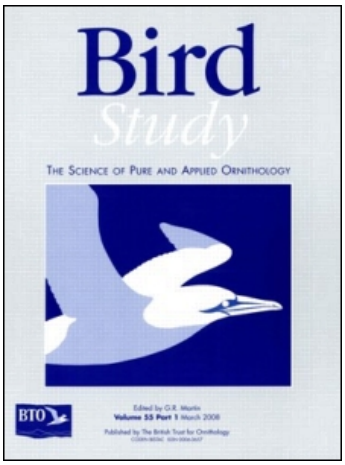

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The status of breeding Woodlarks *Lullula arborea* in Britain in 2006

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Capsule There have been marked increases (88%) in the breeding population and breeding range (46%) of Woodlarks in Britain between 1997 and 2006.

Aims To provide an accurate assessment of the population and distribution of Woodlarks in Britain and how these have changed since a survey conducted in 1997.

Methods Survey coverage included 'core' 1 km squares (known occupancy in 1997) and a stratified random sample, based on suitable habitat and soil type.

Results A population estimate of 3064 territories was obtained, giving an increase of 88% since 1997, while the range of occupied 10 km squares had increased by 46%. The majority of territories were associated with two main habitat types; heathland (66.7%) and forestry plantation (32.4%), and farmland in the southwest (13.4%). Sandy soils held the majority of territories (80.3%).

Conclusion In the UK, the Woodlark is a species of high to moderate conservation concern subject to a national Biodiversity Action Plan (BAP). This survey demonstrated that the population has increased to meet the BAP targets set in 1996 for population size and range expansions in England, and is on schedule to meet targets in Wales. The species has responded to conservation restoration projects and is highly dependent on forest management.

INTRODUCTION

The global Woodlark *Lullula arborea* population is between 2500000 and 6500000 pairs (BirdLife International 2007), with Europe supporting at least 75% of the total breeding range (Burfield & Bommel 2004) and approximately 75% of the European population found in Iberia (Hagemeijer & Blair 1997). The distribution appears to be constrained by warm summers and mild winters, and the UK is at the northern edge of the range. The long-term population trend for Woodlarks in Europe suggest a large decline occurred between 1970 and 1990 but stability since then, although there have been localized increases in countries such as France, the Netherlands, Romania and Sweden (Burfield & Bommel 2004).

In the UK, the Woodlark was widespread across much of southern Britain during the middle of 20th century, probably peaking in the early 1950s (Parslow 1973). Subsequently, it underwent a dramatic decline in numbers and contraction in range. An estimate of 200–450 pairs was derived from the 1968–72 Breeding Bird Atlas (Sharrock 1976). An estimate of 360–400 territories in the late 1970s was thought to represent an increase since the first atlas (despite being within the range of the first atlas' estimate), mainly owing to the creation of large tracts of suitable habitat on the Hampshire/Surrey border, resulting from heath fires (particularly in 1976), and the felling of large areas of forest in Breckland (Sitters *et al.* 1996). In 1981 the population was estimated at 400–430 territories but the hard winter of 1981–82 resulted in a reduction to an estimated 200–250 territories in 1982 (Sitters 1986).

The first full national survey in 1986, found that the population had declined to a minimum of 241 pairs (Sitters *et al.* 1996), but it then increased once again; the 1988–91 Breeding Bird Atlas produced an estimate

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of 350 territories (Gibbons *et al.* 1993). The second full survey in 1997 showed that this increase had continued, to 1426–1552 pairs (Wotton & Gillings 2000).

In Britain, a range decrease of over 50% between 1968–72 and 1997 resulted in Woodlarks being retained on the red list of the *Birds of Conservation Concern* (Gregory *et al.* 2002). Little quantitative information on range is available prior to the 1960s but during the 1968–72 Atlas, a total of 196 10 km squares were occupied (Sharrock 1976). By 1986 only 35 10 km squares were occupied (Sitters *et al.* 1996). Since then the population expanded to occupy 73 10 km squares between 1988 and 1991 (Gibbons *et al.* 1993), and 90 10 km squares in 1997 (Wotton & Gillings 2000). At this point, population changes were tracked by fluctuations in range but overall a net contraction had occurred, with the majority of birds located within core areas of southern England and East Anglia (the latter accounting for 45% of the national population in 1997). The greatest regional range contraction between 1968–72 and 1997 occurred in southwest England, with occupied 10 km squares declining by 88% in this period, although there was slight recovery between 1986 and 1997 (Wotton & Gillings 2000). Breeding in Cornwall had ceased in the late 1980s, despite the nearby Devon population showing a good recovery in numbers by 1997, although the nearest population in Devon, in the Tamar Valley, also disappeared by the late 1980s.

Since the early 1990s there have been significant changes to core Woodlark habitat types, especially through several heathland restoration programmes across southern England, such as the RSPB Dorset Heathland Project and the Suffolk Sandlings Project (Brown & Grice 2005). The age structure and species composition of forestry plantations has changed due to different management regimes and the ageing of forestry plantations, and in addition it has become increasingly apparent that climate change (Hulme *et al.* 2002) has affected the range distribution and life cycles of many plants and animal (Green *et al.* 2001).

Given the conservation status of the species in the UK and the need for periodic monitoring of such vulnerable populations, it was important that an up-to-date national population estimate was produced, and changes in distribution since the last national survey identified. The results of this survey will allow an assessment of progress towards attaining key UK Biodiversity Action Plan (BAP) targets. They include increasing the population from 1500 pairs to 2150 pairs by 2015 and maintaining a range of at least 90 10 km squares (with re-colonization of Wales and southwest England) by 2015 (Anon 2006a). The results will also allow a re-assessment of dependency on key habitats and responses to related conservation measures carried out since 1997.

METHODS

Site selection and targeted coverage

The recording unit for the 2006 survey was the 1 km square. Core squares were classified as those which were occupied during the previous survey in 1997 and/or subsequently, and special protection areas (SPAs), where these had been designated for breeding Woodlarks; in Breckland, Suffolk Sandlings, Thames Basin Heaths, Wealden Heaths, Dorset Heaths and the New Forest (Anon 2007a).

Due to the species' expected expansion of range, information on the occupation of 1 km squares since 1997 was gathered alongside a further sampling strategy that targeted suitable habitat within 5 km and 10 km buffer zones around all known sites.

First, information on the occupation of sites since 1997, including both those occupied in previous surveys or since 1997, was collated through the British Trust for Ornithology (BTO) and Royal Society for the Protection of Birds (RSPB) regional networks and by contacting county bird recorders and regional Woodlark experts. Data were also extracted from birdwatching records submitted to the BTO/Birdwatch Ireland/RSPB BirdTrack website (www.birdtrack.net), the national BTO/RSPB/JNCC Breeding Bird Survey (BBS), and incidental records collected during the 2004 national European Nightjar *Caprimulgus europaeus* survey (Nightjars share a similar habitat preference to Woodlarks across much of the Woodlark's known range). Staff from the RSPB, Natural England and Forestry Commission – England supplied further information.

Secondly, squares containing lowland heathland within the 5 km and 10 km buffer around core squares were identified by Geographical Information Systems (GIS) maps from the Heathland Extent and Potential (HEaP) database (RSPB 2007) and heathland inventories (held by RSPB and Natural England) and suitable areas of plantations derived from forest stock maps (GIS databases of the Forestry Commission). These targeted forestry plantations were of ≤7 years old, or clear fell areas. Other potentially suitable habitat was identified from GIS layers of sandy, chalk and other free-draining soil types (Anon 2006b).

In addition, a stratified random sample of 1 km squares was selected and classed as either Suitable or Non-suitable, according to: (1) their proximity to core breeding locations (again within 5 km and 10 km buffers around core squares); (2) the presence of suitable soil types (i.e. sand, chalky and free-draining (Anon 2006b)); and (3) suitable habitat (heathland containing >5 ha of habitat per 1 km square. Initially, a total of 2000 1 km squares were selected, which were divided between four strata. This approach was adopted, because there is a strong association of Woodlarks with readily identifiable habitats and or soil types (Wotton & Gillings 2000). The strata and respective sample sizes (with percentage cover relative to the squares available) are as follows: (1) suitable habitat within the 5 km buffer (n = 1350, 17.2%) (2) non-suitable habitat within the 5 km buffer (n = 150, 2.4%); (3) suitable habitat within the 10 km buffer (n = 450, 9.4%); and (4) non-suitable habitat within the 10 km buffer (n = 50, 0.5%). The sampling effort within the 5 km buffer and 10 km buffers was set at 75% and 25% respectively, as this is where the majority of range expansion was expected to occur, based on the previous national survey. Within both the 5 km and 10 km buffers, the sampling intensity was 90% in the squares with suitable habitat and 10% in those with non-suitable habitat. It was still deemed necessary to sample some non-suitable squares as small pockets of suitable habitat may not have been identified or types of land use, such as crop stubbles or set-aside, may provide breeding habitat.

Further requests for casual records were publicized in the bird watching press and birding websites, including BirdTrack. Surveyors were also encouraged to visit other sites, either historically supporting Woodlarks or containing potentially suitable habitat. There were also 'extra' observer-selected squares, which contained potential habitat for Woodlarks but for which there was no recent (known) evidence of occupation.

Recording methods

The recording form issued to observers was based on that used in the 1997 national survey but with additional habitat categories included to accommodate new breeding preferences and a site map on which the location of individual birds could be plotted. Maps were derived from 1:25 000 and 1:50 000 Ordnance Survey maps.

The recording period for the survey was restricted to 15 February–31 May, even though the breeding period typically finishes in late July. This minimized the chances of double recording of pairs that may have changed breeding locations between early and late broods, or after early failure due to habitat loss (Wotton & Gillings 2000). A minimum of two visits was required, one within each of the periods 15 February–31 March, and 1 April–31 May, and ideally at least 3 weeks apart. Timing of visits was recommended to take place before midday on mild clear, dry days with little wind. Observers were advised to postpone surveying if daytime (pre-midday) temperature had remained below 5°C for more than 3 days previously, as this was likely to depress Woodlark activity.

Observers were requested to completely cover each 1 km square, walking within 100 m of all areas of suitable habitat to maximize the detection of territorial individuals. Where site access was limited, surveying was conducted from public rights of way or areas of public access. Suitable habitat included heather and grass heaths (particularly where mown, grazed or burnt), conifer plantations recently cleared or replanted not more than seven years ago, and along forest rides and in open space within plantations. Arable habitats, such as set-aside, field margins and other cropped areas, especially where recently disturbed, are also used by Woodlarks and hence were included in the survey. Other suitable areas also include well-drained sites on sand, gravel or chalk, with areas of short vegetation (<10 cm high) and/or patches of bare ground.

The basic counting unit for the survey was territory. Territories were defined as containing: (1) a singing male; (2) a pair exhibiting breeding activity (nest, mating, displaying, etc); (3) individuals present on more than one visit; and (4) two individuals present. Records of individuals only seen in flight (except song flight) were excluded.

Analysis of territories

All registration data for males, pairs, juveniles or unaged/un-sexed individuals, and their behaviour (e.g. singing or flying) was recorded on a site-map. The registrations from the site-map were then plotted on a GIS (arcview, ESRI). For the purposes of consistency across all sites and elimination of double counting (on edges of neighbouring 1 km squares), individual territories were determined from the precise location of bird registrations, according to the interpretation of the field surveyor. Where this information was not available, the following criteria were applied:

1. Where different individuals were identified, such as simultaneously singing males.
2. Where singing males were over 400 m apart, except where known topographical or structural features ('barriers' such as forest blocks) separated males.
3. Where clusters of registrations, from sequential visits, indicated the presence of distinct groupings that were indicative of discrete territories.

Calculation of population estimates

The overall population estimate was derived from three components: (1) the number of territories counted within the core squares; (2) estimates for the number of territories in the suitable habitat within each of the two strata (in 5 km and 10 km buffers around the core squares), derived by extrapolation from sampled squares; and (3) an upward correction for territories missed in squares surveyed fewer than four times. A boot-strapping, re-sampling method (Efron 1982) was used, with 999 reiterations to calculate 95% confidence intervals for estimates of the latter two elements.

Land-use and habitat recording

The habitats used by breeding Woodlarks in the UK have been well documented (Wotton & Gillings 2000, Sitters *et al.* 1996, Bowden & Green 1992), so the same land-use and habitat categories were used as in the 1997 survey. Habitat type was recorded on a hierarchal scale for all individual territorial bird registrations. The primary level was the predominant habitat of the 1 km square, chosen from the following categories: Farmland, Heathland, Plantation, Woodland, Human or Other. The secondary level related to the habitat types within the primary categories (see Appendix 1), as used in the 1997 survey that occurred within a 50 m radius of the first contact with each singing male.

Definition of regions

For analytical consistency with the 1997 survey, six population centres were adopted in 2006 (Fig. 1): (1) Devon and Cornwall in southwest England (SW England); (2) Dorset, New Forest and southwest Hampshire (Dors/NF/SW Hants); (3) northeast Hampshire, west Sussex, Berkshire and Surrey (NE Hants/Surr/Berk/W Suss); (4) 'Breckland' (within East Anglia, a Special Protection Area (SPA) of heathland, forest and farmland straddling west Norfolk and Suffolk); (5) 'Suffolk Sandlings' (an area of heathland and forest in coastal east Suffolk); and (6) Nottinghamshire, Lincolnshire and Yorkshire (Notts/Lincs/Yorks). All other locations were combined as 'Other' (7); that is, Ashdown Forest, north Norfolk, Staffordshire and Wales.

RESULTS

Survey coverage

A total of 3619 1 km squares were surveyed in 2006, a 149% increase in coverage compared to the 1997 survey (Table 1; 1997 was a site-based survey, except for New Forest & Forestry Commission plantations). Within the seven defined regions, coverage was between 110% and 460% greater in 2006 than 1997, except for SW England where coverage decreased by 10%. The distribution of 10 km squares covered during 2006, compared with 1997 is shown in Figure 1. All core sites were covered in 2006, along with an extensive sample of squares within 10 km of the core sites, giving more extensive coverage than in 1997. The majority of 10 km squares covered for the first time, in 2006, were situated on the periphery of core populations or new sites occupied since 1997. Squares not covered in 2006 were sites unoccupied in 1997 or subsequently, particularly SW England and Wales. Levels of coverage of 1 km squares from all survey elements are shown in Table 1 along with the sampling levels and detection levels of the peripheral stratified random sample around core squares. The random sample represented approximately 24% (5 km buffer) and 6% (10 km buffer) of the total coverage of squares (n = 3619), detecting 77 Woodlark territories within the 5 km buffer (75 territories in suitable squares, two territories in non suitable squares). No territories were found in either component of the 10 km buffer (Table 1).

Population size and breeding range in 2006

The 2006 survey recorded 1757 territories (Table 2; Figs. 2 & 3) and an adjusted population estimate for Britain, of 3064 territories (95% CI, 2472–3687). This adjustment accounts for non-surveyed areas of suitable habitat (Table 2), by adding a further 934 (95% CI, 446–1519) territories to the total. On top of this, an additional 373 territories (95% CI, 269–411) were added as a correction for visit frequency and the number of squares

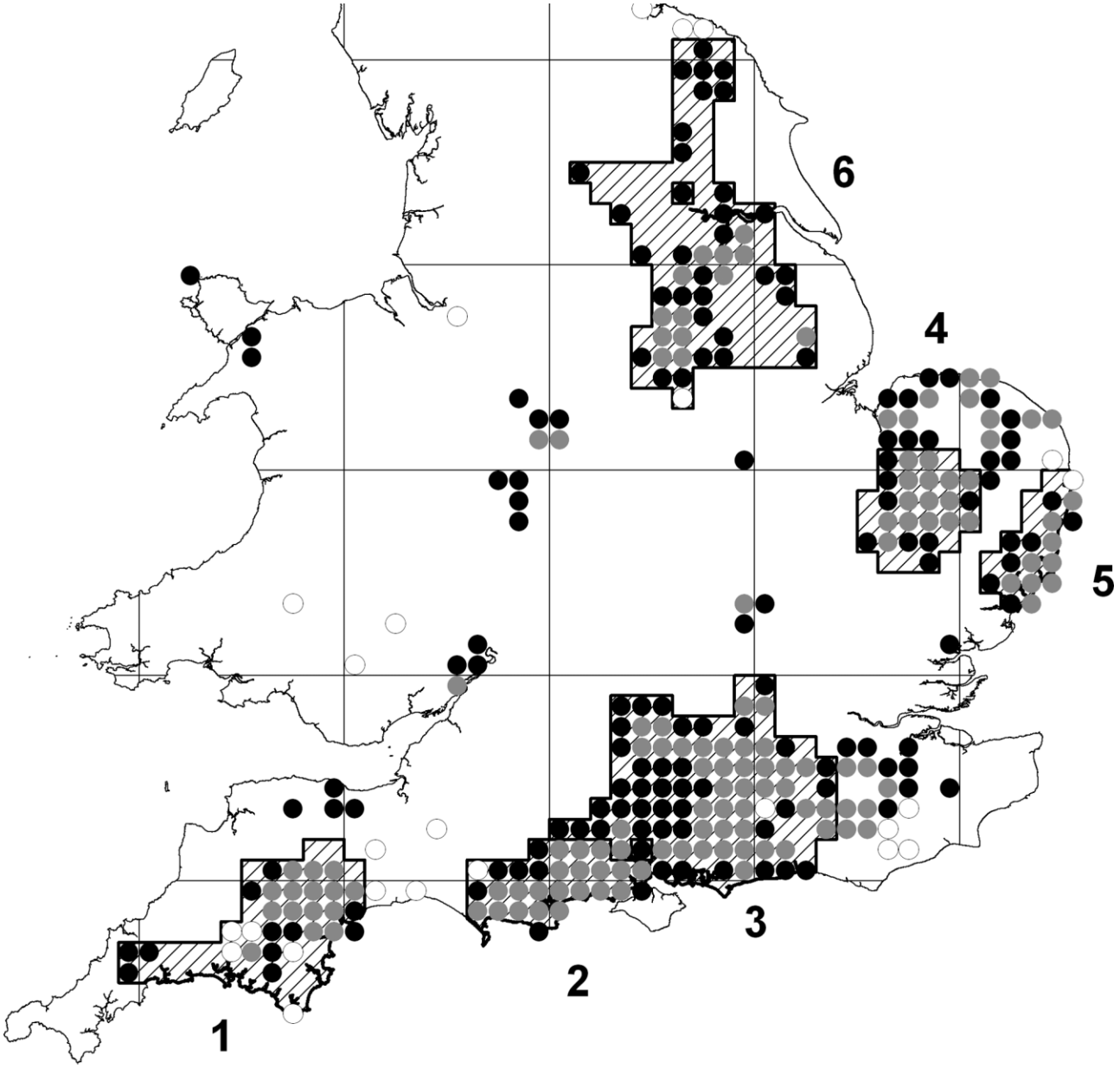

Figure 1. Survey coverage by 10 km squares surveyed for Woodlarks in 2006 and 1997: (●) 2006; (●) 1997 and 2006; (○) 1997. Labels, 1–6 identify the six population centres adopted in 2006: (1) Devon and Cornwall in southwest England (SW England); (2) Dorset, New Forest and southwest Hampshire (Dors/NF/SW Hants); (3) northeast Hampshire, west Sussex, Berkshire and Surrey (NE Hants/Surr/Berk/W Suss); (4) 'Breckland' (within East Anglia, a special protection area (SPA) of heathland, forest and farmland straddling west Norfolk and Suffolk); (5) 'Suffolk Sandlings' (an area of heathland and forest in coastal east Suffolk); (6) Nottinghamshire, Lincolnshire and Yorkshire (Notts/Lincs/Yorks); (7) all other locations (Other).

receiving fewer than four visits (typically most squares received two visits).

In 2006, the population was found within 133 10 km squares, with over 70% of territories located in just three regions: Dors/NF/SW Hants, NE Hants/Surr/Berk/W Suss, and Breckland (Table 3). High occupancy of 10 km squares in Lincs/Notts/Yorks and the 'Other' region demonstrates the extent of change that has occurred since 1997 (see later).

Changes in population size

The population estimate for 2006 represented an 83% increase since 1997 (Appendix 2). This was largely

Table 1. A regional summary of the coverage of all survey 1 km squares in 2006, including coverage, the contribution of the stratified random sample to the sampling regime, and the numbers of Woodlark territories found within the stratified sample. The grand total for 2006 includes the grand total for 1997 (in parentheses) in order to compare coverage between the two survey years.

	All survey squares in 2006				*Random sample of squares in 2006				
					5 km buffer			10 km buffer	
Region	Core	Extra	Random sample*	Grand total	Squares covered	% of stratum	Woodlark territories	Squares covered	% of stratum
SW England	93	28	126	247 (274)	106	24.8	7	20	1.4
Dors/NF/SW Hants	812	11	94	917 (432)	69	5.2	7	25	4.8
NE Hants/Surr/Berk/W Suss	503	89	370	962 (171)	302	6.8	27	68	2.3
Breckland	472	22	113	607 (284)	96	9.1	6	17	2.2
Suffolk Sandlings	164	1	82	247 (86)	74	11.9	9	8	1.5
Lincs/Notts/Yorks	88	46	169	303 (71)	137	5.5	10	32	0.9
Other	128	69	139	336 (137)	97	3.6	9	42	0.9
Britain totals	2260	266	1093	3619 (1455)	881		75	212	

SW England, Devon and Cornwall in southwest England; Dors/NF/SW Hants, Dorset, New Forest and southwest Hampshire; NE Hants/Surr/Berk/W Suss, northeast Hampshire, west Sussex, Berkshire and Surrey; Breckland, within East Anglia, a special protection area (SPA) of heathland, forest and farmland straddling west Norfolk and Suffolk; Suffolk Sandlings, an area of heathland and forest in coastal east Suffolk; Notts/Lincs/Yorks, Nottinghamshire, Lincolnshire and Yorkshire; Other, all other locations (Ashdown Forest, north Norfolk, Staffordshire and Wales).

due to increases in Dorset, NE Hampshire, Surrey, Sussex, Staffordshire, south Yorkshire and north Norfolk. There were, however, declines in Breckland and especially the Suffolk Sandlings (Fig. 3). Generally the largest decreases were within some 'traditional' population centres, whereas the gains have occurred around the extremities of such areas, and in new areas, particularly northern England and the West Midlands (Fig. 2).

Changes in breeding range

There was a 48% increase in breeding range since 1997 (Table 3; Fig. 2), with expansion into the west and north: notably in Wales, West Midlands and Yorkshire. Other areas showing large range increases include East Anglia (especially north Norfolk and even Breckland despite an overall population decline) and southern England, particularly east Dorset and Hampshire. Twelve 10 km squares were no longer occupied since 1997. A notable area of loss occurred in central and southeast England, including local extinctions in Bedfordshire and Buckinghamshire (Fig. 2). The largest regional increase in range, at the 10 km square level, occurred in the regions of Lincs/Notts/Yorks; NE Hants/Surr/Berk/W Suss; Breckland and 'Other' (especially Ashdown Forest and north Norfolk; Table 3 and Fig. 2). A small increase (11.1%) occurred in SW England but no overall change occurred in the Suffolk Sandlings (Table 3). A decrease in Dors/NF/SW Hants involved only a single 10 km square.

The continuity of territory occupancy between the 1997 and 2006 is shown in Table 3b, at a finer 5 km scale. Occupancy was relatively stable in Dors/NF/SWHants, Breckland and Suffolk Sandlings, and to a lesser extent NE Hants/Surr/Berk/W Suss, where between 57% and 83% of 5 km squares were occupied in both periods. By comparison, SW England showed a relatively high turnover in territory occupancy. The remaining two regions, Lincs/Notts/Yorks and Other, were characterized by substantial gains, relative to their losses (Table 3).

Distances between newly occupied sites in 2006 and their nearest site in 1997, ranged from 6 km to 99 km. There were 19 movements between 25 km and 99 km in the West Midlands, Wales and Yorkshire; 13 movements of between 6 km and 15 km in north Norfolk; 44 movements of between 6 km and 21 km in Hampshire, West Sussex and Surrey and eight movements of 6 km to 9 km in SW England.

Distribution of territories by habitat

The relationship between Woodlark territories and habitat is shown in Tables 4 & 5. For Dors/NF/SW Hants and NE Hants/Surr/Berk/W Suss, heathland supported 80% of territories and plantation woodland 24% of territories (Table 4). In SW England, the majority of territories were on farmland (as in 1997), and typically on sparse, fallow grassland. In Breckland, the majority of territories were associated with plantation forest;

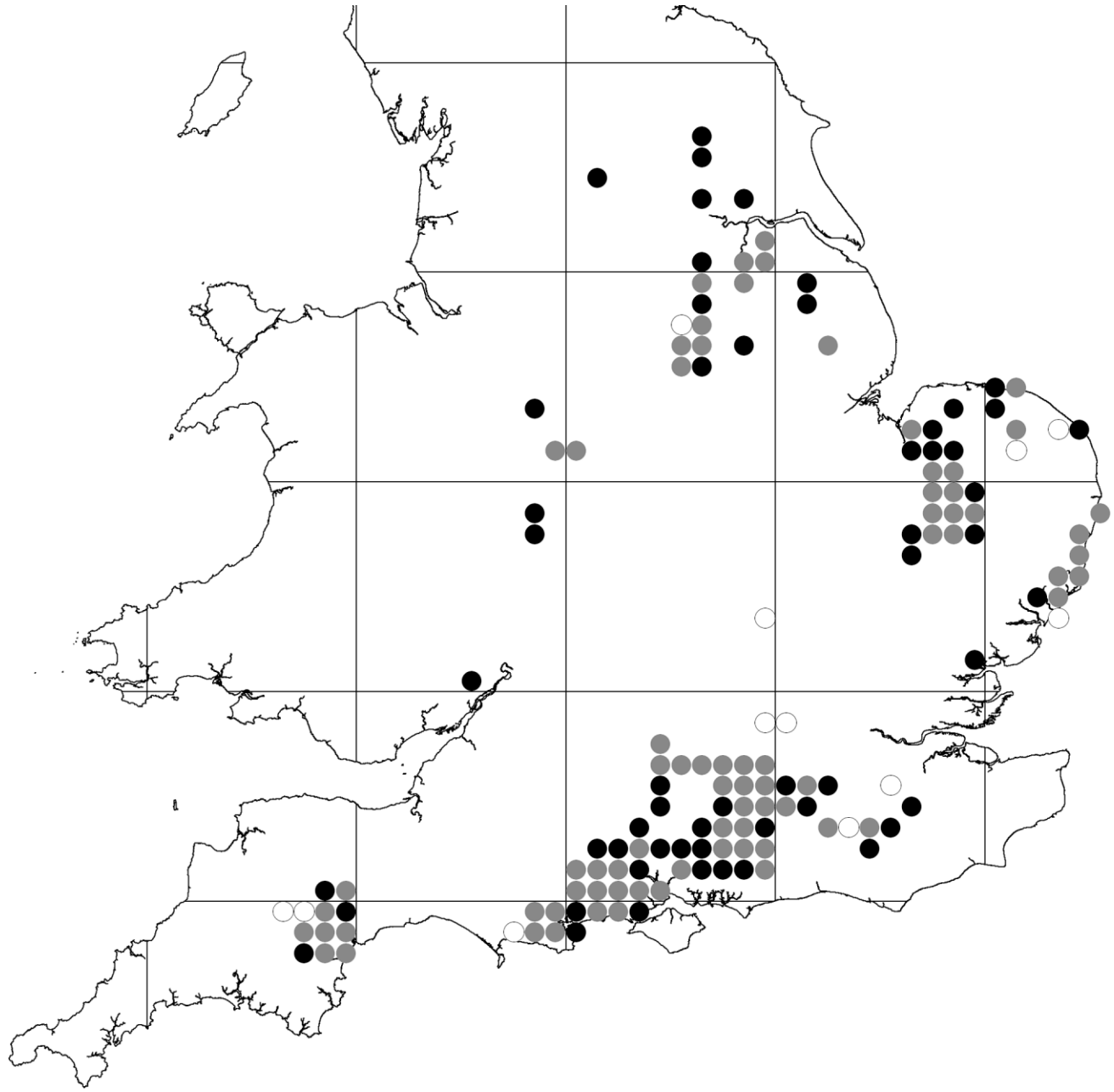

Figure 2. Change in occupation by 10 km squares, between 1997 and 2006: (○) loss; (●) no change; (●) gain.

about half were associated with heathland (Table 4), especially grass-dominated heathland (Table 5), whereas farmland supported just over 5% of all territories in 2006 (Table 4). In Lincs/Notts/Yorks, there was a 20% higher proportion of territories associated with heathland than plantation/woodland in 2006 (Table 4). Territories in the 'Other' category (e.g. Ashdown, north Norfolk, Staffordshire and Wales) were mainly associated with heathland.

Changes in the distribution of territories by habitat

In Britain as a whole, the proportion of territories associated with plantations/woodland declined between 1997 and 2006, by 7% to around 32% of the population but increased on heathland from 47% to 67% of the population. The biggest changes in habitat use were on natural and burnt bare ground and grass heath, but

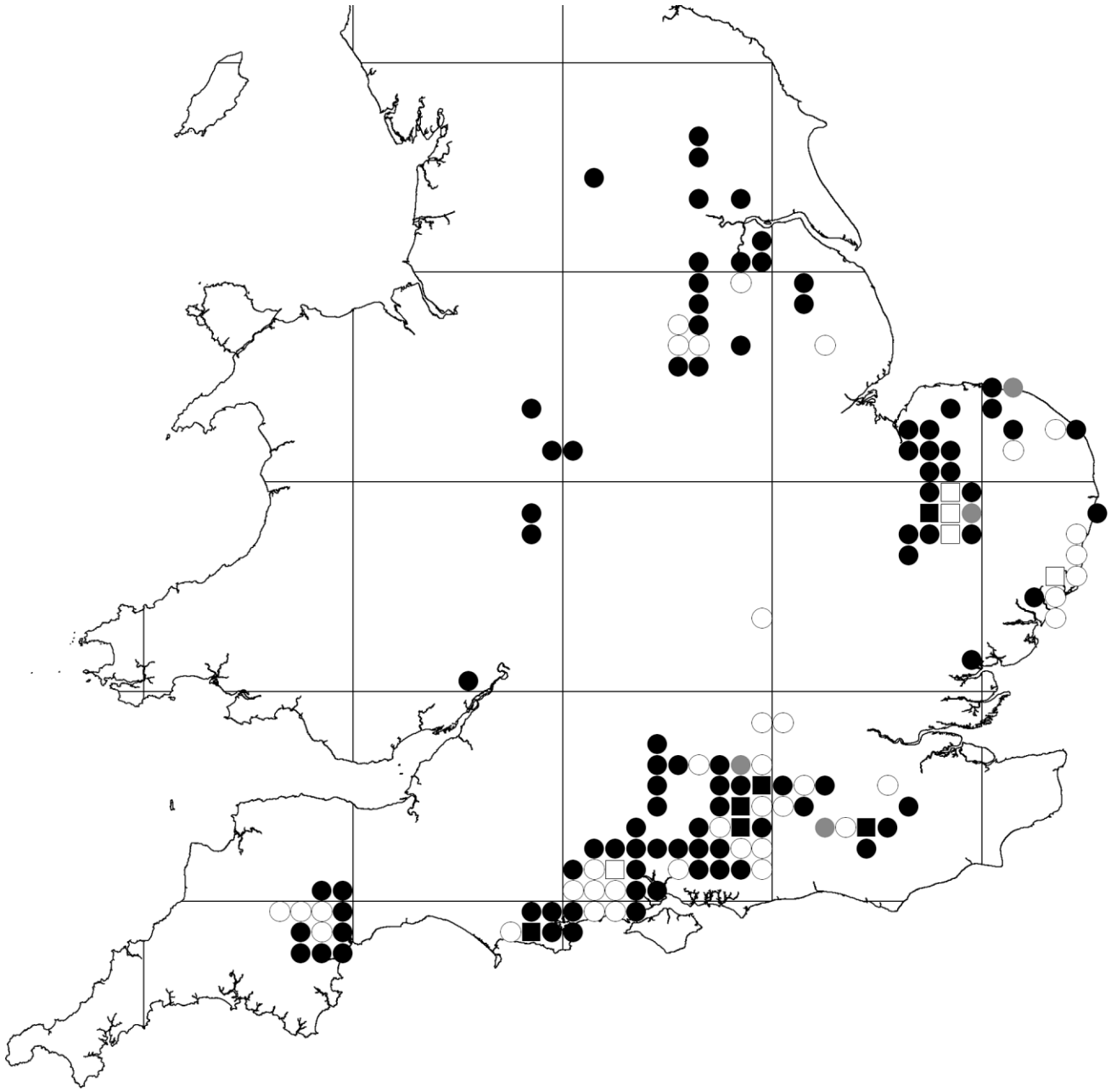

Figure 3. Actual change in number of territories per 10 km square between 1997 and 2006: (■) gain of ≥ 20; (●) gain of 1–19; (●) no change; (O) loss of 1–19; (□) loss of ≥ 20.

not on farmland, as might have been predicted for an increasing population. Generally, the proportions of Woodlark territories associated with grazed grassland or grazed heathland declined by around 50% in both cases, but this may reflect either availability or the availability of alternative non-grazed habitats nearby.

In southern England (Dors/NF/SW Hants and NE Hants/Surr/Berk/W Suss), the proportion of Woodlark territories associated with heathland was similar to 1997 (Table 4), but in Dors/NF/SW Hants there was a two-fold increase in the proportion of territories associated with plantation/woodland. Meanwhile, in SW England, a nine-fold increase in the territories associated with plantation/woodland was based on only a small sample size, and the majority of birds were once again associated with farmland (Table 4). In SW

Table 2. Regional territory estimates for Woodlarks showing the calculated adjustments for extrapolation from the random sample of squares within the 5 km buffer, but before adjustments for survey visit frequency (Fig. 4). There were no birds recorded within the 10 km buffer of any region.

		5 km buffer			
Region	Actual territories found	Territories (mean)	Lower 95% CI	Upper 95% CI	Total estimated territories
SW England	57	114	38	216	171
Dors/NF/SW Hants	332	44	0	107	376
NE Hants/Surr/Berk/W Suss	546	355	234	485	901
Breckland	412	58	26	91	470
Suffolk Sandlings	163	46	5	112	209
Lincs/Notts/Yorks	127	158	74	260	285
Other	120	159	89	248	279
Britain total	1757	934	466	1519	2691

SW England, Devon and Cornwall in southwest England; Dors/NF/SW Hants, Dorset, New Forest and southwest Hampshire; NE Hants/Surr/Berk/W Suss, northeast Hampshire, west Sussex, Berkshire and Surrey; Breckland, within East Anglia, a special protection area (SPA) of heathland, forest and farmland straddling west Norfolk and Suffolk; Suffolk Sandlings, an area of heathland and forest in coastal east Suffolk; Notts/Lincs/Yorks, Nottinghamshire, Lincolnshire and Yorkshire; Other, all other locations (Ashdown Forest, north Norfolk, Staffordshire and Wales).

Table 3. Regional changes in the occupancy by Woodlarks within: (a) 10 km squares during the 1968–72 Breeding Bird Atlas and the 1986, 1997 and 2006 national surveys; and (b) 5 km squares between 1997 and 2006.

	(a) 10 km squares					(b) 5 km squares			
Region	1968–72	1986	1997	2006	% change (1997 versus 2006)	*n*	% Gain	% Loss	% Same
SW England	73	7	9	10	11.1	26	34.6	25.9	38.5
Dors/NF/SW Hants	23	9	18	17	–5.6	44	13.6	4.5	81.8
NE Hants/Surr/Berk/W Suss	21	10	23	42	82.6	93	35.5	7.5	57.0
Breckland	11	4	9	13	44.4	34	23.5	2.9	73.5
Suffolk Sandlings	5	3	7	7	0	18	11.1	5.6	83.3
Lincs/Notts/Yorks	3	2	8	22	175.0	37	56.8	10.8	32.4
Other	56	0	16	22	37.5	32	62.5	12.5	25.0
Britain total	192	35	90	133	47.7				

SW England, Devon and Cornwall in southwest England; Dors/NF/SW Hants, Dorset, New Forest and southwest Hampshire; NE Hants/Surr/Berk/W Suss, northeast Hampshire, west Sussex, Berkshire and Surrey; Breckland, within East Anglia, a special protection area (SPA) of heathland, forest and farmland straddling west Norfolk and Suffolk; Suffolk Sandlings, an area of heathland and forest in coastal east Suffolk; Notts/Lincs/Yorks, Nottinghamshire, Lincolnshire and Yorkshire; Other, all other locations (Ashdown Forest, north Norfolk, Staffordshire and Wales).

England, set-aside was an important component of the farmland landscape for Woodlarks, while crops supported fewer birds than in 1997 (Table 4 & Table 5). In Breckland, although there was an increase in the proportion of territories associated with farmland (mainly set-aside), this represented only a small proportion of the total population (Tables 4 & 5). Meanwhile, the proportion of territories associated with heathland in Breckland doubled between 1997 and 2006. In the Suffolk Sandlings, a substantial shift in habitat association meant a large decline in plantations/woodland (by a quarter), but a two-fold increase on heathland (mainly grass-heathland) and a three-fold proportional increase on farmland (especially non-cropped habitats; Table 4). In Lincs/Notts/Yorks there was a 25% decrease in territories in plantation/woodland and a greater than two-fold increase in territories on grass and heather-dominated heathland between 1997 and 2006 (Tables 4 & 5). In the 'Other' category (Ashdown Forest, north Norfolk, Staffordshire and Wales) the number and proportion of territories associated with heathland increased between surveys. Generally, grass-dominated heathland gained in prominence on heather-dominated heath between 1997 and 2006 (Table 5).

Overall, there was an 8% decrease in all territories associated with plantations/woodland (this category being dominated by plantation forest) between 1997 and 2006. The largest percentage decreases occurred in the Suffolk Sandlings (−35%), Lincs/Notts/Yorks (−23%) and in Breckland (−7%) where the occupancy

Table 4. Numbers of Woodlark territories recorded in 1997 and 2006 by land-use type. Data are maxima, summarized for each region and for the national population. Within-region percentages are shown in parentheses, and are not mutually exclusive, since territories were sometimes associated with more than one habitat type.

	Plantation/ Woodland		Agriculture		Set-aside/ Stubble/Fallow		Horticulture & Tree nursery		Heathland		Grass		Mine/spoil/ slag heap		Golf course		Other	
Region	1997	2006	1997	2006	1997	2006	1997	2006	1997	2006	1997	2006	1997	2006	1997	2006	1997	2006
SW England	1 (1.9)	8 (18.2)	52 (98.1)	23 (52.2)	0	23 (52.3)	0	5 (11.4)	0	0	0	32 (72.7)	0	0	0	0	0	0
Dors/NF/SW Hants	38 (12.8)	58 (24.5)	1 (0.3)	2 (0.8)	0	6 (2.5)	6 (2.0)	2 (0.8)	242 (81.4)	189 (79.7)	6 (2.0)	26 (11.0)	0	5 (2.1)	0	0	4 (1.3)	1 (0.4)
NE Hants/Surr/ Berk/W Suss	72 (18.1)	76 (18.4)	5 (1.3)	17 (3.9)	4 (1.0)	13 (3.0)	13 (3.3)	16 (3.7)	287 (72.3)	343 (79.2)	9 (2.6)	18 (4.2)	2 (0.5)	0	3 (0.8)	2 (0.5)	2 (0.5)	4 (0.9)
Breckland	342 (77.7)	230 (69.3)	2 (0.5)	18 (5.4)	2 (0.5)	14 (4.2)	1 (0.2)	0	89 (20.3)	162 (48.8)	1 (0.2)	9 (2.7)	0	0	2 (0.5)	0	1 (0.2)	1 (0.3)
Suffolk Sandlings	113 (46.1)	16 (10.9)	7 (2.9)	16 (10.9)	10 (4.1)	25 (17.0)	0	0	70 (28.6)	111 (75.5)	45 (18.4)	8 (5.4)	0	0	0	0	0	2 (1.4)
Lincs/Notts/Yorks	35 (52.2)	27 (29.0)	2 (3.0)	5 (5.4)	0	9 (9.7)	1 (1.5)	1 (1.1)	15 (22.4)	49 (52.7)	2 (3.0)	2 (2.3)	11 (16.4)	0	1 (1.5)	0	0	17 (18.3)
Other	13 (34.2)	14 (29.2)	0	6 (12.5)	0	2 (4.2)	0	2 (4.2)	20 (52.6)	36 (75.0)	1 (2.6)	2 (4.2)	0	0	0	0	4 (10.5)	0
Britain total	614 (39.9)	429 (32.2)	69 (4.5)	87 (6.5)	16 (1.0)	92 (6.9)	21 (1.4)	26 (2.0)	723 (47.0)	890 (66.7)	74 (4.2)	97 (7.3)	13 (0.8)	5 (0.4)	6 (0.4)	2 (0.2)	11 (0.7)	25 (1.9)

SW England, Devon and Cornwall in southwest England; Dors/NF/SW Hants, Dorset, New Forest and southwest Hampshire; NE Hants/Surr/Berk/W Suss, northeast Hampshire, west Sussex, Berkshire and Surrey; Breckland, within East Anglia, a special protection area (SPA) of heathland, forest and farmland straddling west Norfolk and Suffolk; Suffolk Sandlings, an area of heathland and forest in coastal east Suffolk; Notts/Lincs/Yorks, Nottinghamshire, Lincolnshire and Yorkshire; Other, all other locations (Ashdown Forest, north Norfolk, Staffordshire and Wales).

Table 5. Numbers of Woodlark territories recorded in 1997 and 2006 by habitat type, summarized for each region and for the British population as a whole. Data are the number of territories associated with each habitat type. Within-region percentages are shown in parentheses, and the percentages are not mutually exclusive since territories were sometimes associated with more than one habitat type.

	Grass				Heath dominated by						Bare Ground				Forest/woodland					
	Improved		Unimproved		Grass		Heather		Bracken		Natural		Burnt		Conifer		Broad-leaved		Crop	
Region	1997	2006	1997	2006	1997	2006	1997	2006	1997	2006	1997	2006	1997	2006	1997	2006	1997	2006	1997	2006
SW England	12	7	4	17	0	0	0	0	0	0	1	2	0	0	2	1	1	7	32	14
	(22.6)	(15.9)	(7.5)	(38.7)							(1.9)	(4.6)			(3.8)	(2.3)	(1.3)	(15.9)	(60.4)	(31.8)
Dors/NF/SW Hants	3	1	9	25	71	83	139	107	17	13	17	51	10	30	25	47	2	11	5	1
	(1.0)	(0.4)	(3.0)	(10.6)	(23.8)	(35.0)	(46.6)	(45.2)	(5.7)	(5.5)	(5.7)	(21.5)	(3.4)	(12.7)	(8.4)	(19.8)	(0.5)	(4.6)	(1.7)	(0.4)
NE Hants/Surr/Berk/W Suss	7	10	9	14	52	110	202	169	16	37	22	61	19	37	47	37	1	36	5	8
	(1.8)	(2.3)	(2.3)	(3.2)	(13.2)	(25.4)	(51.4)	(39.0)	(4.1)	(8.6)	(5.6)	(14.1)	(4.8)	(8.6)	(12.0)	(8.6)	(0.2)	(8.3)	(1.3)	(1.9)
Breckland	1	3	4	7	75	148	12	2	0	4	16	59	1	23	320	220	15	14	3	11
	(0.2)	(0.9)	(0.9)	(2.1)	(17.9)	(44.6)	(2.7)	(0.6)		(1.2)	(3.6)	(17.8)	(0.2)	(6.9)	(72.7)	(66.3)	(6.2)	(4.2)	(0.7)	(3.3)
Suffolk Sandlings	3	0	11	8	49	82	33	29	21	4	1	57	1	12	95	12	0	7	13	1
	(1.2)		(4.5)	(5.4)	(20.2)	(55.8)	(13.6)	(19.7)	(8.6)	(2.7)	(0.4)	(38.8)	(0.4)	(8.2)	(39.1)	(8.2)		(4.8)	(5.3)	(4.8)
Lincs/Notts/Yorks	1	2	3	0	7	25	0	18	0	7	20	25	1	7	31	24	0	2	0	4
	(1.5)	(2.2)	(3.1)		(10.8)	(26.9)		(19.4)		(7.5)	(30.8)	(26.9)	(1.5)	(7.5)	(47.7)	(25.8)		(2.2)		(4.3)
Other	3	0	2	3	6	8	10	23	2	11	2	9	2	10	10	13	19	5	1	3
	(7.9)		(5.3)	(6.3)	(15.8)	(16.7)	(26.3)	(48.0)	(5.3)	(22.9)	(5.3)	(18.8)	(5.3)	(20.8)	(26.3)	(27.1)	(1.2)	(10.4)	(2.6)	(6.3)
Britain total	30	58	41	34	260	456	396	348	56	76	79	264	34	163	530	354	1	82	59	48
	(2.0)	(3.3)	(2.7)	(2.5)	(17.0)	(34.2)	(25.9)	(26.1)	(3.7)	(5.7)	(5.2)	(19.8)	(2.2)	(12.2)	(34.6)	(26.5)	(1.3)	(6.2)	(3.9)	(3.6)

SW England, Devon and Cornwall in southwest England; Dors/NF/SW Hants, Dorset, New Forest and southwest Hampshire; NE Hants/Surr/Berk/W Suss, northeast Hampshire, west Sussex, Berkshire and Surrey; Breckland, within East Anglia, a special protection area (SPA) of heathland, forest and farmland straddling west Norfolk and Suffolk; Suffolk Sandlings, an area of heathland and forest in coastal east Suffolk; Notts/Lincs/Yorks, Nottinghamshire, Lincolnshire and Yorkshire; Other, all other locations (Ashdown Forest, north Norfolk, Staffordshire and Wales).

of different age classes of plantation forest also changed from 2- and 3-year-old compartments, in 1997, to 0- and 1-year-old compartments in 2006 (Fig. 4).

There was a fairly consistent association, between years, for Woodlark territories and their association with soil type. Between 70% and 100% of territories were associated with sandy soils in Dors/NF/SW Hants, NE Hants/Surr/Berk/W Suss, Breckland, Suffolk Sandlings and Lincs/Notts/Yorks), approximately 10% of territories associated with chalky/free-draining soils and 10% with 'All other soil types'. The main contrast was in SW England (Devon) where around 80% of territories, in both years, were associated with 'All other soil types' and only 18% associated with sandy soils.

DISCUSSION

The population estimate of Woodlarks in 2006, of 3064 territories, is 88% higher than that of 1997 and around 12 times higher than the lowest recorded population estimate of 240 pairs in 1986. At the same time, there was a four-fold increase in breeding range between 1986 and 2006 at the 10 km scale. Much of the recent population increase, since 1997, has occurred in broadly traditional parts of southern England, but this partly masks important increases in the population and elsewhere. In all, there have been four important areas of expansion in Britain, since 1997. First, there was significant 'infilling' with greater prominence on farmland, between two formerly discrete populations (NE Hants/Surr/Berkshire/W Suss and Dors/NF/SW Hants), which further consolidates the species' range at the core of its distribution. Secondly, the population in Ashdown Forest (east Sussex) has increased substantially, to 42 pairs in 2006, creating further expansion into southeast England. Thirdly, a significant, though relatively scattered, population now exists across north Norfolk, so partly compensating for declines in other areas of East Anglia and reducing dependency on those relatively few 'traditional' sites. Fourthly, in northern England, the Woodlark population has extended further into Yorkshire, where it is hoped the species will become more fully established. The presence of a single territory in Wales is nevertheless indicative of the future potential for larger scale colonization, for Wales, the Wye Valley and Forest of Dean, in England, and northwest Midlands and northwest England in general where areas of sandy soil and heathland exist. Only the population figures for Cornwall, central England (e.g. Bedfordshire and Berkshire) and parts of East Anglia, were locally disappointing and in these areas a determined conservation strategy is needed to aid re-colonization or recovery, on heathland in central England and on farmland in Cornwall.

Population stability and recovery has been aided by the designation of statutory nature conservation sites, with the majority of breeding Woodlarks found on the relevant Special Protection Areas (SPAs) (JNCC 2005). Specifically, this has provided a focus for appropriate restoration and re-creation of heathland and increasingly sympathetic management of key forests. Much of the population expansion, since 1997, has involved heathlands, rewarding several intensive programmes of management or restoration and re-creation, such as the RSPB Dorset Heathland Project, in operation since 1989 (Woodrow *et al.* 1996) and Tomorrow's Heathland Heritage (Anon 2007b).

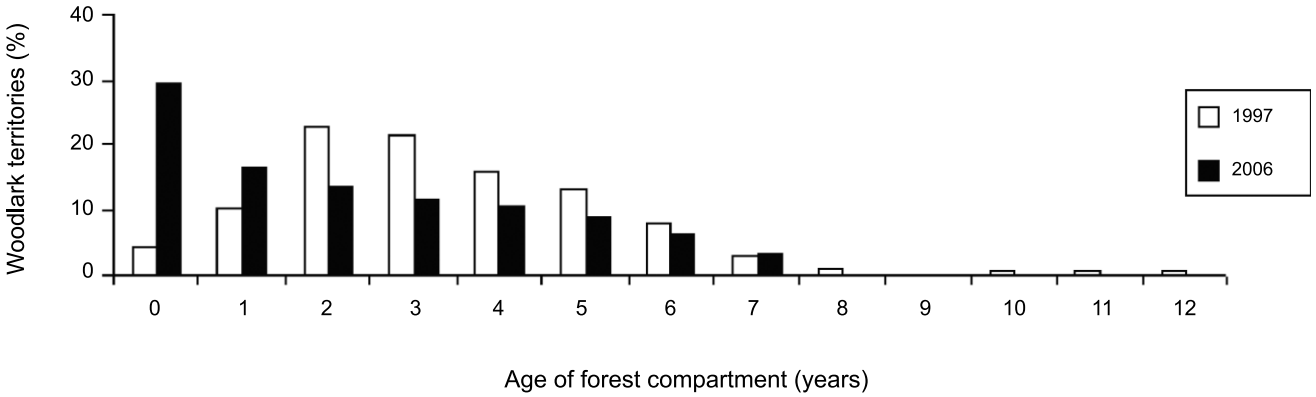

Figure 4. Percentage of Woodlark territories by age of forest compartment in Breckland in 1997 (n = 423) and 2006 (n = 287).

Maintaining the condition of heathland, in the face of increasing pressure for development and recreation (Murison 2002, Liley & Clarke 2003, Woodfield & Langston 2004, Langston, Liley et al. 2007) is imperative for the future population of Woodlarks in Britain.

Apart from heathland, just under half of the population remains dependent on sympathetically managed plantation forests. In forests, there have been population declines since 1997, especially in East Anglia. The Breckland forest population declined from a peak of 449 territories in 2000 to 272 in 2005, but increased to 287 in 2006. Wright (2006) found similar clutch sizes and breeding success within Breckland for heathland and plantations (clear fell and restocks). If this was representative of the population, the limiting factors may have been more closely related to habitat composition, such as the age structure of forest stocks, where higher territory densities of Woodlarks occur in plantation 'coupes' of 2–4 ha and mainly a tree age of less than 10 years (Langston, Wotton *et al.* 2007). Both are likely to change over time, while milder winters may have helped to create less favourable conditions for Woodlarks, within the field-layer by creating more ground cover and less bare ground. These are untested areas of conjecture that would benefit from a clear research programme in future, alongside the current investigation of the predator base for Woodlark nests in Thetford Forest. The results of this research could, where appropriate, be fed in to future management plans for Breckland. In the meantime, around 13 000 ha of rotational clear fell and replanted habitat are potentially available to Woodlarks, in Breckland Forest SPA annually with 1300 ha of retained clear fell (Armour-Chelu, pers. comm.), to help maintain population stability in future, notwithstanding effects of winter survival. Elsewhere in Britain, a move towards continuous cover forestry in some areas is expected to reduce the availability of breeding habitat for Woodlarks, if suitable areas of open ground, provided by clear felling, are diminished.

Apart from heathland and forest plantations, farmland represents a third important habitat for many breeding Woodlarks, particularly though not exclusively, in Devon. In Breckland, for example, farmland was colonized when the forest population was increasing, and smaller clutch sizes were laid on farmland (suggestive of younger adults or adults in poorer breeding condition colonizing secondary habitats; Wright 2006). In all regions, Woodlarks on farmland have become increasingly associated with fallow habitats, such as set-aside. This was especially apparent in Devon, where farmland has always been the primary habitat for Woodlarks, supporting almost all of the territories recorded during the previous national surveys (Lock & Slade 1995, Wotton & Gillings 2000). In Devon, since 1997, a high turnover in site occupancy, relative to other regions, reflects the species' dependency on farmland habitats there. A stable Woodlark population in Devon indicates that suitable habitat was available in 2006. While, for economic reasons, habitats such as set-aside, may cease to exist in Britain in the near future, most Woodlark territories in Devon were on winter stubbles or crops. As such, low input winter stubbles and fallow options within agri-environment schemes may be important for maintaining the current population in Devon and improving efforts to attract Woodlarks back into Cornwall.

Interpreting potential biases in population estimates

Although the coverage of squares in 2007 was higher than in 1997 it was considered that the entire breeding range of Woodlarks was adequately covered in 1997 (Wotton & Gillings 2000). With casual records included, the comparison between the 1997 and 2006 surveys was justified and thus the population and range changes considered valid.

The effects of cold weather during March 2006 are unknown. Maximum daily temperatures in February and early March 2006 were regularly below 8°C (UK Meteorological Office [UKMO] 2006), and apparently temperatures below 5°C can reduce singing activity or delay arrival at breeding sites. However, singing Woodlarks were present in Breckland in mid February 2006, prompting questioning as to the significance of the temperature in that year.

Meeting conservation objectives for Woodlarks

In Britain at the time of writing Woodlarks are on the red list of the Birds of Conservation Concern and they are a UK Biodiversity Action Plan (BAP) species. Woodlarks have responded to conservation restoration projects while still also being highly dependent on forest management. This survey demonstrated that the population has increased to meet the revised UK BAP targets set in 2005 for population size and range expansions in England, and is on schedule to meet targets in Wales, as follows:

1. Increase the number of breeding pairs in the UK, from 1500 to 2150 by 2018 (*target reached*): 1500

pairs in England by 2010 (*target reached*); 2150 pairs in England and 30 in Wales by 2015 (*target reached for England, possibly on schedule for Wales*).
2. Maintain an existing range of at least 90 10 km squares (*target reached*).
3. Increase the range from 90 to 125 10 km squares by 2018 (*target reached*): 108 squares in England and 3 in Wales by 2010; 120 squares in England and 5 in Wales by 2015 *(target reached for England and on schedule for Wales)*.
4. Increase the population size by 2008 (*target reached*).

The current 'strength' of the national population is, probably, mainly attributable to habitat protection, management and restoration or re-creation of preferred breeding habitats. Examples include long-term projects on the Dorset Heaths, Thames Basin Heaths and in East Anglia (north Norfolk, Suffolk Sandlings and Breckland). In England, the Government's target to return 95% of all Sites of Special Scientific Interest to favourable condition by 2010 (Defra 2002) should ensure that improvements are maintained. Overall, the results of the next national survey will be very important, to assess whether populations were maintained or have peaked in the core areas. There are several issues that are likely to influence the population of Woodlarks in future: first, maintaining heathland habitats in the face of increased pressure from housing development and human disturbance in southern and central England will be challenging (Murison 2002, Liley & Clarke 2003, Woodfield & Langston 2004, Langston, Liley *et al*. 2007). Second, forest management plans will need to ensure that sufficient breeding habitat is maintained in the face of changes towards continuous cover forestry. Further range increases for Woodlarks may be limited by habitat availability for nesting but potentially these habitats exist or can be created, for example in Wales or northwest England. Third, the effects of climate change are difficult to predict but milder winters may increase winter survival or allow birds to remain closer to breeding sites (with energy gains). In Breckland, few wintering birds were noted prior to the winter of 2000–01 (Atkinson 2001), until approximately 100 birds wintered on farmland in the winter of 2005–06 (Ron Hoblyn, pers. comm.). The fact that Woodlarks can disperse over large distances from their breeding sites (Wernham *et al*. 2002) is a major asset in terms of further range expansion and re-colonization of former sites. Warmer springs could further assist Woodlarks in colonizing areas beyond their current or historic range.

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APPENDIX 1. LAND USE AND HABITAT CLASSES

FARMLAND	HEATHLAND	PLANTATION WOODLAND	HUMAN	OTHER	GENERAL
Un-improved grasslangd	Grass dominated	Broad-leaved	Quarry	Sand dune	Grazed
Improved grassland	Heather dominated	Coniferous	Mine/Spoil/Slag heap	Chalk downland	Un-grazed
Semi-natural grassland	Bracken dominated	Mixed	Parkland		Bare ground – natural
Crop (cereal, fruit, vegetable, etc.)	Bare ground – burnt	Coppiced			Scrub Present
Plough or recently tilled		Un-managed			Trees Present
Stubble/Set-aside/Fallow					Bushes Present
Horticulture					Other song posts
Tree nursery					
Orchard					

Primary land use categories are shown in uppercase.

APPENDIX 2. SUMMARY OF NUMBER OF TERRITORY ESTIMATES FOR OCCUPIED COUNTIES IN ENGLAND AND WALES DURING THE 1986, 1997 AND 2006 NATIONAL SURVEY, TAKING INTO ACCOUNT SURVEY VISIT FREQUENCY

	1986	**1997**		**2006**		**% Change**
County	**Max**	**Mean**	**(95% CI)**	**Mean**	**(95% CI)**	**(1997 versus 2006)**
Bedfordshire	0	1	–	0	–	[–]
Berkshire	6	66	(66–67)	106	(75–153)	60.6
Buckinghamshire	0	6	–	0	–	[–]
Cambridgeshire	0	0	–	1	–	[+]
Cornwall	6	0	–	0	–	0
Devon	12	56	(55–56)	175	(99–275)	212.5
Dorset	5	106	(105–106)	257	(204–328)	142.5
Essex	0	0	–	1	–	[+]
Hampshire	92	315	(313–317)	549	(490–608)	74.3
Kent	0	3	–	1	–	–66.7
Lincolnshire	4	39	(39–39)	79	(62–104)	102.6
Norfolk	24	261	(259–263)	384	(323–451)	47.1
Nottinghamshire	1*	33	(32–33)	105	(58–173)	218.2
Somerset	1	0	–	0	–	0
Suffolk	49	481	(478–484)	492	(436–565)	2.3
Surrey	38	180	(179–181)	300	(230–384)	66.7
Sussex	1*	74	(73–74)	164	(129–209)	121.6
Staffordshire	0	7	–	93	(29–125)	1228.6
Wiltshire	2	3	–	4	–	33.3
Worcestershire	0	0	–	1	–	[+]
Yorkshire	0	2	–	87	(44–172)	4250.0
England total	241	1633		2799	(2187–3555)	
Monmouthshire	0	0	0	1	–	[+]
Wales total	0	0	0	1	–	[+]
Britain total	241	1633	(1591–1644)	2800	(2188–3556)	

The single territories recorded in Nottinghamshire and West Sussex in 1986, were not found as part of the national survey; Breckland straddles the west Norfolk/west Suffolk border (see Table 2 for totals). The symbols [+] and [–] represent a percentage change that cannot be calculated due to zero counts.