefore have been responsible for the differences in daily trends in total registrations between the two sites.

The number of singing birds recorded during transects declined with date. A decline in the total number of registrations through the season did not begin until mid-July. At Deeping St Nicholas, this coincided with the emptying of the grain-store used for feeding by Turtle Doves. At Ixworth Thorpe, concentrations of feeding and loafing birds away from the transects (notably site nos. 7 & 16, Figure 29) developed after mid-July. Such changes in Turtle Dove behaviour could have increased their absence from the transect recording areas. A reduction in the numbers of Turtle Doves detected has been recorded after late June, in Avon (Duckworth 1992) and after the end of July, in the southern Urals (Kotov 1974). Possible causes given for the latter observations were reduced singing activity or emigration.

At Ixworth Thorpe, there was a marked, linear decline in the number of apparently occupied territories within the whole study area, and not all territories were apparently occupied (or detected) continuously through the season (see Section 4.1.3). Turtle Doves were seen at Ixworth Thorpe from 22 April (J.C. pers. obs.), over a month before the present study was initiated. Therefore it is not possible to decide with any certainty whether the maximums of singing frequency, total registrations and occupied territories recorded in the present study (which were all recorded at the start of the study) actually represented peaks in the seasonal maxima (which may have passed by the time the study was initiated).

4.1.2 Nests

Despite similar, intensive effort at both study sites, nest finding was relatively unsuccessful at Ixworth Thorpe compared to Deeping St Nicholas. Such a difference may have resulted from differences in the number of nests built by Turtle Doves, differences in the extent and nature of the habitat or differences in the ability of the observers to find nests. A single fieldworker carried out the majority of work at each site. However, each one visited the other's site and agreed that nest finding was considerably more difficult at Ixworth Thorpe. Differences in observer ability were, therefore, unlikely to be responsible for the difference in nest-finding success. Ixworth Thorpe contained more scrub and hedge (potential nest sites) per unit area than Deeping St Nicholas (Tables 1 & 2), much of which was thicker and denser at the former site. Hence, more nests probably remained undiscovered at Ixworth Thorpe. At both sites, incubating Turtle Doves were not easily flushed from the nest, so that simply walking along hedges in an attempt to flush sitting birds was largely unsuccessful. Potential nest sites needed to be thoroughly visually searched in order to find nests. At Ixworth Thorpe, three broods fledged before their nests were found, even though territory-holding pairs were suspected at all three sites and consequently searching effort was concentrated in those areas. Two nests at Ixworth Thorpe were found by radio-tracking their owners. One of the latter was in dense scrub, such that it could not be approached without considerable disturbance and potentially damaging the nest. This nest was examined only after it was known to be deserted. The other nest found by radio-telemetry was outside the initial study area but was considered possible to find by 'cold-searching' the hedge. Overall, an unknown proportion of nesting attempts remained undetected.

Young Turtle Doves may remain close to the nest for at least 3 days after fledging (observations at Deeping St Nicholas and Ixworth Thorpe). Such individuals can be easy to see, sitting on the outside or tops of hedges and bushes. The variability of such behaviour, including the time spent close to the nest after fledging, is not known. The three recently fledged broods seen at Ixworth Thorpe were in the most consistently occupied (or detected) territories and no recently fledged young were seen away from sites where breeding was not suspected. The number of successful nesting attempts which were undetected may therefore have been small but could not be checked.

4.1.3 Implications for censusing and monitoring Turtle Doves

Ideally, to census a species such as the Turtle Dove in the breeding season, fieldwork should be carried out during the time(s) of day and stage(s) of season when the majority of individuals or territories can be detected. Failing this ideal, a period when a relatively constant proportion of individuals or territories can be detected would be suitable; the true population can then be estimated by extrapolation, assuming the proportion which was detected during the census is known. In the latter case, a higher efficiency of detection and hence a reduced multiplication factor will give an increasingly reliable estimate. For the Turtle Dove, detection was consistently high only in the early mornings and was very low and somewhat variable for the remainder of the day. Fieldwork to determine numbers of breeding or territory-holding Turtle Doves should therefore be undertaken within 2 or 3 hours after sunrise. Fieldwork outwith the latter period could underestimate, by a variable proportion depending on the time of day, the true population of Turtle Doves. Unfortunately, such a time constraint permits only a relatively small area to be surveyed each day. On average, an estimated 60% of all potential territory holders were detected early during any one morning. The percentage is less than 100% because a bird could have been sitting openly, or even singing, in some parts of a territory but remain undetected during the transect, although it would have been seen during more extensive fieldwork.

The number of Turtle Doves seen tended to decline through the season, from the start of fieldwork, but territory occupancy (or detectability) was not continuous at Ixworth Thorpe. For a small sample of territories at Deeping St Nicholas, a decline in occupancy was not observed until early July and there was no evidence for their discontinuous occupancy. Fieldwork for the extensive surveys at Deeping St Nicholas was necessarily undertaken throughout the day (because of the large area covered). For reasons outlined above, the latter surveys may have underestimated the true abundance or inconsistently recorded it. The apparent decline and non-continuous occupation of territories observed at Ixworth Thorpe may have resulted from a number of factors. For example, a number of birds present may have been missed because individuals may be less detectable during some stages of breeding than others. Movement of males between territories, emigration (temporary or otherwise) of territory holders, or singing by migrants simply passing through the study site in the early part of the field season may have occurred. The monitoring of individually marked birds (preferably radio-tagged, see Section 4.3) in the future should be used to determine the factors responsible for variation in the number of territories detected through the season. This intensive work is essential before an appropriate census methodology can be selected, and its results be interpreted, with confidence.

Searching for nests was very time consuming and, at Ixworth Thorpe, possibly relatively ineffective. At the latter site, seven nests were found during construction or in the early stages of incubation; all were subsequently deserted. In the present study, experience at Deeping St Nicholas suggested that investigator-activity need not cause nest desertion; only one failure at the latter site was thought to occur as a result of observer disturbance. Two of the deserted nests at Ixworth Thorpe were not approached closer than 50 m for nine days after their discovery (nest building was observed through binoculars). Disturbance by other people was unlikely but this possibility could not be completely eliminated. Similarly, two nests belonging to radio-tagged Turtle Doves were also unsuccessful; one was never visited while active, the other was visited once, 11 days before desertion. The latter observations, and the tolerance of nesting Turtle Doves to investigator activity at Deeping St Nicholas, suggested that other, undetermined, factors were responsible for the abandonment of nesting attempts at Ixworth Thorpe. Again the advantage of monitoring via radio-telemetry is apparent.

4.2 Summer ecology of the Turtle Dove

4.2.1 Breeding biology

Census work in the present study suggested potential breeding densities of 3.5 - 4.1 territories per km^2 at Ixworth Thorpe (within a 5.6 km^2 study area) and *c.* 0.5 per km^2 at Deeping St Nicholas (within *c.* 70 km^2). The latter figure was probably an underestimate, however (Section 4.1.3). In 1972, approximately coincident with the time of maximum range and greatest population for the species in Britain, the average density recorded on 'farmland' was 1.4 pairs per km^2 and 2.2 pairs per km^2 in 'woodland', and exceptionally densities of over 30 per km^2 were recorded (Sharrock 1976). Elsewhere, breeding densities have been estimated at 3-11 pairs per km^2 in coastal scrub and pine plantations in France (Genard 1989), 4 per km^2 in mixed habitats in the Netherlands, with the greatest recorded in small woodlands and 'garden cities' (Bijlsma 1985), 21 and 25 per km^2 on two small study sites in Portugal (Fontoura & Dias 1996), exceptionally up to *c.* 20 per km^2 in the upper Rhine plain (Holzwarth 1971) and *c.* 5 pairs per km^2 elsewhere in Germany (Kraus *et al.* 1972). The derivations of the latter figures are either unclear or based on census field work which was less intense than that undertaken at Deeping St Nicholas in the present study. Detailed comparison of breeding densities is therefore inappropriate but Ixworth Thorpe may have held approximately 'average' densities and Deeping St Nicholas less than average densities for the species.

The choice of nest sites in the present study, in shrubs (often thorny) and small trees, between 1.2 and 4.5 m above the ground, were similar to those recorded in other studies and the clutch size of the Turtle Dove is perhaps invariably two (eg. Hosking 1942 in Norfolk, Murton 1968 in Cambridgeshire, Kotov 1974 in the southern Urals, Pikula & Beklová 1984 in Czechoslovakia, Bijlsma 1985 in the Netherlands, Genard 1989 in France, Peiró 1990 in Spain, Nankinov 1994 in Bulgaria). The recorded clutches of one in some studies may have been due to the loss of an egg. The very few instances of larger clutches may refer to more than one female laying in the same nest (Nankinov 1994).

Only two incubation periods were precisely determined in the present study, both were of 15 days duration. Other studies similarly report 13-16 days (Kotov 1974, Pikula & Beklová 1984, Cramp 1985, Genard 1989, Peiró 1990, Nankinov 1994). The period between hatching and fledging is recorded less frequently than for the incubation period; 20 days plus an additional 5-10 days before young are able to fly was recorded for birds in the southern Urals (Kotov 1974) and a figure of *c.* 20 days is given in Cramp (1985). At Deeping St Nicholas the mean fledging period was 15 days (n=8, s.e.=0.5) with an unknown proportion of young remaining close to the nest for at least an additional 3 days. The timing and process of fledging in the Turtle Dove obviously requires further attention.

Previous work implied that Turtle Doves normally attempt to rear two broods (Kotov 1974, Peiró 1990, Nankinov 1994, Fontoura & Dias 1996) or even lay three clutches but normally rear only two broods (Murton 1968). At Deeping St Nicholas, only 4 out of 16 pairs were thought to have laid a second, as opposed to a replacement, clutch, and none were known to have done so at Ixworth Thorpe. The difficulties of monitoring nests in the present study have been discussed (Section 4.1.2). Even assuming that some nesting attempts went undetected, it is likely that the number of nesting attempts by Turtle Doves in the present study may have been lower than is usual for the species. A relatively prolonged breeding season (late April to August/September) has been recorded for the Turtle Dove in England (Murton 1968), Spain (Peiró 1990) and Bulgaria (Nankinov 1994), with the first breeding attempts usually commencing in May. Although the present study did not start until at least a month after the arrival of the first Turtle Doves at the study sites, there was no evidence of breeding earlier than that recorded (eg fledged young in early June). Therefore, when compared to other studies in Britain and mainland Europe, the present study suggests an absence of early breeding with an associated reduction in the number of second broods reared. In the Netherlands, the onset of breeding was possibly enhanced by fine, warm weather in May, which was also associated with earlier arrival at the breeding areas (Bijlsma 1985). Breeding success can also differ significantly between successive years, also perhaps because of weather (Peiró 1990). It is therefore not known whether the present study recorded typical breeding success by Turtle Doves in the study sites. If there is a positive relationship between breeding success and breeding density, the density of territories at Ixworth Thorpe, in 1996, might be expected to have been lower than was recorded if breeding success had been persistently low for a number of years. It is possible that 1996 may have been a poor year for breeding Turtle Doves at the latter site. Early nests are not necessarily the most successful (Murton 1968, Bijlsma 1985, Peiró 1990) but young from early broods probably have increased post-fledging survival compared to their later congeners

(Murton 1968). Therefore persistent failure to rear early broods could have a particularly significant affect on the population.

Recorded rates of hatching success and fledging success range from 46 - 79% and 37 - 82% respectively (Murton 1968, Pikula & Beklová 1984, Bijlsma 1985, Peiró 1990). None of the figures are derived from measured rates of loss over precisely known time-periods and are therefore not directly comparable. The rates recorded in the present study at Deeping St Nicholas, however, lay within the above ranges and were therefore unlikely to differ significantly from them as a whole. Weather may influence breeding success, with cold, wet weather causing a reduction in the Netherlands (Bijlsma 1985) and increased rainfall in May causing an increase in Spain (Peiró 1990); in the latter study, increased rainfall was thought to have increased food availability (seeds) for young later in the year. The majority of known breeding failures have been attributed to predation, the impact being greatest, and perhaps most variable, during the egg stage (Murton 1968, Bijlsma 1985, Peiró 1990); *c.* 35% of hatching failures were due to predation by corvids and snakes in these three studies. The factors influencing the susceptibility of a nest to predation are not clear but early laid eggs may be left unattended, and be subsequently taken by predators, if the adults have to spend excessive time away from the nest feeding (Murton 1968). The only observed incident of nest predation in the present study was of a Jay (*Garrulus glandarius*) taking a single egg from an unattended nest at Ixworth Thorpe. In the latter case, the ultimate cause of the nest succumbing to predation, that is why it was unattended in the first place, is not known.

4.2.2 Habitat use

The Turtle Dove breeds in a range of habitats, generally in lowlands (under *c.* 400 m above sea level) with both open ground (farmland, large gardens or steppe) and hedges, trees or small woods (Kotov 1974, Bijlsma 1985, Peiró 1990, Kraus *et al.* 1992, Fontoura & Dias 1996). Extensive woodland and heathland tend to be avoided (Bijlsma 1985, Kraus *et al.* 1992) but young plantations and managed (felled or coppiced) woodlands can hold high densities of breeding Turtle Doves (Bijlsma 1985, Genard 1989, Kraus *et al.* 1992). In Germany the distribution of the Turtle Dove was largely contained within the 17° C July isotherm (Kraus *et al.* 1992) and, in Britain, it was within the 19° C July isotherm (Norris 1960). Apart from nest-sites, very little attention has been given to the specific habitat requirements of the Turtle Dove. An exception was a comparative study of feeding sites of the Turtle Dove, Wood Pigeon (*Columba palumbus*) and Stock Dove (*C. oenas*) in Britain (Murton *et al.* 1964); Turtle Doves collected their food mostly from weedy waste ground or from tall standing hay and wheat crops, where many weeds were growing. In the present study, four adult Turtle Doves were effectively radio-tracked for the latter part of the season only. When the habitat composition of individual home-ranges was compared to that available in the (arbitrarily chosen) study sites, grassland (which was predominantly pasture) was ranked, in order of relative use, highest, and hedges and woods, lowest. When the habitats used were identified by actual radio-locations and compared to their availability within the home-ranges, contrastingly, hedges and woods were ranked highest. The first comparison was probably influenced by the fact that three monitored individuals were tagged in the most extensive area of pasture in either study site. The latter comparison probably reflected the time spent by Turtle Doves loafing in hedges and trees. Cereals were ranked above grass in the latter comparison which perhaps reflected their importance as a source of food (Section 4.2.3). A greater sample size is obviously required in order to determine which features are actual requirements of the species. Further work should obviously aim to tag a greater sample of Turtle Doves, preferably at several contrasting locations within a study site(s), and to monitor them for the entire season. The feasibility of attaching transmitters to young Turtle Doves in the nest should be investigated with the aim of determining post-fledging dispersal, habitat use and, also, survival.

4.2.3 Diet and foraging

In the present study, diet evaluated from faecal remains consisted almost exclusively of seeds of relatively few species. The importance of seeds in the diet accords with other studies (eg. Murton *et al.* 1964, Murton *et al.*1965, Garzon 1974, Kiss *et al.* 1978, Jimenez *et al.* 1992, Dias & Fontoura 1996). Surprisingly, few chicks produced a faecal sample during handling, and very few samples were collected from adults. One of the latter contained the remains of two insects; insects and other small animals (notably molluscs and also eggs of invertebrates) were regular but small constituents of gut and crop contents in previous studies (eg. Murton *et al.* 1964, Murton *et al.*1965, Garzon 1974, Kiss *et al.* 1978, Jimenez *et al.* 1992) and their presence may sometimes have been the result of having been eaten accidentally with seeds (Dias & Fontoura 1996). Whether faeces are representative of true diet composition in granivorous birds perhaps requires further attention but faecal analysis has been used successfully for a range of insectivorous and omnivorous birds (Rosenberg & Cooper 1990). The present study indicated that seed remains can be readily identifiable in Turtle Dove faeces and therefore their analysis is potentially very useful in the determination of diet but whether all seed types are equally resistant to digestion requires calibration.

The types of seeds identified in faeces from Deeping St Nicholas approximately reflected their availability at that site; Turtle Doves were seen feeding at grain-stores (wheat), maintained feeding stations (wheat, rape and linseed) and in harvested rape fields. Unfortunately, information on species composition and vegetation structure at the precise locations where Turtle Doves were seen feeding was not collected at Deeping St Nicholas. The latter information is available for Ixworth Thorpe but only three faecal samples were collected from that site. Of the seeds identified in them, wheat, chickweed and annual nettle were also present at the feeding sites. Rape, which was also present in the three samples, was grown within 2 km of the study site. For future study, the collection of loose surface material (ie that available to a Turtle Dove) from feeding sites for comparison with similar material from other, randomly-selected areas, may explain why Turtle Doves fed where they did; their feeding sites were frequently restricted in area but visually indistinct from many other areas.

A number of other studies report on the crop and gut contents of adult Turtle Doves collected from across Europe (Murton *et al.* 1964 in England, Murton *et al.* 1965 in Russia, Kiss *et al.* 1978 in Romania, Garzon 1974 and Jimenez *et al.* 1992 in Spain, Dias & Fontoura 1996 in Portugal). All appear to reflect the range of local crop and weed seeds available. A preference for weed seeds, notably Fumitory (*Fumaria officinalis*) and Chickweed (*Stellaria media*), was noted in England and Russia, while seeds from standing weeds and grasses were also taken preferentially to fallen cereal grain (Murton *et al.* 1964, Murton *et al.* 1965). Murton *et al.* (1964) suggested a relationship between the distribution of the Turtle Dove and that of Fumitory in England but no such relationship was apparent at the local level in Lancashire (Spencer 1965) or in Devon (Sitters 1988). In Spain, cereal grain and the seeds of sunflowers (*Helianthus annuus*) were the greatest constituent by volume in gut contents (*c.*85%) but agricultural weed seeds were numerically the most abundant constituent (*c.* 55%) in late summer (Jimenez *et al.* 1992). Similarly, 'wild' seeds (predominantly Poppy *Papaver* sp.) were numerically the most abundant constituent (65%) in Turtle Dove crops and gizzards collected in late summer in southern Portugal, but cereal grain was significantly more abundant in immature than in adult birds (Dias & Fontoura 1996). The seeds of legumes were particularly abundant in samples from the Danube delta (Kiss *et al.* 1978) and seeds from coniferous trees are also perhaps locally important (Bijlsma 1985, Genard 1989). The present study suggests a relatively strong dependence on cereal grain, which contrasts with some other studies (although it differs from others in that it relies on analyses of faeces mostly from chicks and in its small sample size). The study in Cambridgeshire (Murton *et al.* 1964) was geographically close to the present study sites and provides an interesting temporal comparison. In the 1960s, Turtle Doves tended to feed in hayfields and standing clover crops from April to June, while wheat and pea fields and stooked wheat were also important during the latter part of the season. Recent changes in agricultural practices have resulted in the near-absence of hayfields, clover crops and haystooks from the English countryside (O'Connor & Shrubb 1986). Similarly, the continued use of fertilisers and herbicides on arable land and pastures has reduced both the abundance and diversity of agricultural weeds (Williams 1987, Mountford *et al.* 1993, Wilson 1994). Hence at present, the quantity of food available to Turtle Doves in the early summer may be reduced compared to that available during the earlier study, and even though cereal grain is still available (perhaps even abundantly so, see below) in the late summer, the variety of seeds available has been reduced. The general trend for increase in the population of the Turtle Dove in Britain continued to increase after such agricultural changes were well underway, however (Marchant *et al.* 1990). Conversely, two local studies recorded declining Turtle Dove populations coincident with local conversion of grassland into arable but causal relationships were not determined (Miller 1992, Duckworth 1992). Further work to determine the food preferences of the Turtle Dove (ie. a comparison between food availability and dietary content) which may be related to the energetic and nutrient qualities of food (seed) types, should be undertaken. The significance of the small quantities of animal material and minerals (eg grit or stock-animal feeds) taken by Turtle Doves also requires attention.

Radio-tracking proved to be the only effective means of determining time-budgets for individual Turtle Doves. Radio-tagged individuals spent relatively little time feeding and fed relatively close to their nest sites, which suggested that food was not a particularly limited resource during the time when the birds were monitored. Three individuals tagged at Deeping St Nicholas, however, were not located for more than a few days after tagging. The latter individuals may have resided outside the study area (6+ km away from the grain-store where they were tagged), suggesting that food was scarce (or foraging energetically costly or risky) elsewhere. Alternatively, there could have been social attractions, in addition to food, which encouraged Turtle Doves to travel to the site; head-bowing and calling were frequent, and copulating was observed once amongst individuals at or near the grain-store. During the early part of the field season (essentially in May and June), Turtle Doves were rarely seen feeding at Ixworth Thorpe, and virtually all seen at Deeping St Nicholas were at grain-stores and purposely maintained feeding stations. A scarcity of other 'natural' food is possible but not proven (see above). A shortage of food in the early summer could have been the ultimate cause of the poor breeding success, and perhaps a reduced number of breeding attempts, at Ixworth Thorpe (Section 4.2.1).

4.3 Practical implications of monitoring individual Turtle Doves

4.3.1 Catching Turtle Doves

Twenty Turtle Doves were caught using mist-nets in open grain-stores at Deeping St Nicholas. Nets at the entrance of the store and at 'open' feeding sites (spilled grain outside the store) were unsuccessful because the Turtle Doves could see the nets and were able to manoeuvre to avoid them. This implied that nets should be placed in relative darkness. Dark feeding sites are probably unusual for the Turtle Dove hence mist-netting at feeding sites may be successful only at exceptional sites. Mist-netting at nests was unsuccessful (Section 2.2.1), similarly netting at roost sites is also likely to be unsuccessful as was tape-luring. The use of clap-nets (or similar devices) is, perhaps, the best option for catching Turtle Doves. It will normally be essential to use bait (eg grain) to attract birds to the catching area. Prolonged or excessive baiting may influence the behaviour of the birds being (or to be) monitored. At Ixworth Thorpe, however, only a very limited amount of bait, used at a site where Turtle Doves were known to feed, proved successful. The latter approach is perhaps the best way of catching birds without excessively influencing their behaviour. Double clap nets are a traditional, and successful, tool for catching Turtle Doves in Portugal (Dias *et al.* 1996). The latter used tethered live Turtle Doves as a lure; the use of stuffed Turtle Doves or carved decoys may similarly increase the effectiveness of the technique. Large walk-in cage traps have also successfully caught doves, including Turtle Doves, but requires large-scale baiting (P. Wilkinson pers. comm.).

4.3.2 Colour ringing

The use of colour rings to monitor individual Turtle Doves was largely unsuccessful. In the present study, the legs of Turtle Doves were visible only when birds were perched in trees or on wires. In the latter situations, birds were normally viewed against a bright background (the sky) and it was impossible to determine colours even when rings could be seen. Single colour ringed individuals were seen twice at Ixworth Thorpe (where only two young birds were thus marked) and only one colour, the bottom yellow on the left leg, could be seen, and once at Deeping St Nicholas, where only a single green ring was seen. It is unlikely that complete colour combinations could be read frequently in the field, therefore marking birds with individual combinations will be of little use. The sightings at Ixworth Thorpe suggest, however, that some limited observations could be made and that the use of a single site-, age- and year-specific colour ring could provide some information on post-fledging dispersal, site fidelity and philopatry, especially if radio-tracking of fledglings proves impractical.

4.3.3 Radio-telemetry

Radio-tracking Turtle Doves successfully monitored individual behaviour, range size and habitat use, and located nest sites, feeding areas and roosts. Attaching radio-transmitters apparently had little effect on the Turtle Doves. Four individuals incubated clutches after attachment; one commenced incubation within two days of tagging; no tagged bird was found dead.

The combination of transmitters and receiving equipment used gave a reliable detection range of *c.* 700 m, which was probably less than adequate. Three individuals were 'lost' soon after tagging at Deeping St Nicholas. Although radio-failure and transmitter loss can not be ruled out, they are unlikely; two radios which fell off during the study were easily located and retrieved. The extremes of one individual's range, which were briefly documented, were 7 km apart. To regularly search for individuals which can range at least 7 km with equipment that can only reliably detect up to 700 m is extremely time-consuming. A combination of more powerful transmitters and more effective receiving equipment would benefit any future work. We believe that, at a minimum, the equipment should have a detection distance of 2 km, and 5 km would be preferable.

The precision of results obtained by radio-telemetry, for example habitat preferences and behavioural time-budgets, will increase with a greater sample size; 30 tagged individuals has been recommended as a minimum for such studies (Aebischer *et al.* 1993). Although four Turtle Doves were caught and tagged relatively easily at Ixworth Thorpe in 1996, it is unlikely that 30 adults could be caught at such a site without large-scale baiting. At Deeping St Nicholas, the grain-stores were equivalent to large-scale baiting. At the latter site, catching even greater numbers of Turtle Doves would have been feasible in 1996. Three out of four individuals which were tagged at the latter site could not be located shortly after tagging and it is therefore possible that they resided outside the extensive area in which searches were undertaken. Tagging individuals at similar feeding sites, for example a 'heavily' baited catching area, may therefore result in a tagged study population which is too dispersed for effective monitoring. It is also possible that Turtle Doves feeding at such sites may behave atypically. Therefore, there may be a conflict between tagging the desired sample size and creating a study population that can be effectively monitored and behaves typically.

4.4 A comparison of the two sites for studying Turtle Doves

A comparison of the two sites used in the pilot-study is useful for the planning of further work. At Deeping St Nicholas, nests were relatively easy to find and subsequently monitor, compared to Ixworth Thorpe. A number of Turtle Doves were individually colour ringed at the former site, and could contribute to a continuing study of marked birds, but see Section 4.3.2. The artificial provision of food (from open grain-stores and maintained feeding stations) may influence the behaviour and breeding success of Turtle Doves at Deeping St Nicholas, so the use of the latter site in isolation to study a representative sample of British Turtle Doves would be unwise. However, a comparative study involving the Deeping St Nicholas site and other more typical, 'natural' site(s) could form the basis of an experimental investigation to assess the influence of natural food availability on the breeding status of the Turtle Dove.

Ixworth Thorpe is, perhaps, typical of rural south-east England, where the majority of Turtle Doves currently occur in Britain. In 1996, the latter area held similar densities of Turtle Doves as were present when the species was at its peak of abundance and most extensive distribution (Section 4.2.1). Unfortunately, nest-finding and subsequent monitoring proved difficult at

Ixworth Thorpe, and only two individuals were colour-ringed in 1996. Radio-telemetry could improve nest-finding efficiency, however (Section 4.1.3). The difficulties of establishing a sufficiently large population of radio-tagged individuals at Ixworth Thorpe has been discussed (Section 4.3.3). Ixworth Thorpe, apparently containing typical habitat and with a sufficient Turtle Dove population (in 1996), could perhaps be used as the main site for future study. However, given sufficient resources, a comparative study with another site (or sites) would be preferable.

ACKNOWLEDGEMENTS

We thank all land owners and managers who kindly gave permission for us to work on their land, notably Mr. P. Pask, Mr. C. Wilson, Mr. J. Wilson and Mr. A. Smith at Ixworth Thorpe and their neighbours on the Euston estate and around Bardwell. At Deeping St Nicholas we especially thank Mr. P.N. Watts and his family without whose assistance and hospitality the work would not have been possible. We are also grateful to Mr. C. Knight and Mr. P. Knight for permission to use their land but apologize for ultimately working elsewhere. Steve Moreby advised on the faecal analyses and Julie Ewald gave much assistance with the geographical information systems. We also thank Nick Brickle for drawing the cover illustration at short notice. The BTO granted J.C. a licence to fit unconventional marks.

The study was funded by the Lowlands Team of English Nature.

REFERENCES

Aebischer, N.J., Robertson, P.A. & Kenward, R.E. 1993. Compositional analysis of habitat use from animal radio-tracking data. *Ecology* 74: 1313-1325.

Aebischer, N.J., Marcström, V., Kenward, R.E. & Karlbom, M. 1993. Survival and habitat utilisation: a case for compositional analysis. In Lebreton, J.-D. & North, P.M. (eds.) *Marked Individuals in the Study of Bird Populations*, Birkhäuser Verlag, Basel: 343-353.

Baker, K. 1993. *Identification guide to European non-passerines*. British Trust for Ornithology, Thetford.

Bibby, C.J., Burgess, N.D. & Hill, D.A. 1990. *Bird census techniques*. Academic Press, London.

Bijlsma, R.G. 1985. De broedbiologie van de Tortelduif *Streptopelia turtur*. *Vogeljaar* 33: 225-232.

Cederwall, G. 1978. Turturduvan *Streptopelia turtur* på Öland. *Calidris* 7: 12-22.

Cramp, S. (ed) 1985. *The birds of the Western Palearctic*, Vol. 4. University Press, Oxford.

Dias, S. & Fontoura, A.P. 1996. A dieta da rôla-brava (*Streptopelia turtur*) no sul de Portugal. *Revista Florestal* 9: 227-241.

Dias, S., Pereira, A.J. & Fontoura, A.P. 1996. The art of capturing doves: the past and the future of a traditional Portuguese technique. *Transactions of the XXIInd IUGB Congress "The Game and the Man"*, Sophia, Bulgaria, September 1995: 367-372.

Duckworth, W. 1992. Decline of the Turtle Dove in the Saltford Area. *Bristol Ornithology* 21: 64-66.

Flood, R.J. & Gates, G.C. 1986. *Seed Identification Handbook*. National Institute of Agricultural Botany, Cambridge.

Fontoura, A.P. & Dias, S. 1996. Productivity of the turtle dove (*Streptopelia turtur*) in the northwest of Portugal. *Transactions of the XXIInd IUGB Congress "The Game and the Man"*, Sophia, Bulgaria, September 1995: 1-7.

Garzon, J. 1974. Alteración en la trófica de la Tórtola Común (*Streptopelia turtur*). *Ardeola* 20: 262-263.

Genard, M. 1989. Contribution à la connaissance de la Tourterelle des bois (*Streptopelia turtur L.*) en Gironde (France): migration et nidification. *Nos Oiseaux* 40: 11-24.

Gibbons, D.W, Reid, J.B. & Chapman, R.A. 1993. *The new atlas of breeding birds in Britain and Ireland: 1988-1991*. T. & A.D. Poyser, London.

Goodwin, D. 1989. Decline of the Turtle Dove. *Bristol Ornithology* 20: 176-180.

Grigg, D. 1989. *English Agriculture - an historical perspective*. Basil Blackwell, Oxford.

Holzwarth, G. 1971. Ornithologischer Sammelbericht für Baden-Württemberg. *Anzeiger der ornithologischen Gesellschaft in Bayern* 10: 174-182.

Hongell, H. & Saari, L. 1983. A mixed pair of Collared *Streptopelia decaocto* and Turtle Doves *S. turtur* in Kokkola, W. Finland, in 1978-79. *Ornis Fennica* 60:61-62.

Hosking, E.J. 1942. Some observations on breeding-habits of the Turtle-Dove. *British Birds* 36: 1-4.

Jimenez, R, Hodar, J.-A. & Camacho, I. 1992. La alimentación estival de la Tórtola Común (*Streptopelia turtur*) en el sur de España. *Gibier Faune Sauvage* 9: 119-126.

Kenward, R.E. 1987. *Wildlife Radio-tagging: Equipment, Field Techniques and Data Analysis*. Academic Press, London.

Kiss, J.B., Rekasi, J. & Sterbetz, I. 1978. Dati sull'alimentazione di alcune specie di uccelli nel nord della Dobrugia (Romania). *Avocetta* 2: 3-18.

Kotov, A.A. 1974. [Ecology of the Turtle Dove in the southern Urals. *Byulleten M.O-va Isp.Prirodi, Otd.Biologii* 79: 36-43]

Kraus, M., Krauß, W. & Mattern, U. 1972. Zur Verbreitung der Turteltaube (*Streptopelia turtur*) in Nordbayern. *Anzeiger der ornithologischen Gesellschaft in Bayern* 11: 263-268.

MapInfo Corp. (1992). *MapInfo Professional 4.0*, desk-top mapping program.

Marchant, J.H., Hudson, R., Carter, S.P. & Whittington, P. 1990. *Population trends in British breeding birds*. British Trust for Ornithology, Thetford.

Marchant, J. & Wilson, A. 1996. Common Bird Census: 1994-95 index report. *BTO News* 204: 9-13.

Mayfield, H. 1975. Suggestions for calculating nest success. *Wilson Bulletin* 73: 456-466.

Miller, A. 1992. Twenty years of the Common Bird Census on Hollesley Heath. *Suffolk Birds* 41: 7-11.

Mountford, J.O., Lakhani, K.H. & Kirkham, F.W. 1993. Experimental assessment of the effects of nitrogen addition under hay cutting and aftermath grazing on the vegetation of meadows on a Somerset peat moor. *Journal of Applied Ecology* 30: 321-332.

Murton, R.K. 1968. Breeding, migration and survival of Turtle Doves. *British Birds* 61: 193-212.

Murton, R.K., Westwood, N.J. & Isaacson, A.J. 1964. The feeding habits of the Woodpigeon *Columba palumbus*, Stock Dove *C. oenas* and Turtle Dove *Streptopelia turtur*. *Ibis* 106: 174-188.

Murton, R.K., Westwood, N.J., Isaacson, A.J. 1965. Russian observations by G.N. Likhachev on the diet of the Stock Dove *Columba oenas* and Turtle Dove *Streptopelia turtur*. *Ibis* 107: 254-256.

Nankinov, D. 1994. The breeding biology of the Turtle Dove (*Streptopelia turtur*) in Bulgary. *Gibier Faune Sauvage* 11: 158-165.

Norris, C.A. 1960, The breeding distribution of thirty species in 1952. *Bird Study* 7: 129-184.

O'Connor, R.J. & Shrubb, M. 1986. *Farming and birds*. University Press, Cambridge.

Peiró, V. 1990. Aspectos de la reproducción de la Tórtola Común (*Streptopelia turtur, l.*) en Madrid. *Mediterránea Ser. Biol.* 12: 89-96.

Pikula, J. & Beklová, M. 1984. Bionomy of *Streptopelia decaocto* and *S. turtur* in Czechoslovakia. *Acta Scientiarum Naturalium Academiae Scientiarum Bohemoslovacae - Brno* 18: 1-45.

Rosenberg, K.V. & Cooper, R.J. 1990. Approaches to avian diet analysis. In Morrison, M.L., Ralph, C.J., Verner, J. & Jehl, J.R. (eds) Avian Foraging: Theory, methodology and applications. *Studies in Avian Biology* 13: 80-90.

dos Santos Jr., J.R. 1983. A Rola *Streptopelia turtur* (L.) ameaçada de extinção. *Cyanopica* 3: 105-107.

Sharrock, J.T.R. 1976. *The atlas of breeding birds in Britain and Ireland*. BTO IWC, Tring.

Sitters, H.P. 1988. *Tetrad atlas of the breeding birds of Devon*. Devon Birdwatching and Preservation Society, Yelverton.

Spencer, K.G. 1965. A history of the non-domestic doves and pigeons in Lancashire during the past century. *The Naturalist*, Hull 1965: 48-50.

Tucker, G.M. & Heath, M.F. 1994. *Birds in Europe: their conservation status*. BirdLife International (BirdLife Conservation Series no.3), Cambridge.

Yeatman-Berthelot, D. & Jarry, G. 1995. *Nouvel atlas des oiseaux nicheurs de France 1985-1989.* Société Ornithologique de France, Paris.

Williams, E.D. 1978. *Botanical composition of the park grass plots at Rothamsted 1856-1976.* Harpenden: Rothamsted Experimental Station.

Wilson, P.J. 1994. Botanical diversity in arable field margins. In Boatman, N. (ed.) *Field margins - Integrating agriculture and conservation*. British Crop Protection Council Monograph No. 58: 53-58.