Report

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# Trends in Nightjar, Woodlark and Dartford Warbler on the Dorset Heaths, 1991 - 2013

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## Summary

An understanding of the direction, magnitude, and the timing of changes in bird populations is fundamental to inform conservation. In this report we plot the trends in the numbers of the three key heathland breeding bird species: nightjar, woodlark and Dartford warbler, on the Dorset Heaths over the period 1991-2013. This period encompassed various pulses of habitat management on the heaths, including the Heritage Lottery funded Tomorrow's Heathland Heritage work. More recently, and in response to growing urban pressures on many heathland sites, various projects have been initiated to reduce the impacts associated with urban development.

National surveys of each species have been conducted at roughly twelve year intervals, and these have provided snapshots of the status of each species in Dorset. Here for the first time we fill in the gaps between the national surveys, modelling trends in the numbers of each species. We have pooled from 46 survey locations, representing over half of the Dorset Heathlands SPA.

Across all sites combined, nightjar numbers rose steadily in the early 1990s, peaking in 1996. Numbers remained relatively stable through to 2000, after which a general decline (with some marked fluctuations) is evident, with numbers dropping to a similar level to 1991. Since 2010 numbers have risen steadily. Overall the trends indicate no significant increase or decrease since 1991. Data suggests considerable variation between sites in the urban conurbation and significant differences between sites in Purbeck compared to those further east. Sites in Purbeck have increased in the period 2008-2013 whereas sites to the east have seen little change.

Woodlark numbers appear to have fluctuated markedly over the period 1991-2013. As with nightjar the overall trend from 1991-2013 for woodlark shows no significant increase or decrease. In general the woodlark data involve low counts from many sites, only three sites had minimum counts that were above three territories. Of the 47 sites, 34 had counts of zero in at least one year and 12 sites had no woodlark records at all in any year surveyed. The occurrence of woodlark on particular heathland sites seems to be linked to tree clearance, forestry management or other habitat management on those sites and is also probably linked to forestry management and amount of clearfell in the wider area, particularly nearby forest blocks.

Dartford warbler numbers rose in the late 1990s, peaking in 2000 and then they remained relatively high until there was a marked decline from 2009, with numbers dropping to below the 1991 baseline in 2011. This crash followed a series of particularly harsh winters.

These trends provide an overview of the status of these birds and for the first time show the extent of annual fluctuations across the Dorset Heaths as a whole. The results have implications for the design of long term monitoring.

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## Acknowledgements

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The data pooled in this report has come from a range of sources, primarily the work of the Dorset Heathland Project (RSPB) in the 1990s and subsequent monitoring undertaken by the RSPB and others across multiple sites. Our thanks to Toby Branston (RSPB), Chris Dieck (RSPB), Andrew Nicholson (Natural England) and Nick Squirrell (Natural England) for helping us source data. Andrew Nicholson (Natural England) and Phil Sterling (Dorset County Council) provided useful discussion. Paul Moreton, Chris Dieck, Andrew Nicholson and Ian Alexander (Natural England) provided comments on an initial draft. Thanks also to Carolyn Steele for the provision of data from DERC. We also recognise the enthusiasm and dedication of the numerous surveyors who have undertaken the counts and the foresight of the RSPB back in the 1990s to collect regular, repeat monitoring data.

Ralph Clarke provided initial help on the models the use of TRIM and the code for R.

# 1. Introduction

## Overview

1.1 This report summarises data on nightjar *Caprimulgus europaeus*, woodlark *Lullula arborea* and Dartford warbler *Sylvia undata* across the Dorset Heaths. These species are key features of the designated heathland sites and are ones for which the UK has an international responsibility. In this report we pool data from multiple sites and years to plot the overall trends for each species over the period 1991-2013. The results have implications for the long term monitoring of the birds on the Dorset Heaths and have implications for local conservation effort, planning policy and heathland management.

## The selected bird species

1.2 Nightjar, woodland and Dartford warbler are the three component breeding bird species of the Dorset Heathlands Special Protection Area (SPA). This site qualifies under Article 4.1 of the Birds Directive (79/409/EEC) by supporting populations of European importance of these three species. This designation as an SPA brings particular responsibilities to local authorities and other bodies and means that the heaths are afforded strict legal protection.

1.3 Nightjars are summer migrants, arriving in April and May and leaving for their sub-Saharan wintering grounds in September-mid November (Cramp & Simmons 1977). They are multi-brooded and nest on the ground. They are crepuscular insectivores, catching their food on the wing. Their diet consists mainly of moths (Lepidoptera) and beetles (Coleoptera), but includes a wide range of flying invertebrates with diet composition mainly dependent on the available supply (Cramp & Simmons 1977).

1.4 Nightjar numbers have increased considerably since the first national survey in 1981, which estimated a British population of 2100 churring males (Gribble 1983) Subsequent surveys estimated 3400 in 1992 and 4606 in 2004 (Morris *et al.* 1994; Conway *et al.* 2007; Langston *et al.* 2007). This population recovery has been associated with colonisation of clear-fell within conifer plantation (Langston *et al.* 2007).

1.5 Woodlarks are multi-brooded ground nesting passerines favouring dry, well drained sites with short vegetation for feeding, longer vegetation, often as tussocks for nesting and scattered trees, bushes or tree stumps and debris as song and look-out posts (Harrison, & Forster, 1959; Bowden & Green 1992; Burges, D. 1997). Their chicks are mainly fed on Lepidopteran larvae, Coloeptera (beetles) and Aranea (spiders) (Bowden & Green 1992).They were formerly associated with close cropped areas, grazed by rabbits but following Myxomatosis and the growth of longer vegetation they declined in some former heathland areas (Cramp & Simmons 1977; Wright 2006). Whilst formerly woodlarks had bred on heathland, primarily in the vicinity of woodland, copses and plantations (Holloway 1996), following the decline in rabbits and the clear felling of areas of plantation planted on former heathland during and after World War 1, woodlarks colonised clear fells. Since 1970 most of the Breckland population of woodlarks has bred in clear fells (Bowden & Hoblyn 1990; Bowden & Green 1992), but

elsewhere breeding was mostly confined to heathland, especially where there had been a recent fire, in cleared and re-stocked forestry and in tree nurseries (Sitters 1986).

1.6 Dartford warblers are resident, multi-brooded breeding birds, more or less confined to the heaths of southern England, East Anglia and the south-west. There appears to be no regular migration but birds have been recorded in Ireland, the Scilly Islands and at sea (Bibby 1979a). Dartford warbler populations are very vulnerable to hard winter weather and population crashes have taken place following the hard winters of 1946/7, 1962/63, 2008/09 and 2009/10 (Raynsford 1960; Tubbs, C. R. 1967; Pickess 1976; Clark & Eyre 2012).

1.7 Dartford warblers in the UK breed almost exclusively on open heathland with a mix of heather and gorse, nesting on or close to the ground mostly in mature heather. In the latest national survey in 2006 (Wotton et al. 2009), 89% of Dartford warbler territories were found on lowland heath, 7% on upland heath, 3% on the coastal fringe in a mosaic of gorse, heath and rough grass and the remainder in gorse or other scrub.

## Dorset status and the need for this report

1.8 National surveys provide an overview of the status and distribution of all three species but such surveys are only conducted at ten twelve year intervals. Within Dorset there has been much monitoring and survey work conducted between these surveys, but this has never been pooled in a way that allows the overall trend for each species to be determined across multiple years. While the national surveys allow a direct comparison of how the numbers in a particular area have changed over, say a 12 year interval, it is hard to draw conclusions as to how well the birds are really doing and how much numbers fluctuate between years.

1.9 Data for single years has been pooled across sites: for example the data from the 1992 and then the 2004 national survey data for nightjar in Dorset have been considered in relation to urban development (Liley & Clarke 2003; Liley et al. 2006). Detailed fieldwork on breeding success of Dartford warbler and woodland have been conducted in Dorset, as doctoral studies lasting a few years (e.g. Bibby 1979b; Mallord et al. 2007a; b; Murison et al. 2007) and nightjars have been the subject of detailed work finding nests and using nest cameras (Murison 2002; Woodfield & Langston 2004) and of radio-tracking to look at off-site foraging (Alexander & Cresswell 1990). These studies have all provided very important information that has underpinned conservation effort for these species in Dorset.

1.10 One of the pieces of information that is however lacking for these species is how numbers have fluctuated across the Dorset Heaths over time. Such trends are useful in providing a strategic view of how the species are doing at a local level. Considerable emphasis in recent years has been placed on resolving the pressures of increased urban development surrounding the heaths. As part of this work monitoring has been undertaken on selected sites, yet it is difficult to know how much monitoring is necessary and how best to target surveys. As part of a monitoring strategy for the

Dorset Heaths (Liley 2007), it was identified that a review of bird data were necessary to identify:

- Whether similar trends were present across all sites, or whether certain sites, such as urban heaths or those with high visitor pressure, tend to have different trends
- Whether broad conclusions about the SPA population could be drawn from monitoring a small sample of sites
- How well national surveys capture any trend
- What timescale, interval and monitoring protocol would be the most effective for the future

1.11 Within this report we consider these questions – or at least the extent to which it is possible to answer them with the available data.

# 2. Methods

## Data sources

### Bird data

2.1 Bird data were pooled from a range of sources. We aimed to use data that represented comparable survey effort and survey methods, excluding casual counts, ad hoc records and data that could not be clearly assigned to a particular location and survey boundary. The data are not comprehensive for all heathland sites in Dorset, but rather represent sites which have had repeat, similar surveys conducted over multiple years. Most of the survey data were conducted by the RSPB.

2.2 For the 1990s the main source of data were the Dorset Heathland Project (Auld, Davies & Pickess 1992). The project involved mobile teams that undertook habitat management and surveys across Dorset, and hence provides comparable data from a range of sites and years. These data were supplemented with national survey data (provided by Natural England) for woodlark (1994 and 2006), for Nightjar (1992 and 2004/2005), Dartford warbler (1994 and 2006) and with data from 2010 for nightar (work undertaken to survey SSSIs for this species). The RSPB also provided comprehensive annual count data from three of their reserves – Stoborough, Arne and Grange Heaths. More recent data from multiple sites (primarily the urban heaths) came from monitoring undertaken by the RSPB between 2008 – 2013, work undertaken for local authorities in Dorset alongside the heathland mitigation work set out in Dorset Heathlands Supplementary Planning Document. Bird data were therefore from a range of sources, but were mostly conducted by the RSPB. Data are summarised in Appendices 1-3.

### Site and survey boundaries

2.3 Site boundaries were plotted in GIS to reflect the areas with data (Map 1). The boundaries are largely based on the survey boundaries adopted by the Dorset Heathland Project and the majority closely follow the boundaries of discreet SSSI's units. Where the RSPB survey boundaries differ from the SSSI visual checks were made using Google Earth and contact with local bird surveyors (who had undertaken some of the bird surveys) to map the most representative survey boundary.

2.4 The site boundaries which span an area of 4097 hectares (defined in Map 1) cover 50% of the Dorset Heathland SPA (8169 ha).

### Data collation

2.5 Data for each site were extracted from paper records and a number of GIS data sets. For each site and year with data we extracted a single figure for the number of territories present. Within the GIS data, a small number of mapped territories fell outside the defined site boundaries but were clearly associated with the site. Some of these records contained attribute data linking them to the surveyed site and records with these missing data a 100m buffer was placed around sites and records which fell

within the buffer were assigned to the buffered site. For adjacent sites (which meant a record could be assigned to two sites and therefore double counted) records were checked manually and assigned to the nearest site.

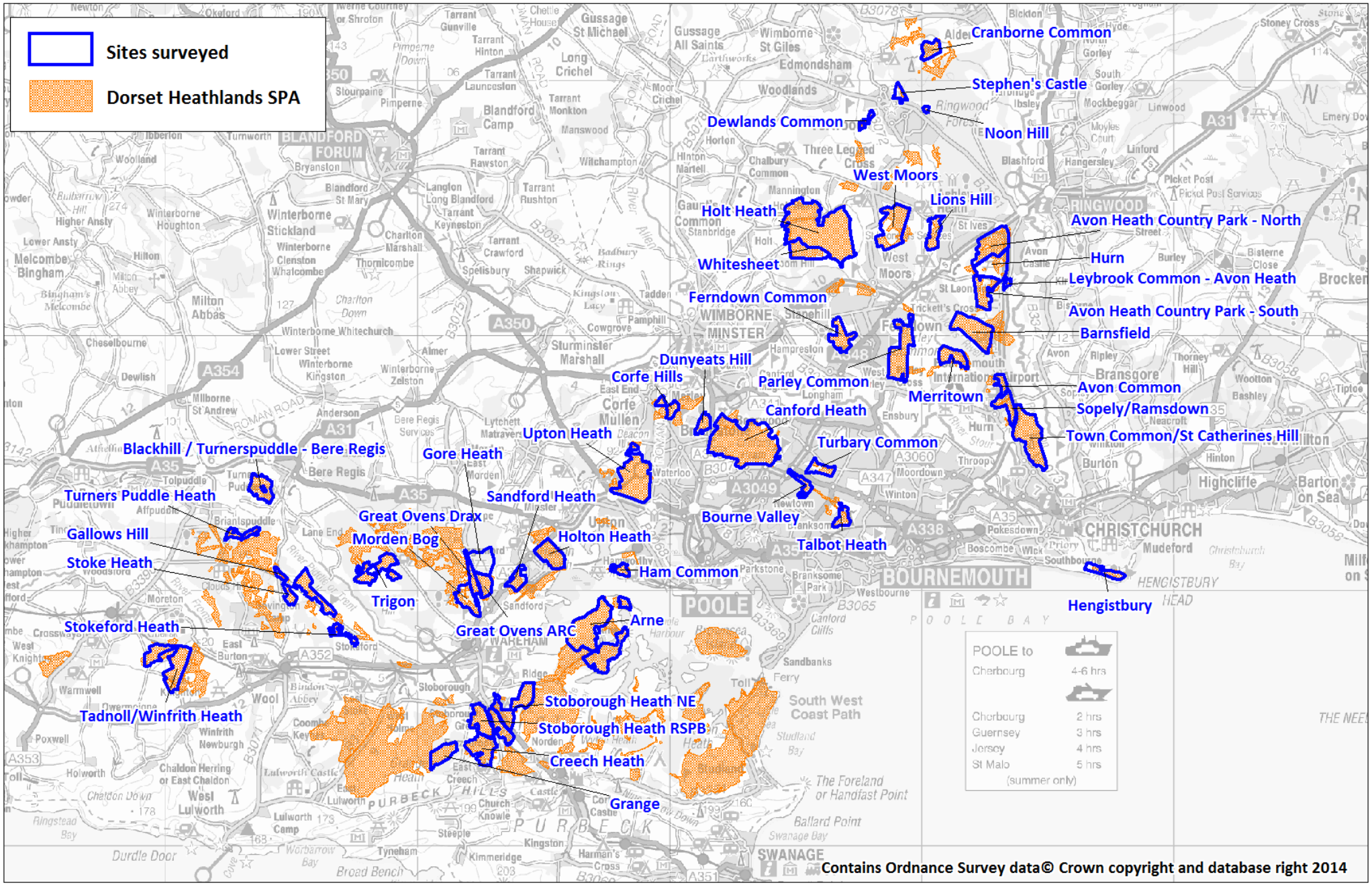
2.6 Maps 2, 3 and 4 detail the sites from which the data were pooled and summarise the level of survey effort at each site. For nightjar and Dartford warbler Avon Heath, Hurn, Barnsfield, Arne, Grange and Stoborough RSPB have the most survey coverage (Maps 2 and 3) and for woodlark Arne and the Avon Heath, Hurn and Barnsfield sites have been most frequently surveyed (Map 4).

### Fire data

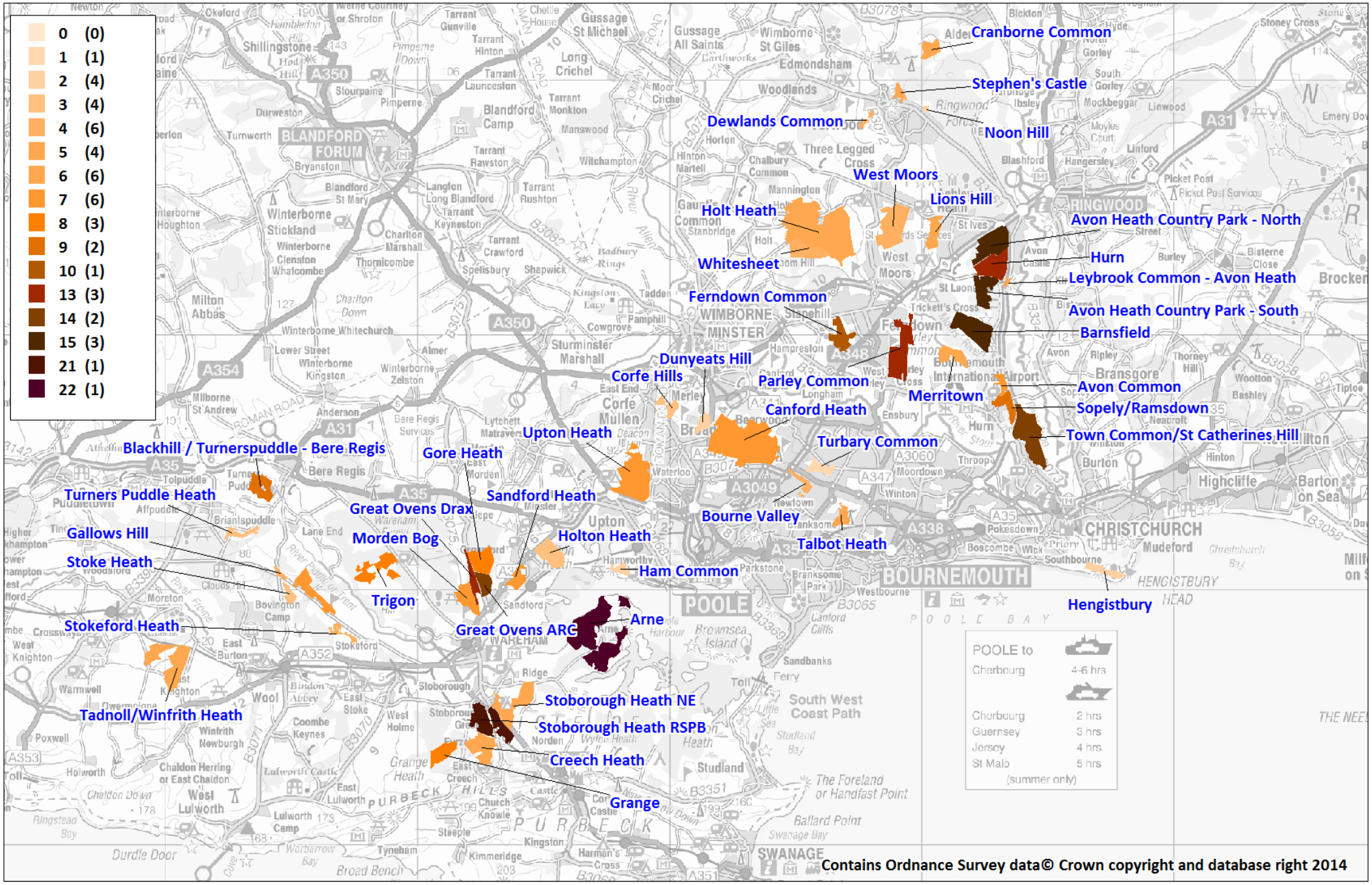
2.7 Fire data between 2002 and 2013 were extracted and sorted by site name to dovetail with the site data analysed in this report. The data were sourced from the Dorset Explorer[1] incident database and included all logged records of fires over 400m$^2$.

[1] http://explorer.geowessex.com/

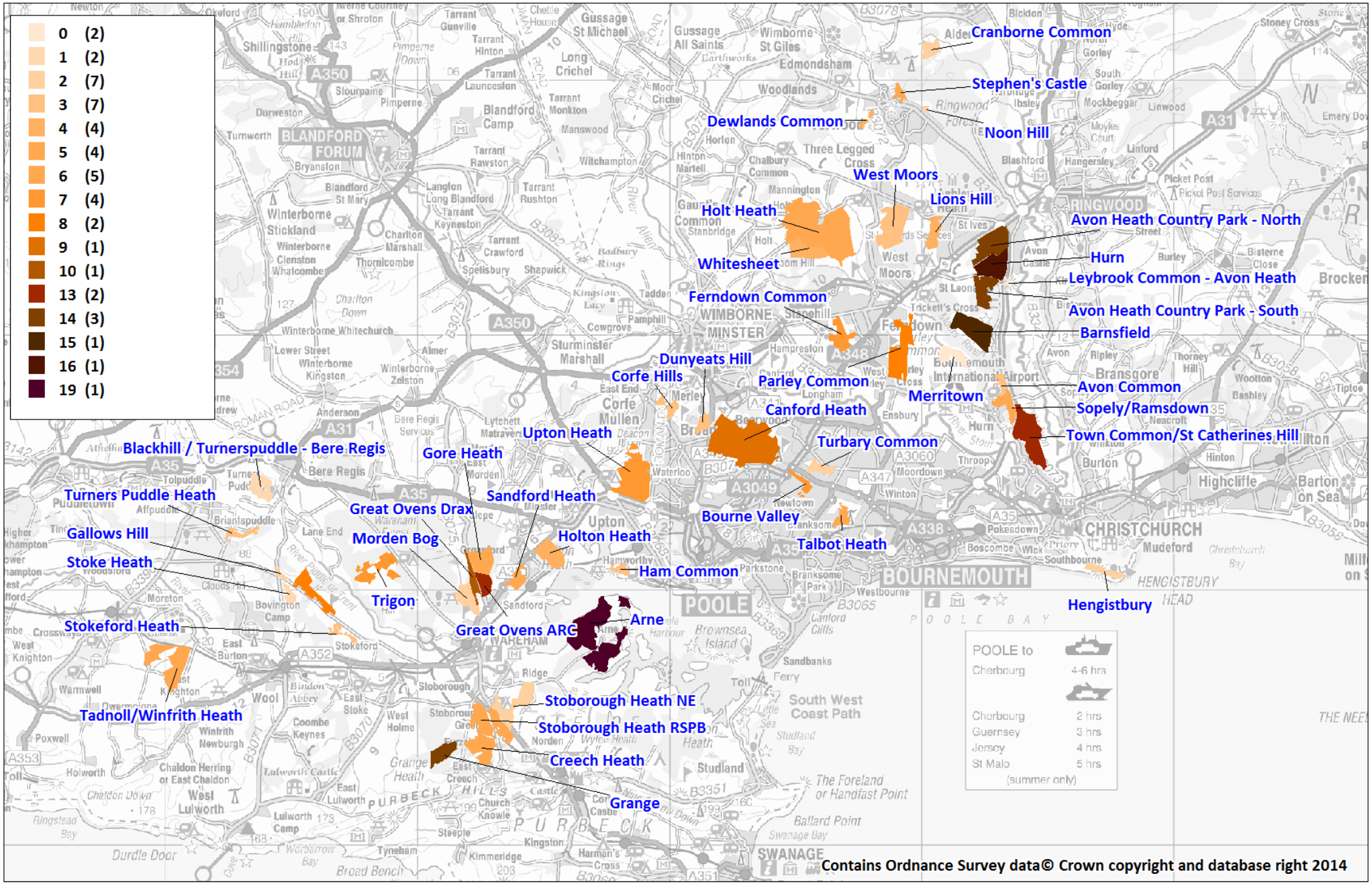
# Map 1: Dorset Heathlands SPA and sites surveyed



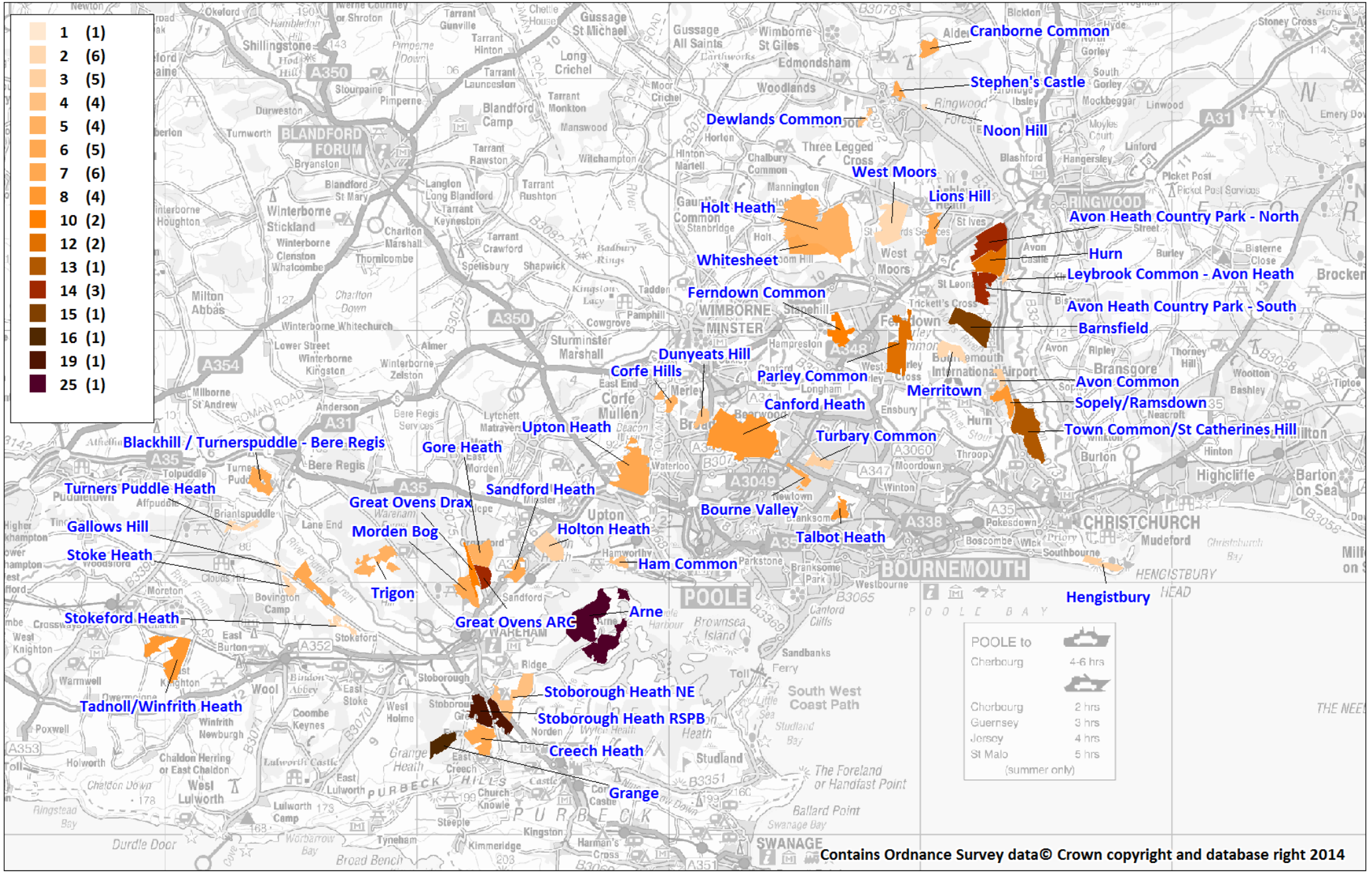
# Map 2: Nightjar surveys per site



# Map 3: Woodlark surveys per site



# Map 4: Dartford warbler surveys by site



## Trend Analyses

2.8 Trends for each bird species were developed using TRIM ('Trends and Indices for Monitoring data) (Pannekoek & Van Strein 2001), a program designed to analyse time-series counts with missing observations. The program estimates missing counts from particular sites in particular years based on other counts at the particular site and changes at other sites.

2.9 TRIM fits a generalised linear model with Poisson errors and log-link (McCullagh & Nelder 1989). We used version 3.2 of the software and used it to generate indices for each year. By convention, the estimated abundance in the first year is set to one and each annual index, $A_i$, for year i, is calculated relative to the first year.

2.10 Trends were generated for all years and using data from all sites. Models (unless otherwise stated) were time effects models in TRIM and account for over-dispersion and serial correlation. Survey area was included as a weighting within the model. Model fits were assessed using the Likelihood Ratio test ($p>0.05$) and models were compared using the Akaike's Information Criterion (AIC), with the lower value implying a better fit (Pannekoek & Van Strein 2001).

2.11 We then tried different groupings of sites to determine whether there were different trends for different groups of sites. Groupings were included as covariates in the models. In order to compare different groups it is necessary to have data from at least one site in the group in each year, and depending on the grouping this was not always possible. Different subsets of years were therefore sometimes considered or, alternatively, linear trend models with particular years set as change points were used. Where linear trend models were used, change points were identified using the stepwise procedure in TRIM.

2.12 We tried four main covariates within the analysis, allowing us to look for differences in the trend between different kinds of sites. These covariates represented relatively simple groupings; more sophisticated classifications were not possible due to the paucity of data for some groups over some time periods. Categories for each site are given in Appendix 4.

- Urban / rural (sites were classified as urban if the number of residential properties within 1km of the site divided by the area of the site was greater than 25.
- Geographic spread – Whether the site was located in either Purbeck, Borough of Poole of East of Poole (Map 5)
- Large sites: sites above or below 100ha
- Small sites: sites above or below 30ha

2.13 In addition to yearly indices, for each species we summarise the trend over the whole study period. This is based on the slope of the regression line through the logarithm of the indices. The computation of this slope (in TRIM) takes into account the variances and covariances of the indices. Where quoted the overall trends are the slope of the

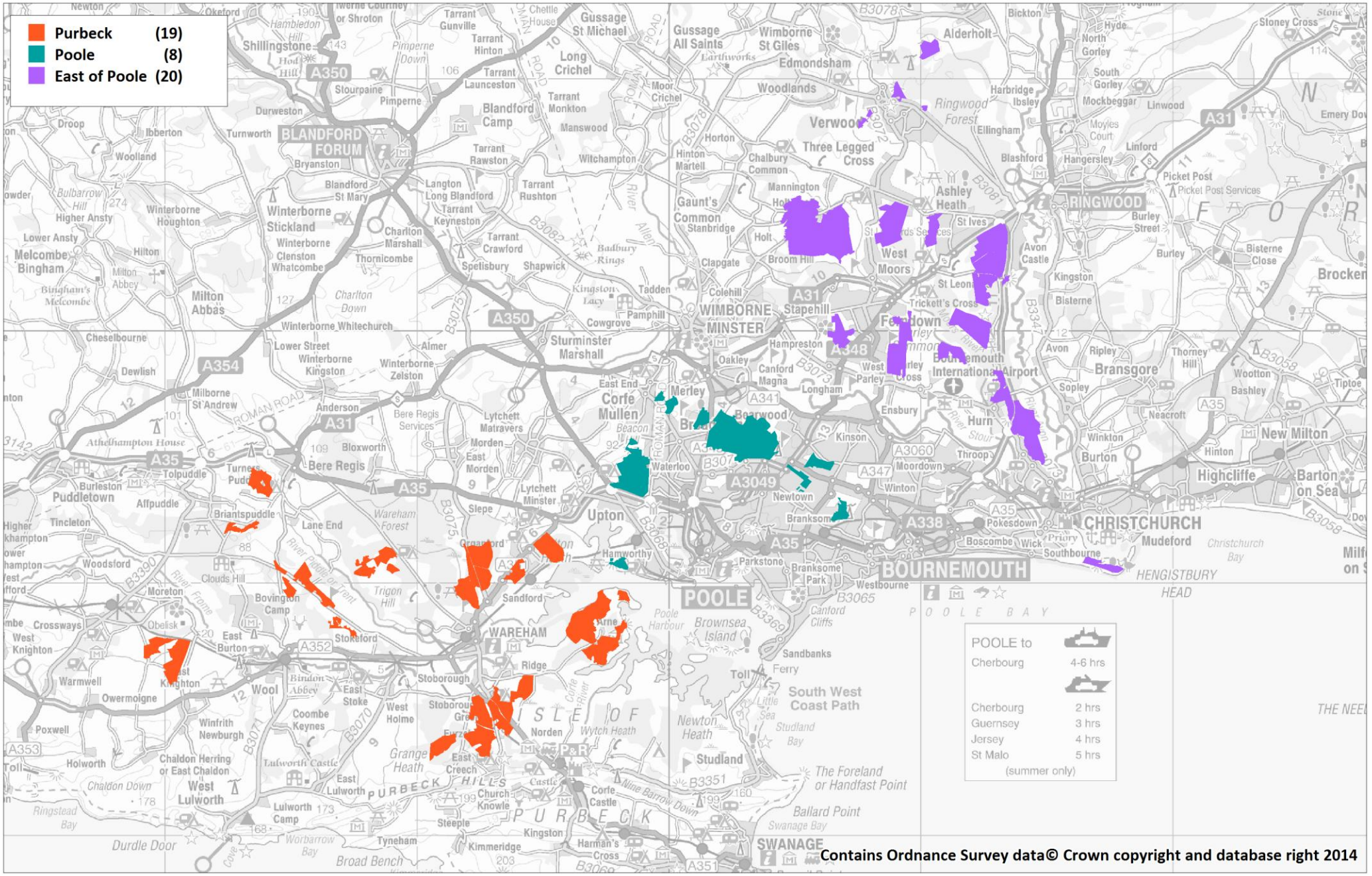
regression line based upon imputed indices, and are given + 1 standard error. The values are multiplicative, reflecting the average percentage change per year. If this trend is equal to 1, then there is no trend. If the trend is, for example, 1.08, then there is an increase of 8% per year.

## Structure of report and approach

2.14 We structure the report by species, and our approach is to generate the trends for each species and explore the variation in those trends. In order to understand the differences between sites, as relevant we compare data for groups of sites for single years. Our aim is not to explore the factors that explain the differences in density between sites, but rather to determine how trends vary across sites and how well we can group sites.

2.15 We plot the trends for each species side-by-side at the end of the species sections, in order to allow direct comparison between species. While our aim is not to explore all factors that may be driving these trends, we do consider how the birds have responded to key variables, in particular weather. Alongside these bird plots we summarise weather data (drawn from the nearest weather station at Hurn, and extracted from the Met Office website), as weather is likely to be a key factor underlying the trends.

# Map 5: Geographic categories of sites



# 3. Nightjar

3.1 Across all sites combined, nightjar numbers rose steadily in the early 1990s, peaking in 1996. Numbers remained relatively stable through to 2000, after which a general decline (with some marked fluctuations) is evident, with numbers dropping to a similar level to 1991. Since 2010 numbers have risen steadily. The overall trend (time effects model; LR Goodness of fit = 290.70, 254 d.f., p=0.056; AIC=-217.30) is shown in Figure 1. The overall slope is 0.996 ± 0.004, representing an overall average decline per year of 0.43%. This trend was classified by TRIM as uncertain (no significant increase or decrease). -

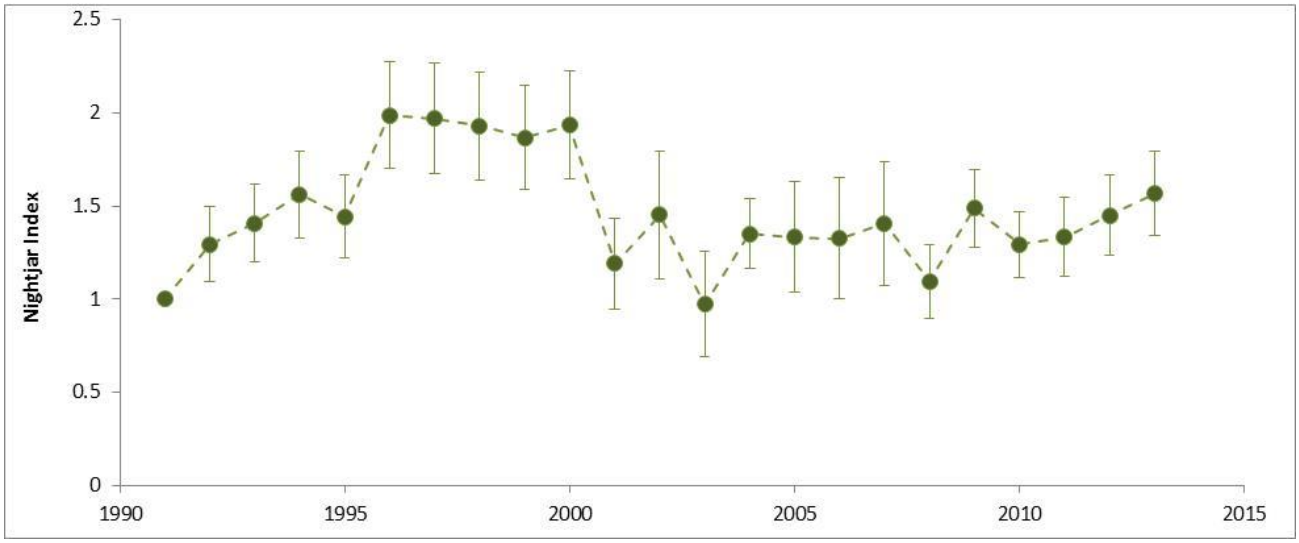



**Figure 1: Nightjar trend across all sites and all years. Plot shows model indices (± 1 SE) derived using time effects model in TRIM for all sites and all years.**

3.2 There were insufficient data to compare rural and urban heaths over the entire time period 1991-2013, as there were years with no data for any of the urban heath sites. Using a linear trend model with change points (change points selected using the stepwise procedure in TRIM) did not allow us to include covariates in the model as there were still time periods with insufficient data.

3.3 Survey effort was more focussed on the more urban sites in more recent years (post 2008) and for these years it is possible to compare rural and urban sites. For the period 2008-2013 there were significant differences in the trends for rural and urban sites (urban/rural covariate significant (Wald=12.04, 5 df, p=0.034) when added to time effects model and model fit improved with lower AIC). Numbers of nightjar appear to have dipped at rural sites in 2010 (Figure 2) but have subsequently increased, whereas on the more urban sites numbers did not dip in a similar fashion and appear to have declined slightly since 2010. Error bars are much higher for the urban heaths, suggesting a wide variation between different sites (and also a smaller sample size compared to rural sites). This variation can be clearly seen in the data from individual

sites. Numbers of nightjars have dropped by around a third at Canford Heath since 2009 (from 30 down to 21), yet over the same period numbers at Upton have stayed reasonably similar (between 10 and 12), at Ferndown they have fluctuated between more widely than Upton, ranging from 4 to 8 churring males over the period 2008-13. At nearby Parley Common numbers have fluctuated between 8 and 14 over the same period. At Talbot Heath 2 churring male Nightjar in 2013 was the highest count for that site.

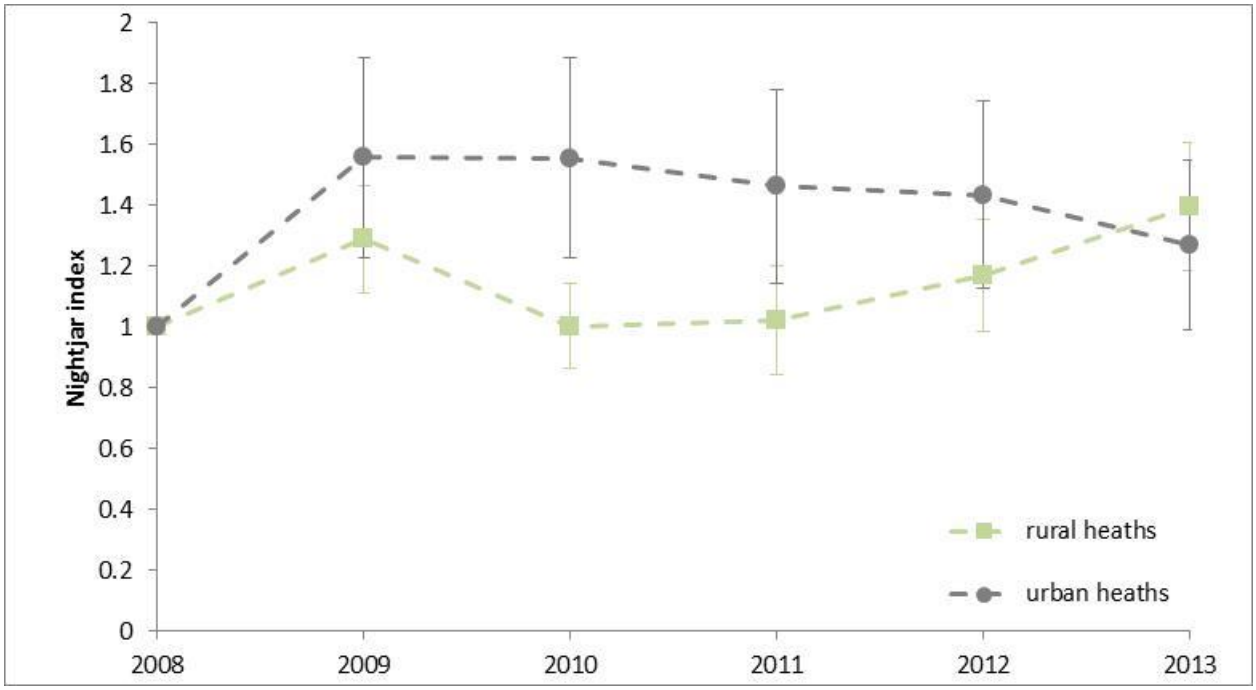



**Figure 2: Nightjar trends for urban and rural sites for the period 2008-2013. Trends generated using time effects model in TRIM**

3.4 Splitting the sites geographically (with sites groups into three simple groups broadly relating to Purbeck, Poole and west of Poole), indicated a markedly different trend for the Purbeck sites compared to others. The inclusion of the geographic covariate was significant (Wald = 19.87, 10 d.f., p=0.031) and resulted in a better model fit (AIC=-86.95 with covariate compared to -94.93 without). Numbers of nightjar on Purbeck sites have increased while other sites show little change over time. This geographic split is in part similar to the urban/rural split as the Purbeck sites are rural, but this split results in a better model than the model including the rural/urban covariate

3.5 Reviewing the data for individual Purbeck sites it can be seen that there are a number of Purbeck sites where there were particularly high counts in 2013; these included Arne, Winfrith/Tadnoll and Stoborough RSPB. There was also a marked increase at Creech Heath over the period 2008-2010 (from 4 - 12 churring males) but no data post 2010 for that site.

3.6 For the data 2008-13 there was no evidence that trends were any different on the big (over 100ha) sites (Wald = 1.45, 5 d.f., p=0.919).

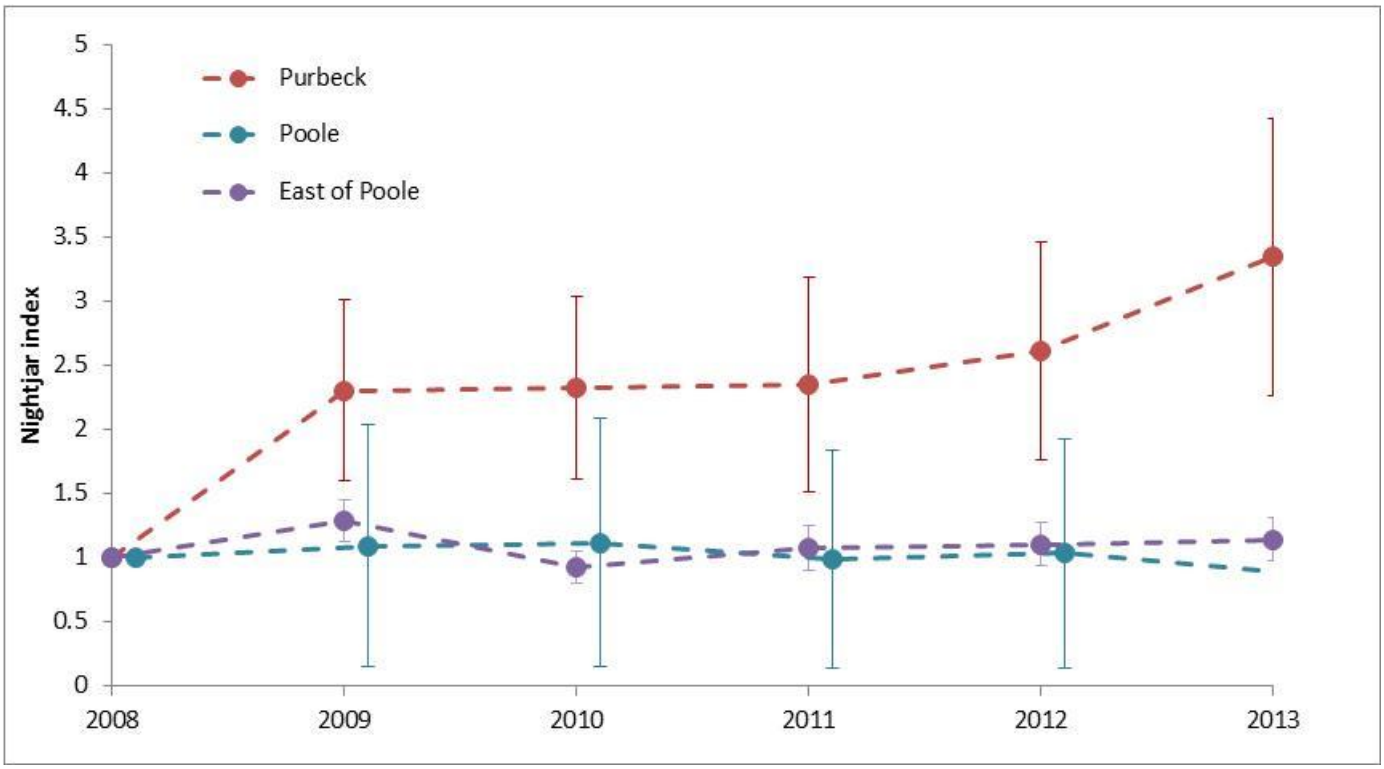



**Figure 3: Nightjar trends for different geographic patches. Trends generated using time effects model in TRIM. Points for Poole sites are slightly offset to allow error bars to be seen.**

3.7 The different covariates as tested do reflect overlapping groupings, and it is therefore difficult to tease apart the effects of site size, geographic location and degree of urban development. This can be seen in Figure 4 and Figure 2, which are the same plots with points coloured differently. Both plots show the number of nightjar in relation to site size with data for a single year (2010, with near complete coverage across all sites). As might be expected there was a significant positive correlation between site size and nightjar number (Spearman's rank correlation coefficient = 0.785 $p<0.001$). It can be seen that the 'Poole' sites tend to be smaller sites and categorised as urban. It also appears that the groupings – as we have classified sites – do not have markedly different densities of nightjar in 2010. The sites with the highest nightjar density were Noon Hill (1 record), Avon Common (7 records) and Stokeford Heath (5 records) and reflection of the small site size. . Even though Canford Heath supported the highest number of nightjars in 2010 the density of birds at the site is relatively low with 0.08 birds per hectare.

3.8 Map 6 which shows the densities of nightjar across all the surveyed sites a clearly show the lower densities at the sites within the Poole conurbation and higher densities at the sites east of Poole (Avon Heath South, Barnsfield , Parley Common and Merritown) and also higher densities on some of the smaller sites within Purbeck.

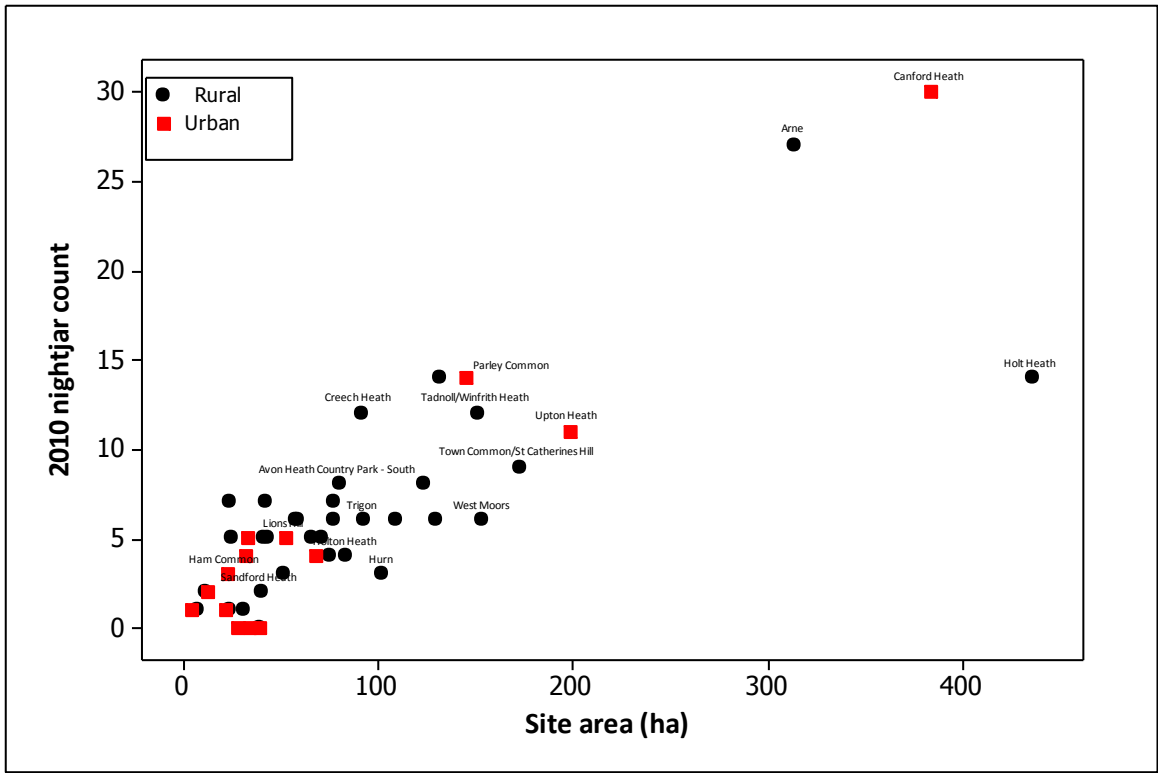



**Figure 4: Nightjar count per site against site area with sites grouped by number of surrounding residential properties (urban and rural).**

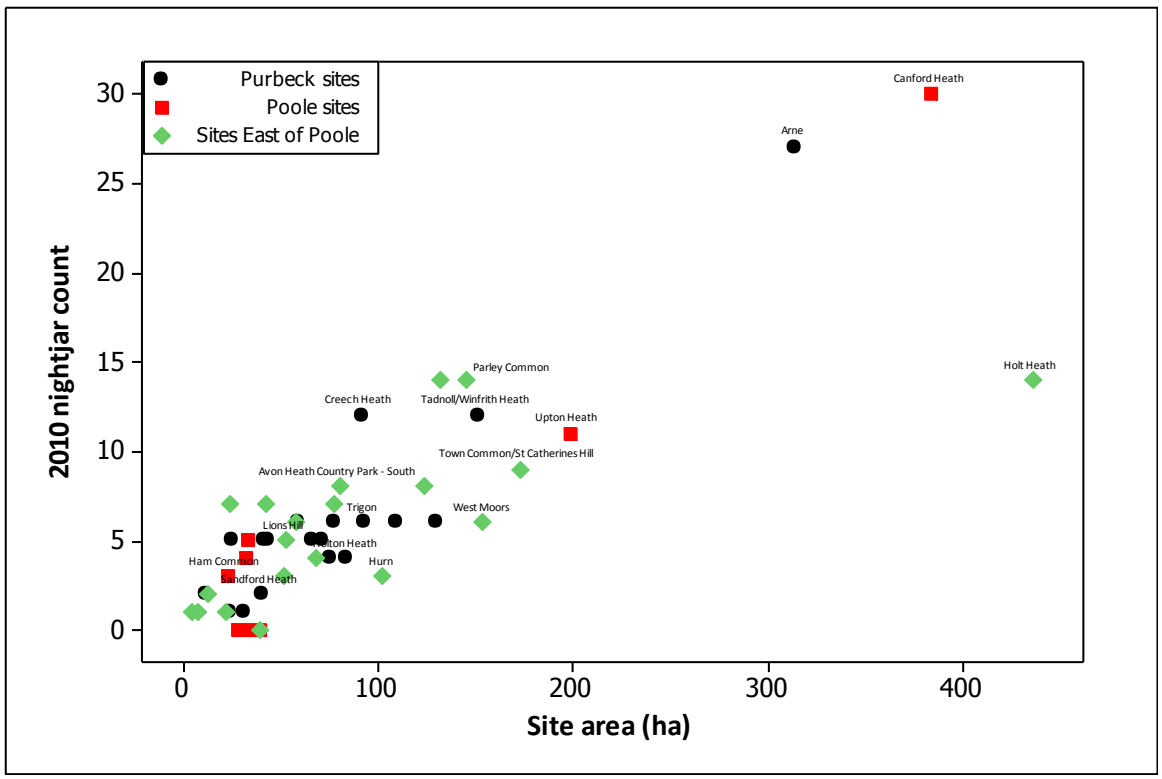
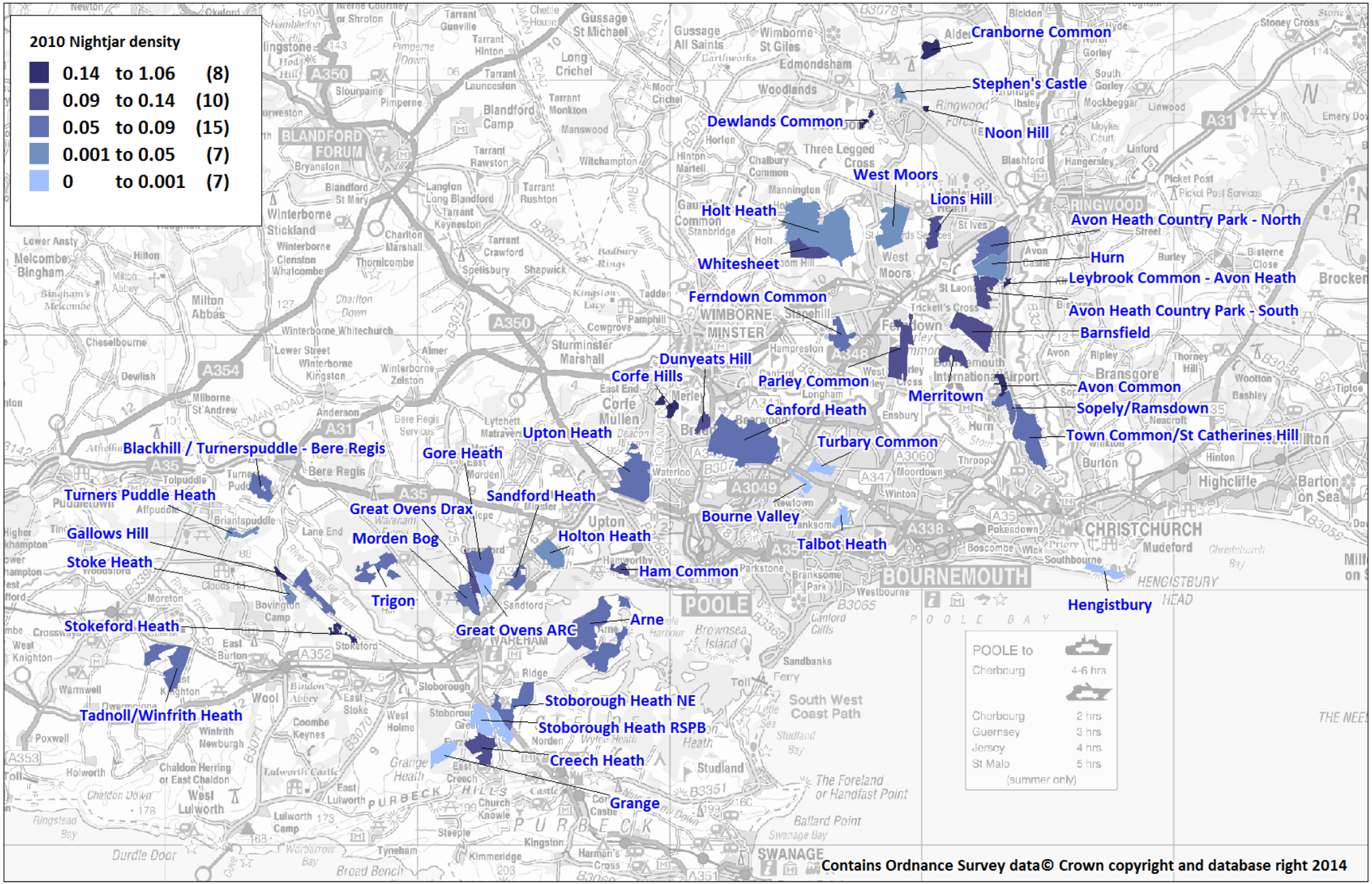



**Figure 5: Nightjar count per site against site area with sites grouped geographically.**

# Map 6: 2010 nightjar densities by site



# 4. Woodlark

4.1 Using woodlark data from all years for all sites, woodlark numbers appear to have fluctuated markedly over the period 1991-2013 (Figure 6). The model fit was reasonable (LR goodness of fit =200.48, 204 df, p=0.557; AIC = -207.52) and indicates marked fluctuations and the TRIM indices have high standard errors, reflecting a degree of uncertainty around the estimates. The overall slope is 1.019 $\pm$ 0.847, representing an overall average increase per year of 1.9%. This trend classified by TRIM as uncertain (no significant increase or decrease).

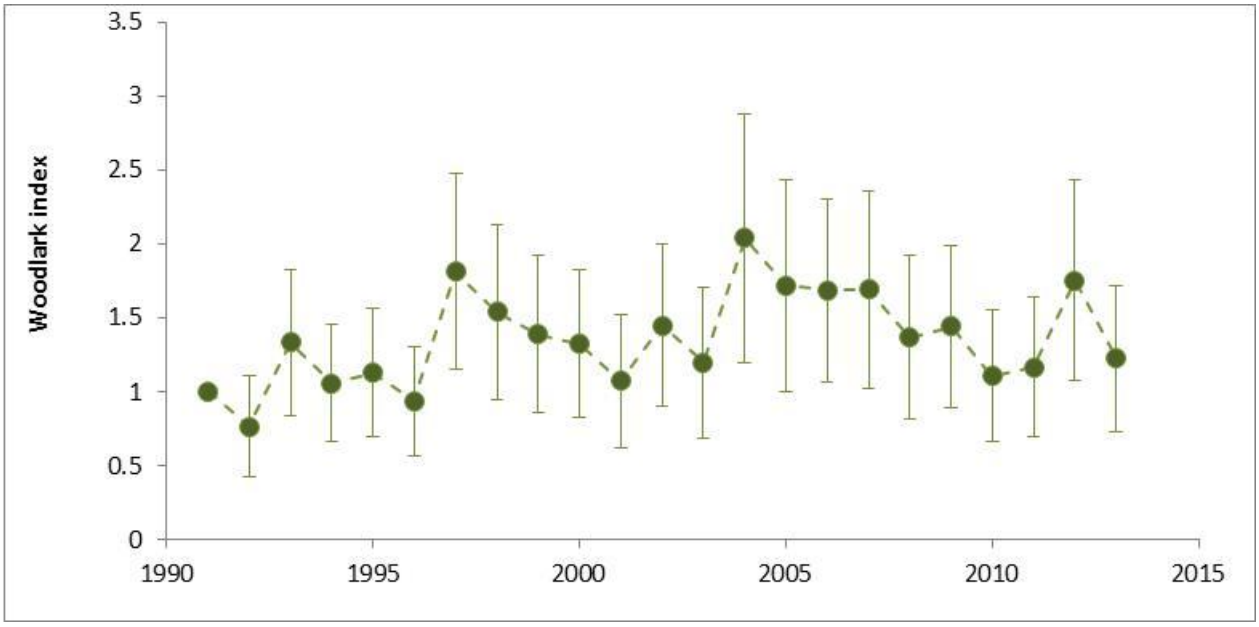



**Figure 6: Woodlark trend 1991-2013, generated using time effects model in TRIM. Plot shows model indices + 1 S.E.**

4.2 In general the woodlark data involve low counts from many sites, only three sites (Barnsfield, Hurn and West Moors) had minimum counts that were above three territories. Of the 47 sites, 34 had counts of zero in at least one year, 12 sites had no woodlark records at all in any year surveyed and only one site (Barnsfield) had counts in double figures (10 territories) in any one year. Reviewing the data across all years there are six sites that stand out as having relatively high counts and a reasonable spread of data across multiple years, the data for these sites (Arne, Avon Heath (north and south), Barnsfield, Hurn, and Grange) are summarised in Figure 7. Besides these six sites, also notable are Trigon, which had up to four territories in 1997 and 1998 but has relatively little survey effort in more recent years; Holton Heath (maximum of five territories, in 2000 and 2006); and the MOD Petroleum Depot at West Moors, where there are data for three separate years and for two of these there are counts of nine territories (in 1997 and 2006). This latter site is particularly uncharacteristic of other heathland sites as it has no public access and a proportion of the site is tightly mown to minimise fire risk to the stored petroleum; this management creates areas suitable for woodlark to

forage in. It is notable that all the sites with reasonable woodlark counts have seen intensive management, in most cases clearance of conifer plantation.

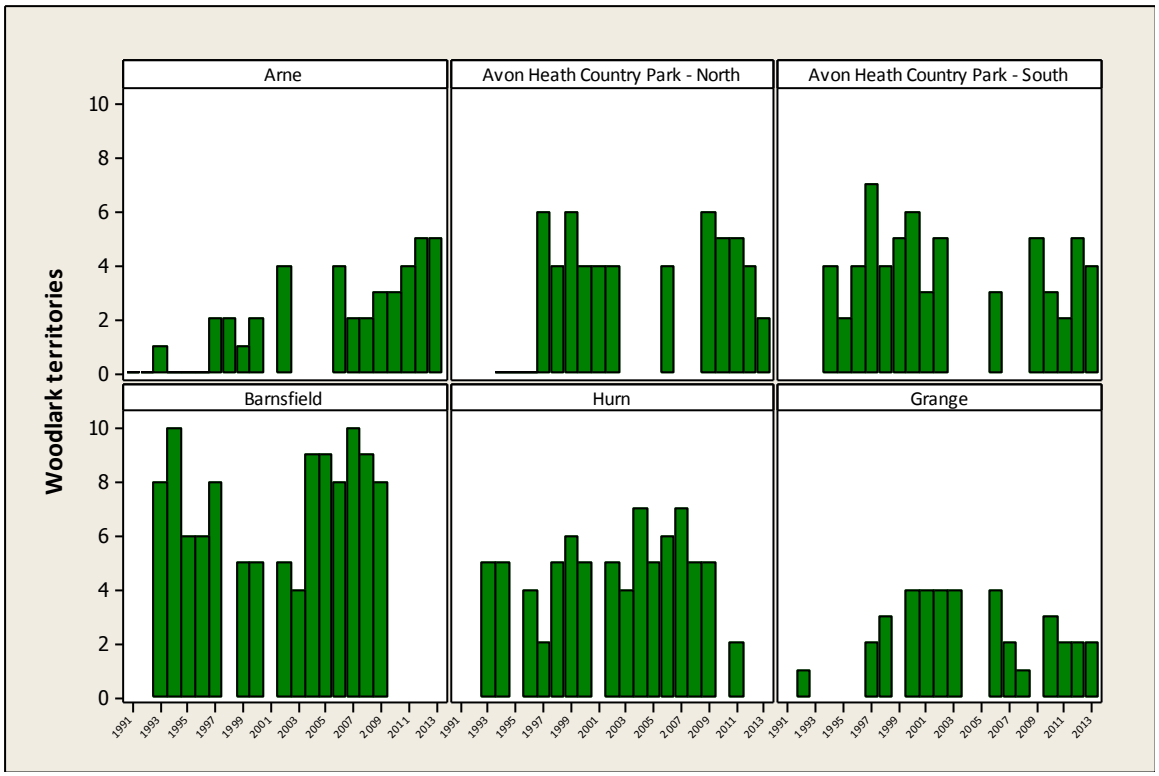



**Figure 7: Woodlark count data for selected sites, the sites shown are the main sites that have multiple positive counts over the period 1991-2011. Plots show actual count data, gaps represent no counts.**

4.3 The overall trend – as shown in Figure 6 – appears to show marked fluctuations and little evidence that numbers (over the period 1991-2013) have particularly increased or decreased. The reasonable fit to the model suggests sites do track each other and this can be seen in the data, as for example the overall trend reflects suggests a rapid increase in the number of territories between 1996 and 1997. Data from individual sites for these two years highlights the variation in the scale of the change: Arne (0 in 1996, 2 territories in 1997); Avon Heath Country Park north (0 territories in 1996, 6 in 1997); Avon Heath Country Park south (4 territories in 1996, 7 in 1997); Barnsfield (6 territories in 1996, 8 in 1997); Great Ovens Drax (2 territories in 1996, 3 in 1997); Hurn (4 territories in 1996, 2 in 1997); and Trigon (1 territory in 1996, 4 in 1997).

4.4 It was not possible to test for differences in the trend between urban and rural sites, by geographic area or for differences between large/small sites, due to the sample sizes, even after generating a simpler model based on linear trends with selected change points.

4.5 Woodlark densities for a single year (2006, when reasonable coverage) are summarised in Map 7. The patchiness in woodlark distribution and abundance is reflected in the fact there was no significant correlation between site size and number of woodlark in 1994 (a year with good survey coverage; Spearman's rank correlation coefficient Rs=0.269,

p=0.159) and only a weak correlation between count and site size in 2006 (Spearman's rank correlation Rs=0.405 p=0.01) (see Figure 8). The high counts of woodlark are on sites with adjacent forestry and where extensive forestry clearance have taken place, particularly on the sites east of Poole.

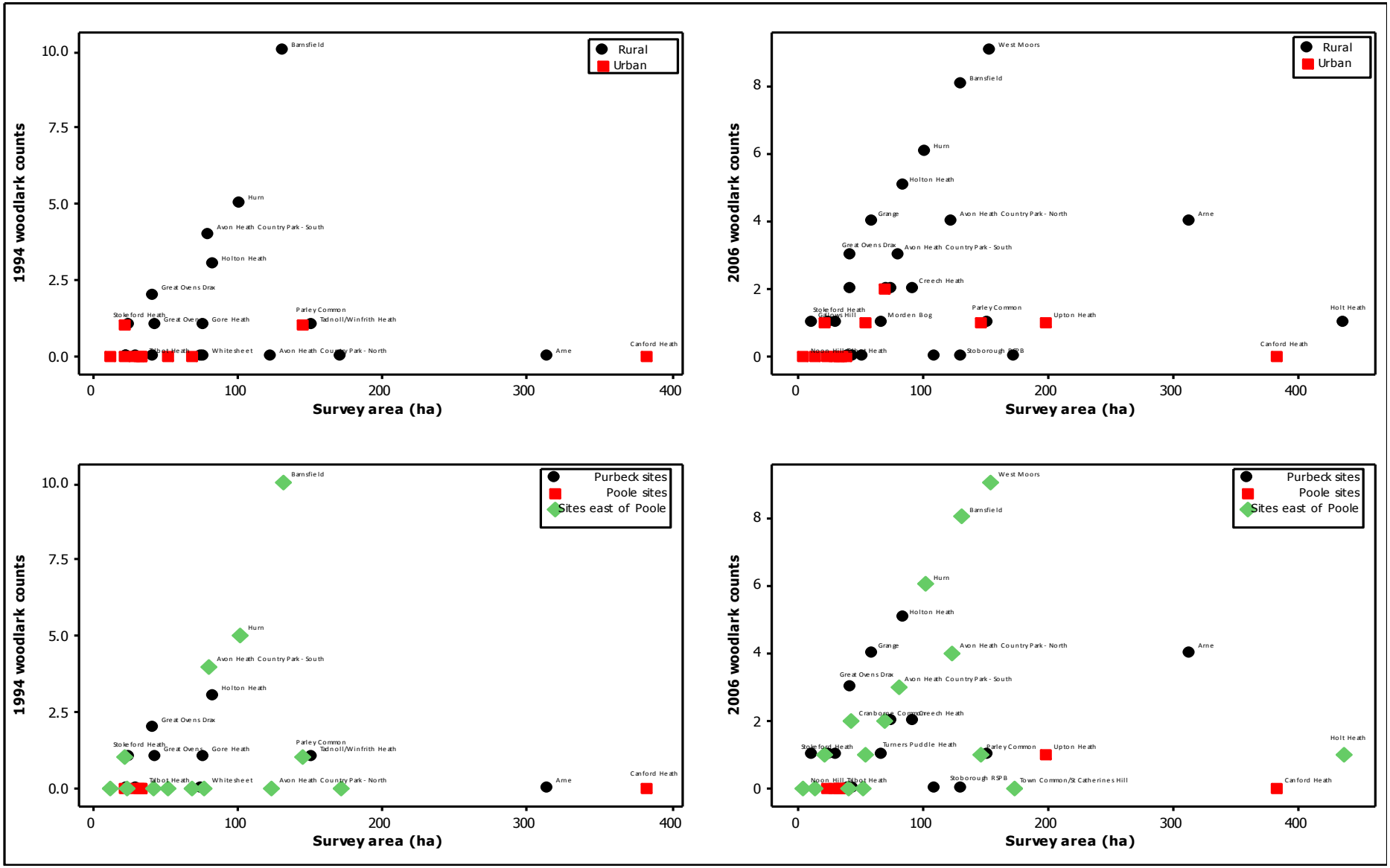
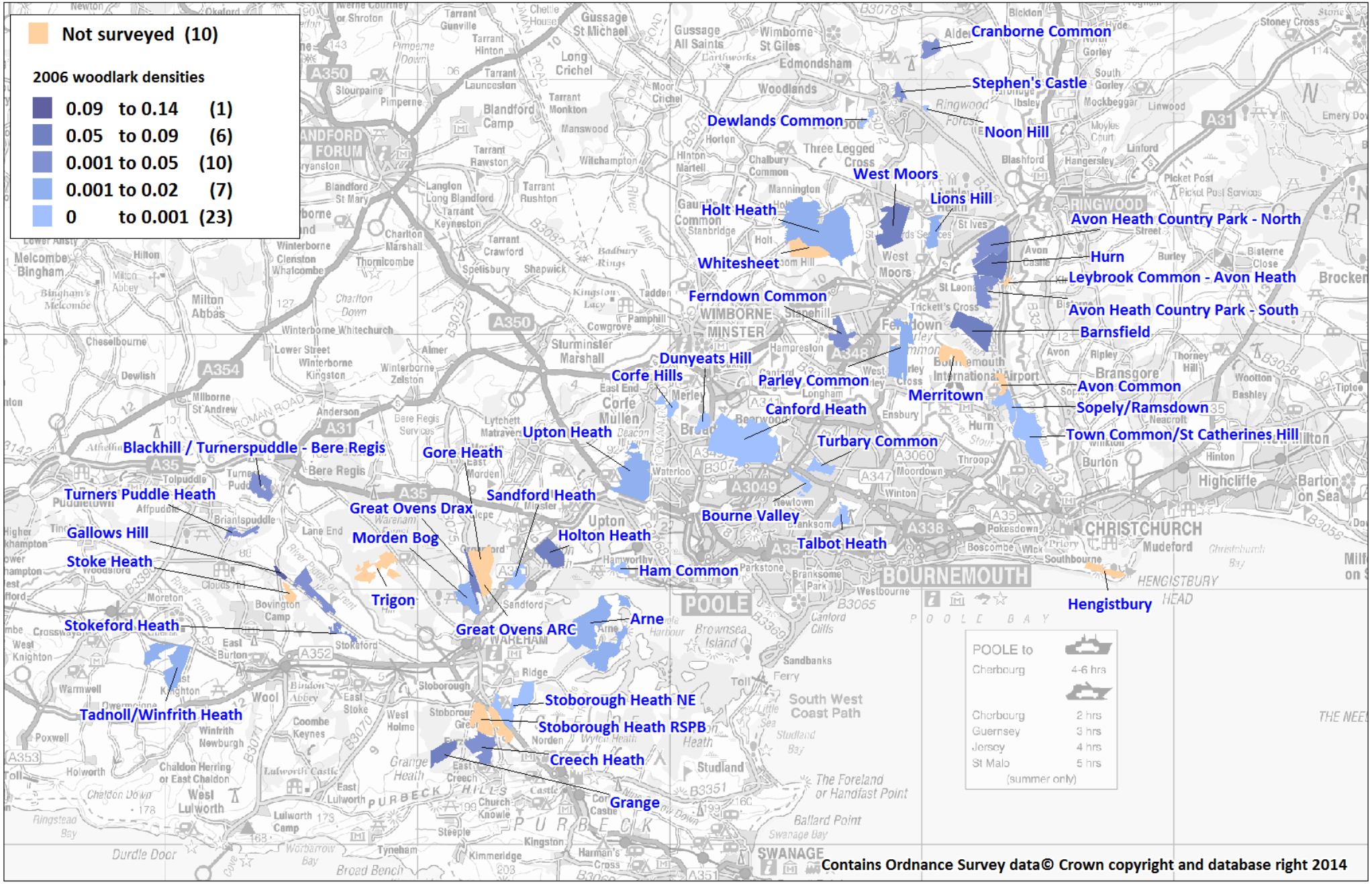



**Figure 8: Woodlark records from 1994 and 2006 national surveys grouped by urban/rural and by site geography.**

# Map 7: 2006 woodlark densities per site



# 5. Dartford warbler

5.1 Using data from all years, it was not possible to get a significant fit to a model, suggesting wide variation in trends between sites. Models that were tested included time effect models and linear trend models (run with all years as change points and the stepwise removal of years). There was no significant improvement on the best linear trend model (with eight change points) after adding urban/rural as a covariate or whether sites were over 100ha or not. The change points were such that it was not possible to use geographic categories as covariates or separate out small sites, as there were categories with no data for particular time periods.

5.2 The overall trend from one model is shown in Figure 10. This model (time effects) did not fit well (LR goodness of fit =411.75, 269 d.f., p=0.<0.001; AIC = -126.25), and the standard errors are high, particularly for the period 2001-2007. Despite the high standard errors the general pattern is likely to be reliable, indicating a rise in the late 1990s, relatively high numbers from 2000 and then a marked decline from 2009. The overall slope is 1.001 $\pm$ 0.003, representing an overall average increase per year of 0.01%. This trend classified by TRIM as stable.

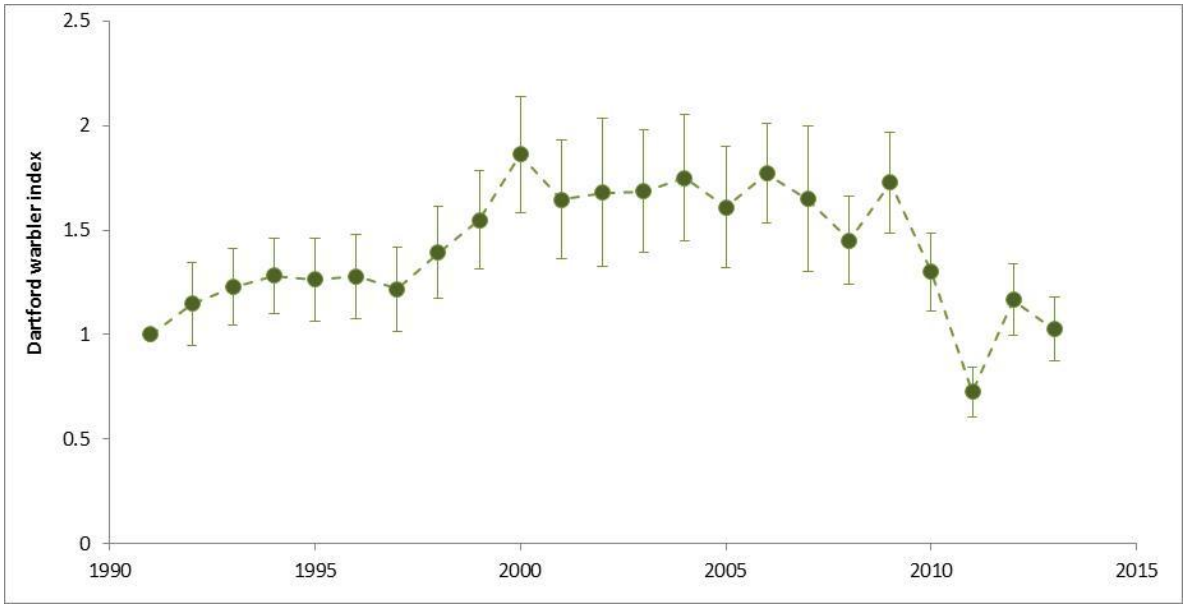



**Figure 9: Trend in Dartford warbler numbers across all sites, 1991-2013. Trends generated using time effects model in TRIM and plot shows imputed results, $\pm$ 1SE.**

5.3 Actual count data for a selection of sites is summarised in Figure 10. It can be seen that there is marked variation between sites. For example the number of territories at Arne is relatively stable in the early to mid 90s before sharply increasing to a peak in 2000. At Stoborough RSPB the number of territories also increased in the late 90s but numbers at that site peaked in 2006. At Town Common/St. Catherine's numbers of Dartford warblers rose in the early 1990s as they did at Barnsfield, yet at Avon Heath Country Park numbers declined from 1994-1997.

5.4 The particular problems with the data relate to the period 2002-2007, where, with the exception of 2006 (the national survey year) the data are limited to a small number of sites (largely Barnsfield, Grange, Hurn and Stoborough RSPB). We therefore split data into two periods 1991-2001 and 2008-2013 and analyse these time periods separately.

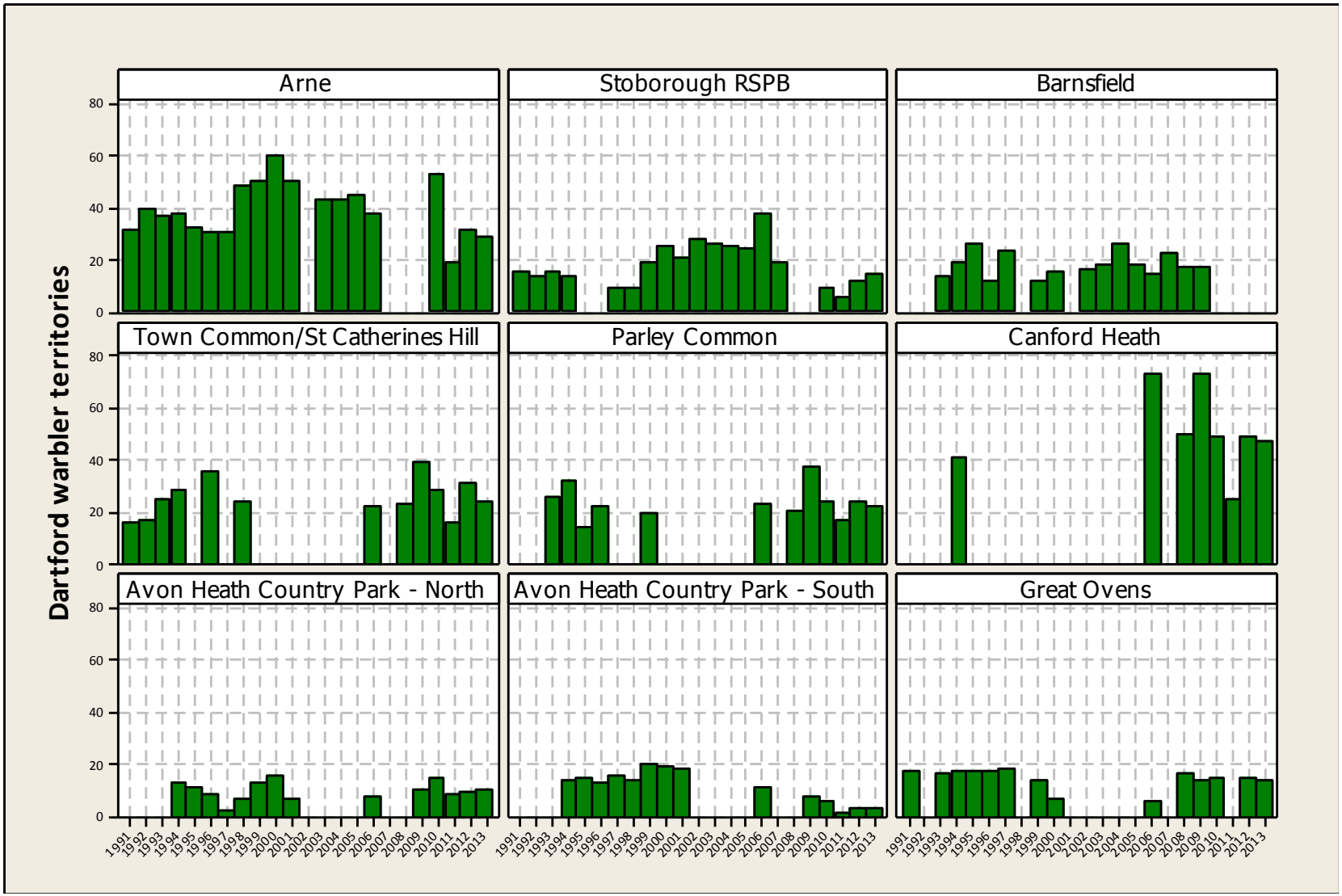



**Figure 10: Dartford warbler data for a selection of sites with good coverage 1991-2011. Plots show actual count data, gaps represent no counts.**

5.5 Using data from the period 1991-2001 (11 years) there was a reasonable fit for data from all sites (time effects model; LR goodness of fit = 129.17, 106 d.f., p=0.063; AIC=-82.83). The model (Figure 11) shows a moderate increase in Dartford warblers over this time, with numbers peaking in 2000.

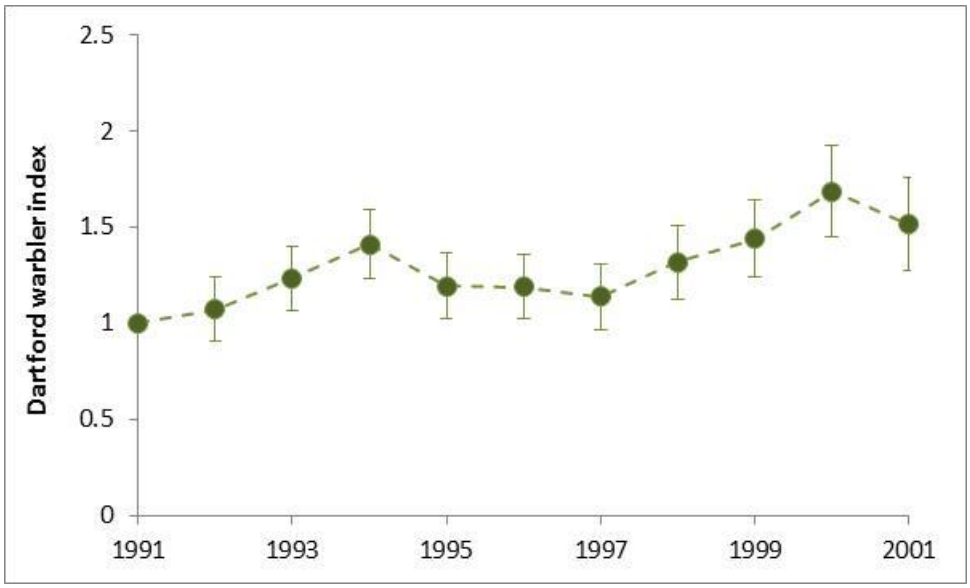



**Figure 11: Overall Dartford warbler trend derived from data from all sites, for the period 1991-2001. Trends generated using time effects model in TRIM and plot shows model results, ± 1SE.**

5.6 There was no significant difference in the trend (1991-2001) on big (>100ha) sites compared to small ones (Wald = 2.75, 4 d.f., p=0.601; covariate added to linear trend model with changepoints in 1991, 1994, 1997 , and 2000) nor on small sites (<30ha) compared to other sites (Wald = 0.32, 4 d.f., p=0.988; covariate again added to linear trend model with changepoints in 1991, 1994, 1997 and 2000). Due to the distribution of counts between years it was not possible to test for differences in trends on urban compared to rural sites nor by geographic grouping.

5.7 Using data for all sites for the period 2008-2013 (i.e. six year period) there was a good overall fit across all sites for a time effects model in TRIM (LR goodness of fit =86.24, 80 df, p=0.297; AIC = -73.76). The overall trend for this period showed a significant steep decline.

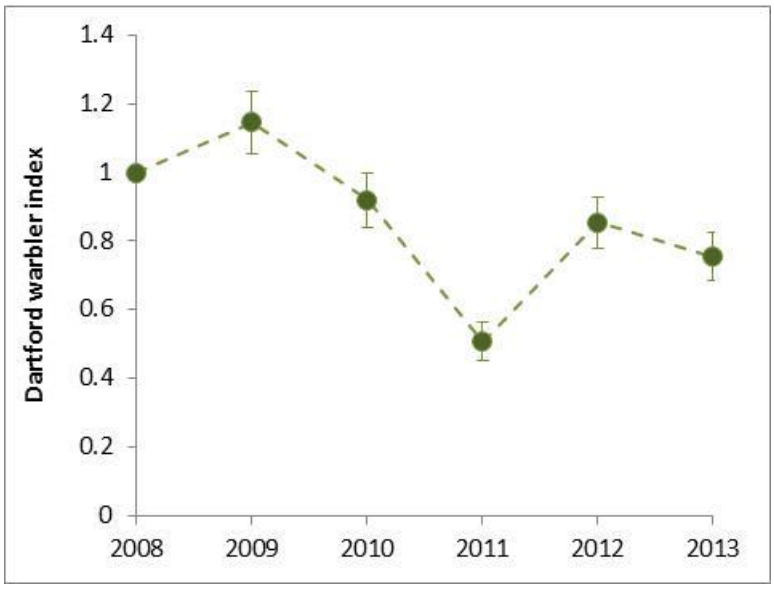



**Figure 12: Dartford warbler trend for all sites (n=30 with data for the period) post 2008. Plot shows model outputs from TRIM time effects model. Error bars show ± 1 SE.**

5.8 There was no significant difference in this trend for the period 2008-13 between rural and urban sites (Wald = 2.58, 5 d.f., p = 0.765). Similarly there was no significant difference in the trends for heaths when grouped geographically (Wald = 8.96, 10 d.f., p = 0.536), nor for big sites (over 100ha) compared to smaller ones (Wald = 8.03, 5 d.f., p = 0.154). It was not possible to test small sites (below 30ha) compared to others as there were insufficient data in 2010.

## The crash in 2011

5.9 There was a marked low in Dartford warbler numbers in the 2011 season, which followed a particularly severe winter (2010/11).

5.10 The trends in Dartford Warbler numbers were similar across sites and the indices suggest that across all sites the numbers of Dartford warblers had dropped in 2011 to nearly half that of 2008. Arne and Canford Heath saw particular large drops in the number of territories (Figure 13), while Talbot Heath and to some extent Avon Heath suffered the least losses. While 2011 clearly had a dramatic impact, the overall trend for the period 2008 to 2013 is a decline.

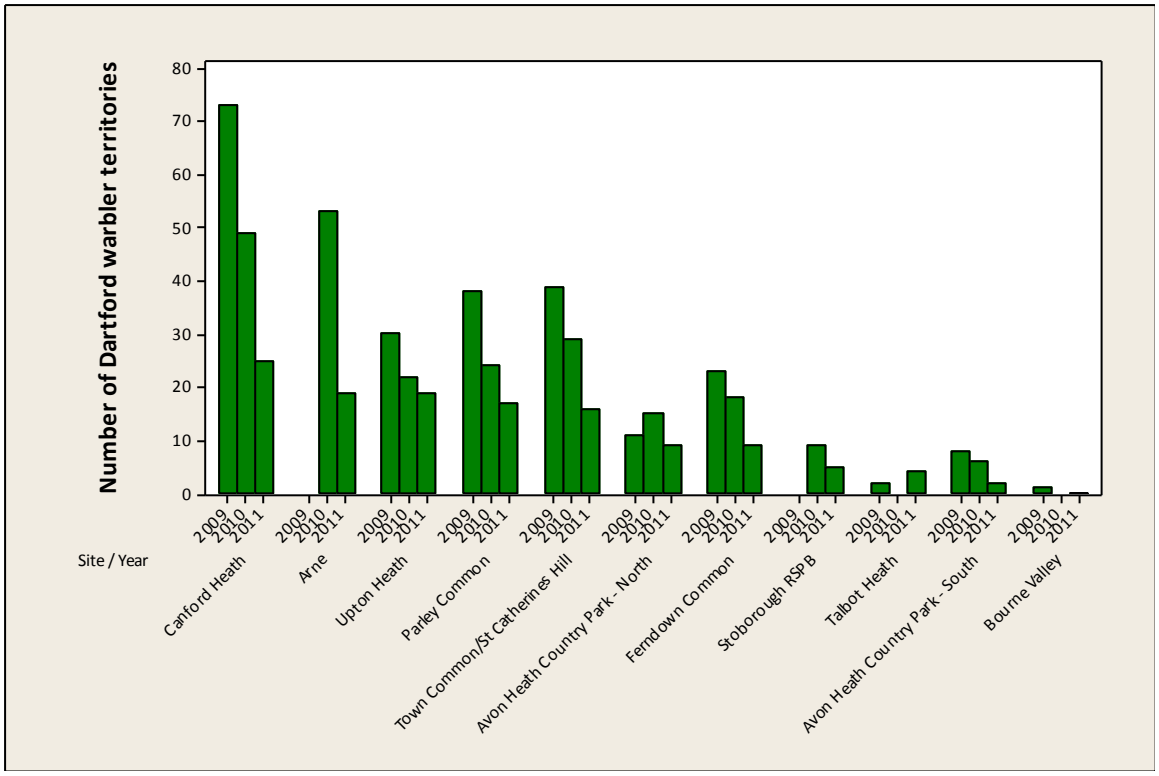



**Figure 13: Number of Dartford Warbler territories on sites with data for 2011 and at least one of the two previous years. Sites are ordered by the number of territories in 2011.**

5.11 There was a strong positive correlation between the number of Dartford warbler present in 2006 (the year with the best coverage) and site size (Spearman's rank correlation coefficient, $R_s$= 0.726, P<0.001) but there does not appear to be any clear differences in the data (Figure 14) when sites are categorised by geography or by rural/urban.

5.12 In 2006, the highest number of Dartford warblers were recorded on Holt Heath (the second largest sites, as defined by the boundaries in Map 1), Stoborough Heath RSPB appears to support particularly high densities (Figure 14 and Map 8).

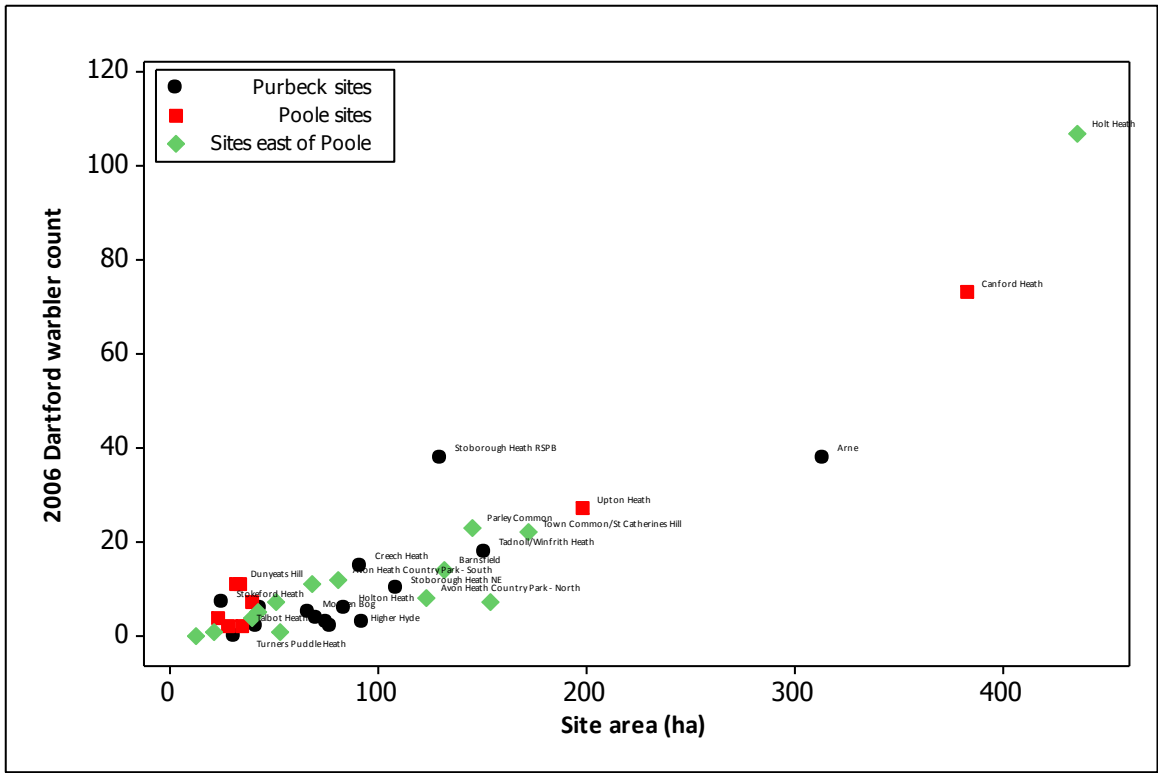
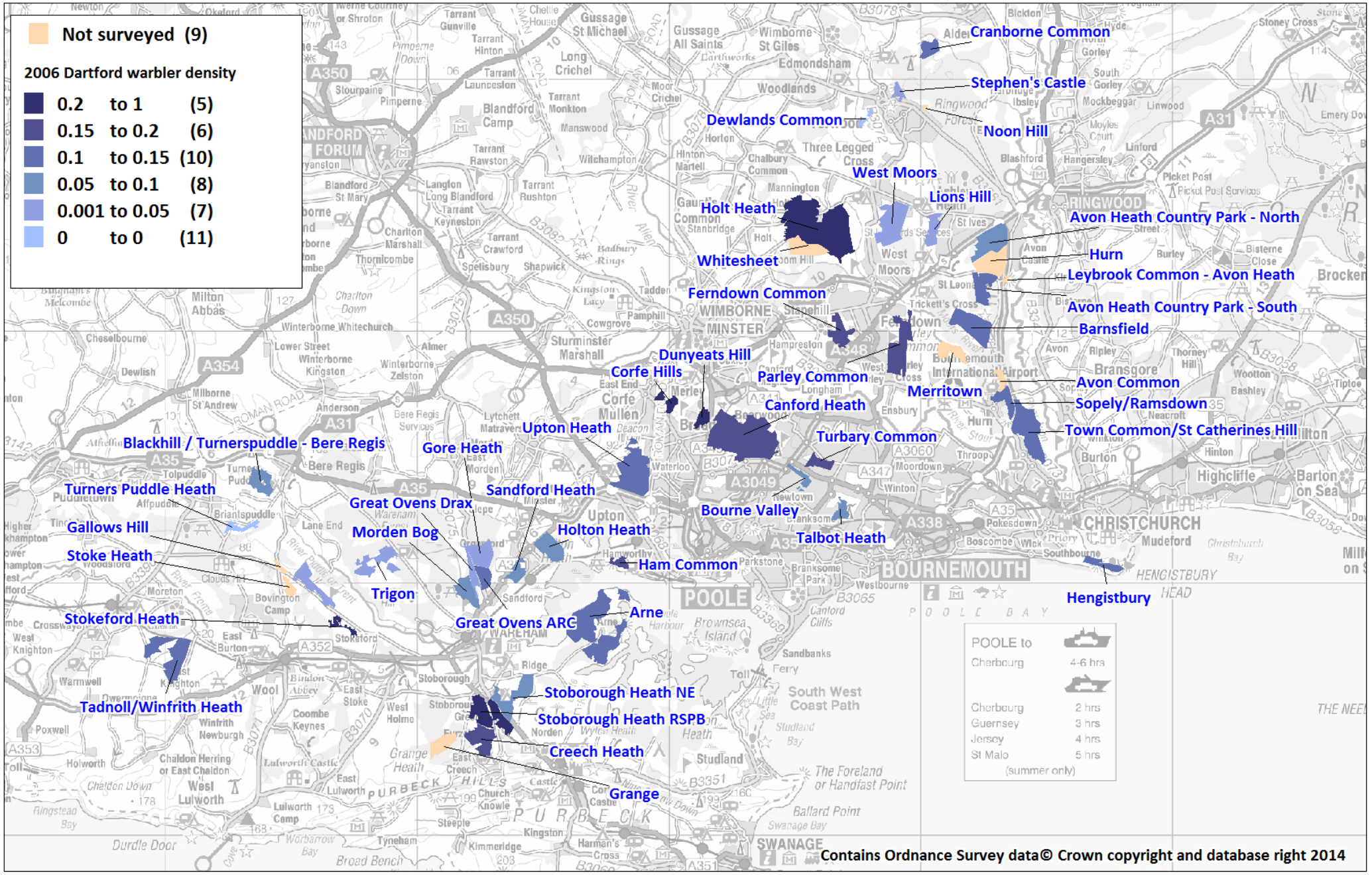



**Figure 14: Number of Dartford warbler from 2006 national survey against survey area grouped by geographic location of the site.**

# Map 8: 2006 Dartford warbler densities per site



# 6. Summary of trends for each species

6.1 Having reviewed the trends of all three species separately for the period 1991-2013, we now consider the three species together. A summary plot of the trend for each species is given in Figure 16. It can be seen that the trends for each species are different and that particular peaks for one species do not correspond to others.

6.2 The period shown in the plots covers 1991 through to 2013, and across this time period many variables that relate to the birds and the habitats will have also changed across sites. For example housing within 5km of the sites has increased by around 10% (21,000 dwellings)[2] over the last ten years at least, and development will have occurred in pulses, linked to the recession. As housing levels increase, sites are potentially likely to become more fragmented, some off-site feeding areas will be lost and recreation levels on the heaths will increase. Habitat management work will have occurred in pulses relating to resources (for example there was a marked pulse of management in the early 2000s relating to the HLF funded Tomorrow's Heathland Heritage).

## The impact of weather

6.3 Weather is likely to be one factor that has a strong impact on the birds. Some weather data are summarised adjacent to the bird trends Figure 17. More recent years seem to be characterised by a series of colder, wetter springs with less sunshine. December 2010 was exceptionally cold across the UK and is described by the Met Office as the coldest December in over 100 years[3]. Dartford warblers are likely to be the most vulnerable to winter weather and the crash in 2011 is presumably linked to the previous cold winter. Woodlark numbers were also relatively low in 2011.

6.4 The peak numbers of nightjar do follow a year (1995) with particularly low rainfall and high levels of sunshine (over the May-August period), however across all years there is no indication that the changes in nightjar abundance are particularly linked to the weather variables extracted. For example the marked dips in nightjar abundance (in 1995, 2001, 2003, 2010) do not follow particularly wet or cold summers. There was no statistically significant correlation between the nightjar index in a given year and the previous year's total precipitation (during May-August), sunshine hours (May-August) or minimum temperature (period May – August). Similarly there was no significant correlation between the change in nightjar abundance between subsequent years and the same weather variables.

6.5 There was no statistically significant correlation between the woodlark index in a given year and the previous year's total precipitation (during March-July) or sunshine hours (March-July). Similarly there was no significant correlation between the change in woodlark abundance between subsequent years and the same weather variables.

[2] Old postcode data held by Footprint Ecology shows 218,757 residential delivery points within 5km of the sites included in the analysis here in 2003 and 239,514 residential delivery points for the same area in 2014.
[3] See http://www.metoffice.gov.uk/climate/uk/2011/winter.html for details

There was some suggestion that a marked increase in woodlarks (a difference between successive years of at least 10%) were dry and sunny (Figure 15), but differences were not significant (following categories in Figure 15: for rainfall, Kruskal-Wallis H=3.21, H=0.77, 2 d.f., p=0.201; for sunshine hours: Kruskal-Wallis H=0.77, 2 d.f., p=0.682).

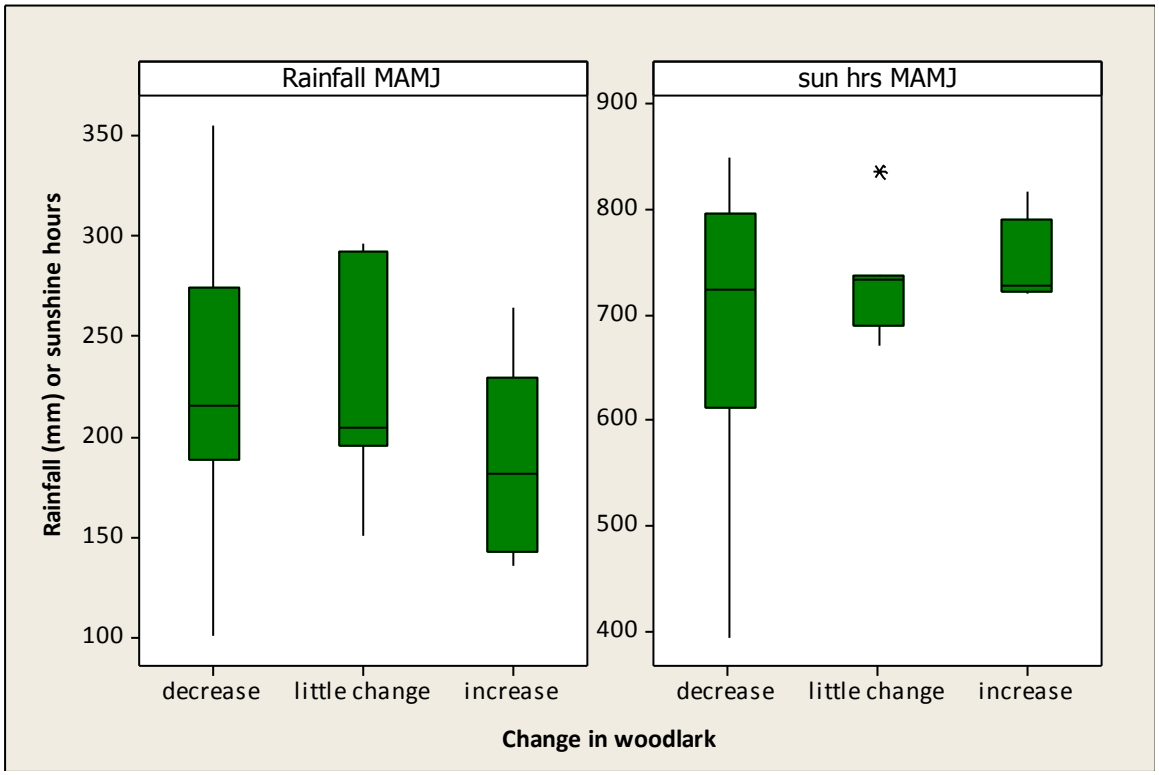



**Figure 15: Change in woodlark numbers between successive years in relation to rainfall (left) and sunshine hours (right) in the initial year. Data from Hurn weather station for months March-July, reproduced from http://www.metoffice.gov.uk/climate/uk/stationdata/hurndata.txt. Change between years is categorised as a decrease if less than -10% difference (n=11), increase if greater than 10% (n=5) and little change if between -10 and 10 (n=7).**

6.6 Fire data for more recent years are also summarised in Figure 18. Fire occurrence is likely to be closely linked to the weather and if large parts of the area were to be burnt in a particular year then it would be expected that bird numbers of all three species may be affected. The area burnt in any one year is however relatively small in relation to the overall area of the surveyed sites and therefore it is perhaps unlikely that any pattern will be apparent.

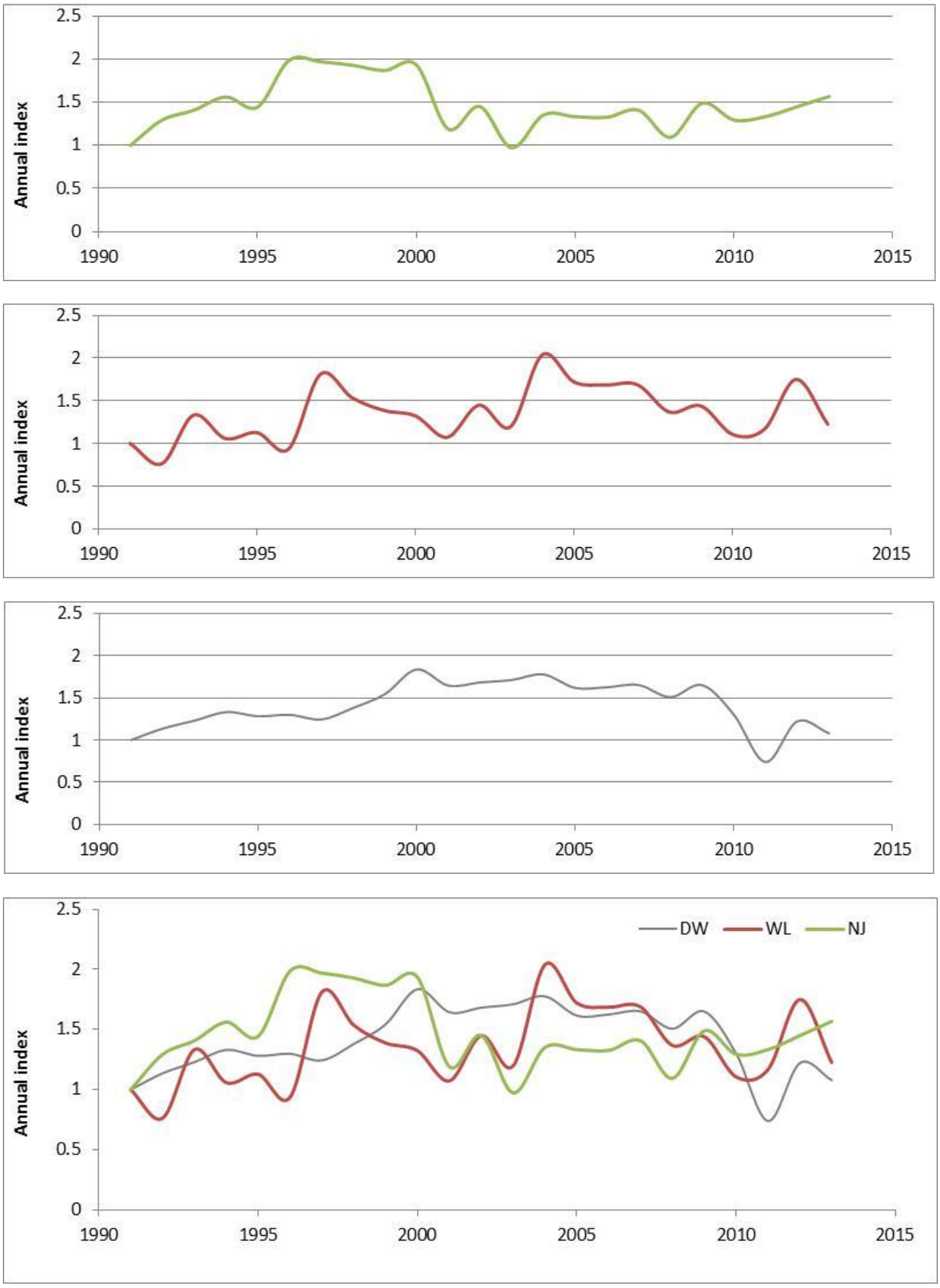



**Figure 16: Smoothed trends for Nightjar (green), woodlark (red) and Dartford warbler (grey) for the period 1991-2013 across the Dorset Heaths.**

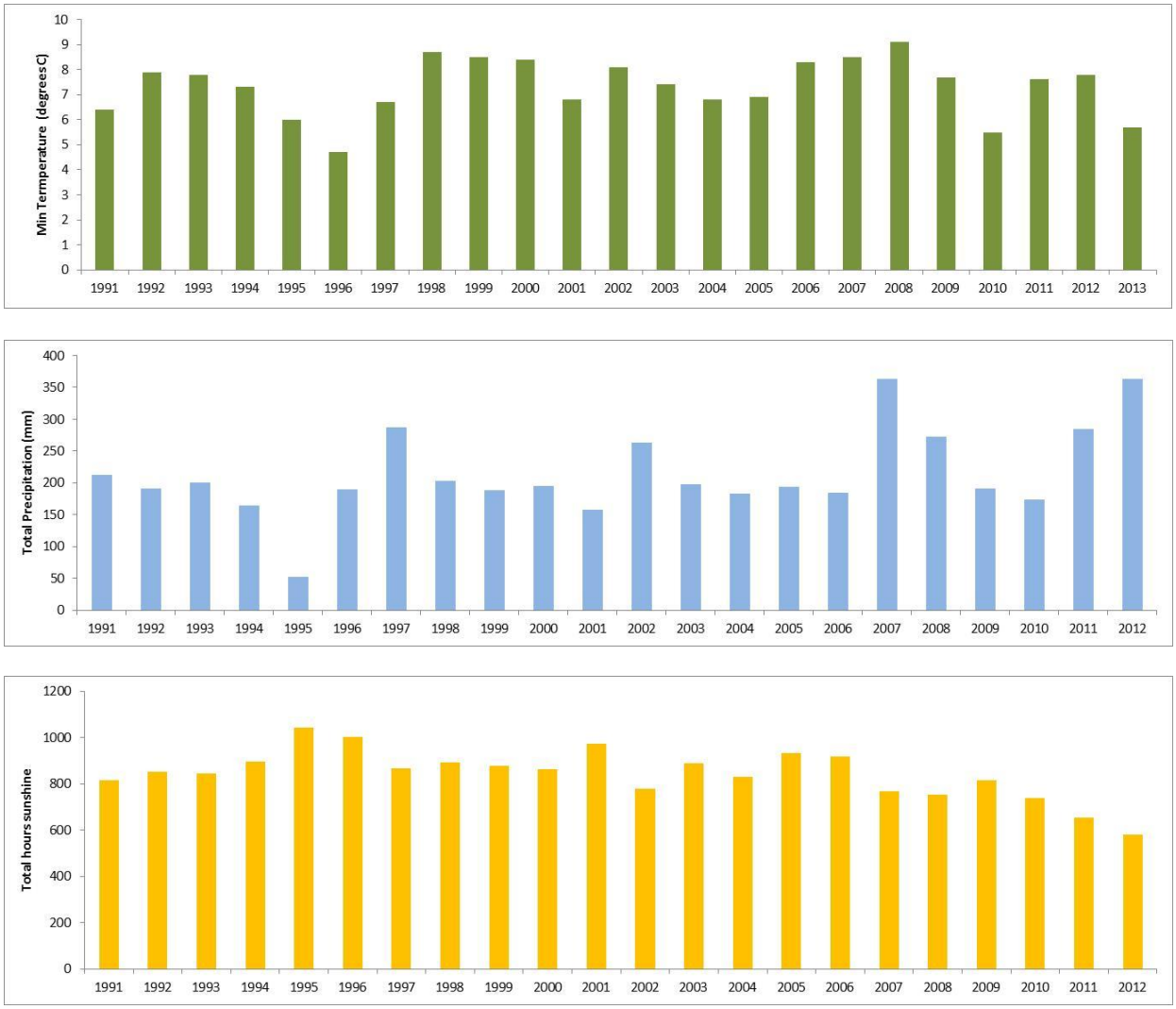



**Figure 17: Weather variables by year (for the months May-August only). Plots show min temperature (green), total precipitation (blue) and total hours of sunshine (orange). Data from Hurn weather station and reproduced from http://www.metoffice.gov.uk/climate/uk/stationdata/hurndata.txt.**

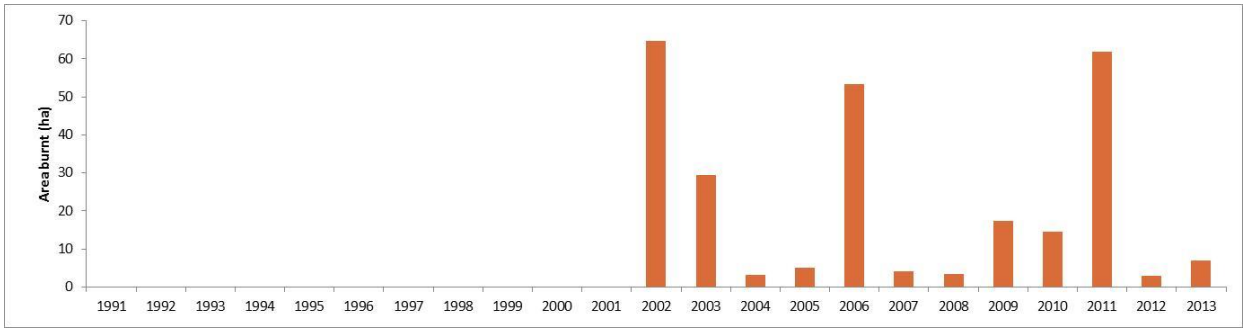



**Figure 18: Total areas (ha) burnt on the named sites in this report for the period 2002-2013. Fires under 400m$^2$ are excluded.**

# 7. Discussion

7.1 We have generated trends for each of the three key breeding bird species on the Dorset Heaths for the period 1991-2013. Over this period of 23 years all three species have shown marked variation. Nightjar numbers peaked in 1996, subsequently declined (such that in 2003 numbers had dipped below 1991 levels), but since 2003 there appears to have been an increase and numbers in 2013 were over 50% above the baseline level in 1991. Woodlark levels have shown the most marked fluctuations of the three species. In most years numbers have been well above those in 1991, clear peaks in 1997,2004 (when numbers where twice that in 1991) and 2012. Dartford warbler numbers rose steadily over the period from 1991 to 2000 (when they peaked). Numbers remained high until 2006, and in 2011 numbers were below those recorded in 1991.

7.2 These trends provide an overview of the status of these birds with the Dorset Heaths and additional detail above those levels recorded in the national surveys. The results have implications for the design of long term monitoring.

## Conservation Implications

7.3 In general, the results give some cause for optimism. During a period when development pressure surrounding the Dorset Heaths has continued to increase and a period when there have been some severe winters and some very wet summers the overall trends for all species have not declined. During the period numbers for all species have reached relatively high levels, but the most recent data suggests populations are of a similar (or slightly higher) size now than they were in 1991. On the flip-side, the 23-year time period has seen considerable management and a focus of conservation interest and effort on the heaths, yet despite these efforts we are not able to demonstrate a significant increase in the population of any of the three species.

7.4 For Nightjar it would be useful to understand what factors influence the trend and why the Purbeck sites have done so much better than the other sites. It has not been possible to include the level of management undertaken at different sites in any of the analyses, these data are simply too difficult to collate for the time period involved. nightjar are summer migrants and little is known about where they spend the winter (Wernham *et al.* 2002). It may be that factors in wintering grounds in Africa influence the trends. Woodlark are only partial migrants, sometimes wintering on the heaths themselves, and Dartford warblers remain on the heaths year round, so for these other two species it would be expected that local factors are the most relevant.

7.5 The most recent National Survey results for woodlarks indicate marked changes(since the last survey) in the proportion of nests in heathland habitats compared to forestry plantations (Conway *et al.* 2009). Analysis of data from other parts of the country indicates that the amount of clearfell and other open habitats within forestry blocks changes over time and there is a strong relationship between area of habitat and bird numbers (e.g. Dolman & Morrison 2012). Management of forestry blocks in Dorset is therefore likely to have a strong effect on the number of woodlarks on the heaths.

Ringing data shows that the majority of birds settling on territories for the first time tend to do so within 4km of the natal site, and few heaths fall more than 4km from forestry plantations. For woodlarks (and nightjars) it would be ideal to view trends for heathlands and plantations separately and in relation to the amount of available habitat within the plantations.

7.6 Harsh winter weather caused the marked crash in Dartford warblers, and the vulnerability to harsh winters for this species is well documented (Bibby 1977, 1979c). The results here show that impact of the cold winters was consistent across all sites, and that populations on rural or large sites did not fare any better than those on rural or small sites. While the decline was very severe, it was not at the same magnitude as some other heathland areas, for example in the Thames Basin Heaths there were almost 1000 territories in 2004 and by 2010 this was down to just 50 (Holling & The Rare Bird Breeding Panel 2012). The difference between the two areas may relate to the less severe weather in the more coastal areas of Dorset compared to the Thames Basin.

## Limitations

7.7 The plots show overall trends across multiple sites. There are particular challenges in establishing these trends.

7.8 The data are patchy in terms of time. Around 69%[4] of the data were missing values – in other words sites had counts for around a third of the years.

7.9 Whether sites were surveyed in particular years was also not random. For example the urban heaths have much better survey coverage in more recent years only, with monitoring on these sites in recent years being funded by local authorities. The original Dorset Heathland Project surveys in the 1990s were targeted at sites where the Project was undertaking (or about to undertake) habitat management work and it is clear that for many sites surveys occur in a run of years and then no count data exists for multiple years.

7.10 Data are also patchy in terms of space. Many key sites within Dorset have been omitted from the analysis due to lack of data – at least in the form of comparable annual counts from a defined survey area. Key sites omitted include Studland, Hartland Moor, Rempstone Forest and most of Wareham Forest. The overall trends in bird numbers as plotted may therefore not reflect the Dorset Heaths as a whole. As an indication of the scale to which the sites included in this report encompass the Dorset population of each species it is possible to calculate what proportion of bird records occur within our survey sites in a single year. Woodlark is the species for which the surveyed sites are perhaps the least representative. In total 153 woodlark records were captured from the 2006 national survey in and surrounding the Dorset Heathlands SPA. Of these, 70 records (46%) fell within the boundary of the SPA and 54 (35%) within the boundaries of the survey areas mapped in this report.

[4] 69% is the figure for Dartford warblers, all years, all sites

7.11 The site boundaries we have used relate to the historic survey boundaries adopted by the Dorset Heathland Project in the 1990s and are boundaries that make practical sense in terms of surveying. Some of the sites are adjacent and could certainly have been merged, for example Stoborough RSPB and Stoborough Natural England are separated by a road, while Avon Heath Country Park (N), Avon Heath Country Park (S), Hurn and Bansfield form a nearly contiguous block. The problem with merging such sites would have been a loss of data for some years when only part of a single bigger site would have been surveyed. Neatly defining a single site is difficult, other studies on the Dorset Heaths (Rose et al. 2000; Liley & Clarke 2003) have used a set of rules to define patches, based on merging adjacent grid cells with set levels of heathland. Such an approach if adopted here would have resulted in an even greater loss of data. The inclusion of some kind of fragmentation index – perhaps relating to the amount of heathland and forestry surrounding each site – may have allowed us to account for any effects relating to how sites are defined, but is difficult to generate as a simple categorical variable suitable for inclusion in the trend models.

7.12 While mostly collected by the RSPB, a number of different surveyors have been involved in the surveys – this is inevitable given the geographic spread and time period. Nightjars in particular are difficult to survey, as single males can hold large territories (Cadbury 1981), sing from different parts of the territory in a short space of time and are only active in the dark, making it harder to differentiate between individuals and accurately map territories. Differences between surveyors may account for some of the variation in time and space, particularly with nightjars.

## Implications for long-term monitoring

7.13 The trends are in some ways encouraging, indicating that all three species have not significantly declined over the period. Compared to other parts of the country, Dartford warblers seemed to have survived better in Dorset; for example in the Thames Basin Heaths, Dartford warblers crashed much more severely in 2009 and numbers remained low across the Thames Basin Heaths through 2009, 2010 and 2011 (Natural England, unpublished data). Nationally, the number of Dartford warbler records submitted to the Rare Birds Breeding Panel indicates an increase across the period 2003-2006, after which numbers declined to a low in 2011 (Eaton *et al.* 2014) whereas in Dorset numbers appear to have been stable through to around 2009. Such comparisons suggest that trends in Dorset will not necessarily be the same as those in the rest of the country and highlight the need for local monitoring and the varying role of the Dorset Heathlands SPA, in terms of the proportion of the national population of each of these species that it supports.

7.14 Pooling data as we have done here presents an overview of the three species. A key question is what monitoring would be ideal in the future to provide an overview of the three species' status in Dorset. In the future climate change will possibly bring pressure on the three species and there is a need to ensure that new development does not have an adverse effect on the integrity of the designated sites, for example through increased recreational pressure. Mitigation measures such as additional green space for recreation and on-site wardening have been established and it is necessary to

ensure these are working effectively. The results here highlight some particular challenges and issues with respect to long term monitoring:

- The heaths and associated forestry blocks cover a wide area, meaning comprehensive coverage on an annual basis will be impossible to achieve.
- Comprehensive surveys of all sites as part of national surveys, undertaken at 10-12 year intervals, are not adequate at a local level to inform how well the birds are doing.
- For woodlark (and to some extent nightjar) there will be a relatively high proportion of the population on non-heath sites, particularly commercial forestry blocks (such as Wareham Forest, Rempstone Forest, Puddletown Forest and Ringwood Forest). Monitoring these sites is likely to be important to understand fluctuations in the populations of woodlark and nightjar in the future. Some of these sites, such as Wareham Forest are perhaps more important, due to their size and location relative to the heaths/SPA than others.
- Woodlark numbers are highly variable between years and the occurrence of birds at particular sites is linked to management that creates open, bare ground.
- For nightjar there are some years at some sites where numbers seem particularly high. These erratic counts may reflect variations between observers and the difficulties in counting and mapping birds in the dark, but could also reflect real variations. For all species standardised monitoring, conducted in a systematic way to ensure direct comparison is essential.
- For nightjar at least there are significant differences between groups of sites, suggesting that monitoring effort needs to encompass sites across the area – from rural Purbeck to the Hampshire border and including sites within the urban conurbation.
- All species will respond to local site factors, but in particular woodlark numbers on individual sites are likely to fluctuate according to the levels of forestry clearance, rotovation and other management.
- Virtually all the data collated here has been collected by professional conservation staff rather than volunteers. At some sites, such as Arne, local site-based staff have undertaken annual monitoring in a regular, comparable fashion, but this is not the case on all reserves and all sites. Many of the counts have been conducted by a mobile team of surveyors employed by the RSPB.

7.15 If we assume national surveys will continue, and provide a snapshot across all sites in the given years, and that some reserves such as Arne will continue to do some regular annual monitoring, then it is necessary to determine what surveys would be useful to cover the gaps in time and space. In particular, it is the urban heaths that are under the most pressure, and it is relevant to ascertain what level of monitoring would act as an early warning for the urban sites. It is vital that monitoring continues and covers enough of the Dorset Heaths at a regular enough interval to pick up trends.

7.16 There are perhaps three main options for future monitoring. One approach would be repeated annual monitoring focused on the urban sites, this is the approach that has been followed in recent years. An alternative would be to undertake comprehensive

monitoring across all sites at regular intervals (for example an interval of every three or four years). An alternative would be to undertake monitoring at a sub-site level, for example by grid cell, where a random sample of cells could be surveyed on an annual basis. This latter option is likely to provide the most robust approach for long term analysis of bird data in relation to site variables. The selection of squares could be stratified to ensure coverage across the Dorset Heaths and so as to include urban and rural sites. The approach could also be one that lends itself well to involving a wider community of surveyors. For example a level of core sampling could be achieved through professional surveyors and additional surveys undertaken by local volunteers, reserve staff and the local birding community, with squares being allocated to individuals that come forward/express interest. In order to set up such a monitoring programme some liason with both the BTO and RSPB would be required, along with local reserve staff and potentially the local bird club.

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## Appendix 1: Nightjar data, n=number of surveys, min=minimum number of birds recorded on any survey , max=maximum number of birds recorded on any survey

| Site / Year | n | min | max | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arne | 15 | 20 | 33 | 22 | 27 | 25 | 24 | 20 | 22 | 20 | 21 | 22 | 22 | | | | 25 | | | | | | 27 | 25 | 28 | 33 |
| Avon Common | 6 | 1 | 10 | | | | 10 | 1 | | | 6 | | | | | | 3 | 4 | | | | | 7 | | | |
| Avon Heath Country Park - North | 14 | 6 | 20 | | | | 9 | 9 | 17 | 19 | 20 | 13 | 19 | 9 | | | 16 | | | | | 15 | 8 | 9 | 8 | 6 |
| Avon Heath Country Park - South | 14 | 5 | 22 | | | | 8 | 10 | 15 | 19 | 22 | 18 | 14 | 9 | | | 10 | | | | | 8 | 8 | 5 | 7 | 5 |
| Barnsfield | 14 | 13 | 26 | | | | 18 | 22 | 26 | 21 | | 17 | 20 | | 17 | 13 | 18 | | 17 | 18 | 14 | 15 | 14 | | | |
| Blackhill / Turnerspuddle - Bere Regis | 9 | 4 | 8 | 6 | 7 | 8 | | 7 | 5 | | 5 | | 7 | | | | 4 | | | | | | 5 | | | |
| Bourne Valley | 4 | 0 | 0 | | | | | | | | | | | | | | | | | | | 0 | | 0 | 0 | 0 |
| Canford Heath | 6 | 10 | 30 | 10 | | | | | | | | | | | | | | | | | | 30 | 30 | 26 | 26 | 21 |
| Corfe Hills | 3 | 4 | 8 | 4 | | | | | | | | | | | | | | | | | | 8 | 5 | | | |
| Cranborne Common | 5 | 7 | 15 | | | 10 | | | | 13 | | 15 | | | | | 8 | | | | | | 7 | | | |
| Creech Heath | 6 | 4 | 12 | | 5 | 12 | | | | | | | | | | | 7 | | | | 4 | 7 | 12 | | | |
| Dewlands Common | 4 | 1 | 4 | | | | | | | 4 | | | | | | | 2 | | | | 1 | 2 | | | | |
| Dunyeats Hill | 2 | 3 | 4 | | | | | | | | | | | | | | | | | | | 3 | 4 | | | |
| Ferndown Common | 9 | 3 | 8 | 5 | | 3 | | | | | | | | | | | 7 | | | | 5 | 6 | 4 | 7 | 8 | 5 |
| Gallows Hill | 4 | 1 | 2 | | | 2 | | | | | | | | | | | 2 | | | | | 1 | 2 | | | |
| Gore Heath | 8 | 1 | 8 | 1 | | 1 | 2 | 2 | 1 | 3 | | | | 8 | | | 6 | | | | | | | | | |
| Great Ovens | 13 | 2 | 10 | 3 | | 5 | 3 | 5 | 4 | 9 | | 7 | | 2 | | | 2 | | | | | 6 | 4 | | 5 | 10 |
| Great Ovens Drax | 11 | 3 | 6 | 3 | | 3 | 4 | 4 | 4 | 6 | | 5 | 6 | 4 | | | 6 | | | | | | 5 | | | |
| Ham Common | 2 | 1 | 3 | | | | | | | | | | | | | | | | | | | 1 | 3 | | | |
| Hengistbury just heaths | 1 | 0 | 0 | | | | | | | | | | | | | | | | | | | 0 | | | | |
| Higher Hyde | 7 | 4 | 10 | | 4 | 6 | | 6 | 10 | | | 6 | | | | | 7 | | | | | | 4 | | | |
| Holt Heath | 4 | 14 | 26 | | | | | | | | | | | | | | 17 | | | | | 22 | 14 | | | 26 |
| Holton Heath | 3 | 4 | 17 | | | | | | | | | | 17 | | | | 10 | | | | | | 4 | | | |
| Hurn | 12 | 1 | 16 | | | | | | 16 | | 8 | 9 | 11 | 1 | 6 | | 2 | | 5 | 6 | 6 | 8 | 3 | | | |
| Leybrook Common - Avon Heath | 5 | 1 | 4 | | | | | 3 | | | | 4 | 1 | 2 | | | 1 | | | | | | | | | |
| Lions Hill | 6 | 2 | 5 | | | | | | | | | | | | | | 3 | | | | 2 | 4 | 5 | | 4 | 3 |
| Merritown | 4 | 4 | 8 | 4 | | | 7 | | | | | | | | | | 8 | | | | | | 6 | | | |
| Morden Bog | 7 | 1 | 6 | | | | 1 | | 3 | 1 | | 1 | 6 | | | | 4 | | | | | | 5 | | | |

| Site / Year | n | min | max | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Noon Hill | 2 | 1 | 1 | | | | | | | | | | | | | | 1 | | | | | 1 | | | | |
| Parley Common | 13 | 8 | 16 | | 9 | 8 | 16 | 10 | 13 | | | 13 | | | | | 10 | | | | 8 | 13 | 14 | 13 | 9 | 12 |
| Grange | 11 | 5 | 8 | | 5 | | | 7 | 6 | 6 | 8 | | | | | | 8 | | | | | 8 | 6 | 6 | 5 | 5 |
| Sandford Heath | 6 | 1 | 4 | | | | | | | | | | 4 | | | | 1 | | | | | 2 | 2 | | 2 | 2 |
| Sopely/Ramsdown | 9 | 1 | 10 | 1 | | 2 | 10 | | | | 6 | | | | | | 5 | 9 | | | 7 | 7 | 3 | | | |
| Stephen's Castle | 6 | 1 | 8 | | | | | | | 8 | | | | | | | | | | | 1 | 2 | 1 | | 1 | 1 |
| Stoborough Heath NE | 6 | 2 | 12 | | | | | 4 | | | | | 11 | | | | 2 | | | | 4 | 12 | 6 | | | |
| Stoborough RSPB | 20 | 4 | 14 | 4 | 8 | 6 | 6 | 6 | | 6 | 6 | 6 | 6 | 5 | 6 | 4 | 10 | 7 | 6 | 6 | | 5 | 6 | | 14 | 14 |
| Stoke Heath | 2 | 1 | 1 | | | | | | | | | | | | | | 1 | | | | | | 1 | | | |
| Stokeford Heath | 4 | 0 | 5 | | 0 | 1 | | | | | | | | | | | 5 | | | | | | 5 | | | |
| Tadnoll/Winfrith Heath | 6 | 10 | 18 | | | 10 | | | | | | | | | | | 17 | | | | | 12 | 12 | | 12 | 18 |
| Talbot Heath | 5 | 0 | 2 | | | | | | | | | | | | | | | | | | 1 | 0 | | 1 | 1 | 2 |
| Town Common/St Catherines Hill | 14 | 9 | 39 | 15 | 18 | 21 | 21 | | 39 | | 25 | | | | | | 12 | 12 | | | 14 | 15 | 9 | 12 | 15 | 17 |
| Trigon | 8 | 3 | 9 | 7 | 6 | 7 | | 5 | 6 | | 9 | | | | | | 3 | | | | | | 6 | | | |
| Turbary Common | 1 | 0 | 0 | | | | | | | | | | | | | | | | | | | 0 | | | | |
| Turners Puddle Heath | 3 | 1 | 4 | 4 | | | | | | | | | | | | | 2 | | | | | | 1 | | | |
| Upton Heath | 6 | 8 | 12 | | | | | | | | | | | | | | 8 | | | | | 11 | 11 | 10 | 12 | 10 |
| West Moors | 3 | 6 | 14 | | | | | | | | | | 14 | | | | 11 | | | | | | 6 | | | |
| Whitesheet | 4 | 5 | 23 | | | | | | | 19 | | 23 | | | | | 5 | | | | | 7 | | | | |

## Appendix 2: Woodlark data, n=number of surveys, min=minimum number of birds recorded on any survey , max=maximum number of birds recorded on any survey

| Site / Year | n | min | max | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arne | 19 | 0 | 5 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 2 | 1 | 2 | | 4 | | | | 4 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| Avon Common | 3 | 0 | 3 | | | | 0 | 3 | | | 2 | | | | | | | | | | | | | | | |
| Avon Heath Country Park - North | 15 | 0 | 6 | | | | 0 | 0 | 0 | 6 | 4 | 6 | 4 | 4 | 4 | | | | 4 | | | 6 | 5 | 5 | 4 | 2 |
| Avon Heath Country Park - South | 15 | 2 | 7 | | | | 4 | 2 | 4 | 7 | 4 | 5 | 6 | 3 | 5 | | | | 3 | | | 5 | 3 | 2 | 5 | 4 |
| Barnsfield | 15 | 4 | 10 | | | 8 | 10 | 6 | 6 | 8 | | 5 | 5 | | 5 | 4 | 9 | 9 | 8 | 10 | 9 | 8 | | | | |
| Blackhill / Turnerspuddle - Bere Regis | 1 | 2 | 2 | | | | | | | | | | | | | | | | 2 | | | | | | | |
| Bourne Valley | 7 | 0 | 0 | | | | 0 | | | | | | | | | | | | 0 | | | 0 | 0 | 0 | 0 | 0 |
| Canford Heath | 10 | 0 | 2 | 1 | | 2 | 0 | | | | | | | | 1 | | | | 0 | | | 0 | 0 | 0 | 0 | 0 |
| Corfe Hills | 3 | 0 | 0 | | | | 0 | | | | | | | | | | | | 0 | | | 0 | | | | |
| Cranborne Common | 2 | 0 | 2 | | | | 0 | | | | | | | | | | | | 2 | | | | | | | |
| Creech Heath | 6 | 1 | 2 | | 1 | 1 | | | | 1 | | | | | | | | | 2 | | | 1 | 1 | | | |
| Dewlands Common | 4 | 0 | 2 | | | | 0 | | | 2 | | | | | | | | | 0 | | | 0 | | | | |
| Dunyeats Hill | 3 | 0 | 0 | | | | 0 | | | | | | | | | | | | 0 | | | 0 | | | | |
| Ferndown Common | 7 | 0 | 2 | | | | 0 | | | | | | | | | | | | 2 | | | 0 | 0 | 0 | 1 | 1 |
| Gallows Hill | 2 | 0 | 1 | | | | | | | | | | | | | | | | 1 | | | 0 | | | | |
| Gore Heath | 6 | 1 | 1 | 1 | | 1 | 1 | 1 | 1 | | | | | 1 | | | | | | | | | | | | |
| Great Ovens | 13 | 0 | 4 | 2 | | 1 | 1 | 2 | 1 | | | 0 | 0 | 0 | | | | | 0 | | | 2 | 0 | | 4 | 0 |
| Great Ovens Drax | 10 | 0 | 3 | 1 | | 2 | 2 | 3 | 2 | 3 | | 0 | 0 | 0 | | | | | 3 | | | | | | | |
| Ham Common | 3 | 0 | 0 | | | | 0 | | | | | | | | | | | | 0 | | | 0 | | | | |
| Hengistbury just heaths | 2 | 0 | 0 | | | | | | | | | | | | | | | | 0 | | | 0 | | | | |
| Higher Hyde | 8 | 0 | 2 | | 0 | 0 | 0 | 1 | 0 | | | 0 | 0 | | | | | | 2 | | | | | | | |
| Holt Heath | 6 | 1 | 6 | | | | | | | 6 | | | | | | | | | 1 | | | 1 | 1 | | 3 | 3 |
| Holton Heath | 4 | 3 | 5 | | | | 3 | | | 4 | | | 5 | | | | | | 5 | | | | | | | |
| Hurn | 16 | 2 | 7 | | | 5 | 5 | | 4 | 2 | 5 | 6 | 5 | | 5 | 4 | 7 | 5 | 6 | 7 | 5 | 5 | | 2 | | |
| Leybrook Common - Avon Heath | 0 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | |
| Lions Hill | 4 | 0 | 1 | | | | 0 | | | | | | | | | | | | 1 | | | | | | 0 | 0 |
| Merritown | 0 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | |
| Morden Bog | 2 | 1 | 1 | | | | | | | | | | 1 | | | | | | 1 | | | | | | | |

| Site / Year | n | min | max | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Noon Hill | 2 | 0 | 0 | | | | | | | | | | | | | | | | 0 | | | 0 | | | | |
| Parley Common | 9 | 0 | 2 | | | 2 | 1 | | | | | | | | 2 | | | | 1 | | | 2 | 0 | 1 | 2 | 1 |
| Grange | 14 | 1 | 4 | | 1 | | | | | 2 | 3 | | 4 | 4 | 4 | 4 | | | 4 | 2 | 1 | | 3 | 2 | 2 | 2 |
| Sandford Heath | 5 | 0 | 1 | | | | | | | | | | | | | | | | 0 | | | 1 | 1 | | 1 | 1 |
| Sopely/Ramsdown | 6 | 0 | 1 | | | 1 | | | | 1 | 1 | | | | 1 | | | | 0 | | | 0 | | | | |
| Stephen's Castle | 6 | 0 | 1 | | | | 1 | | | | | | | | | | | | 1 | | | 1 | 0 | | 0 | 0 |
| Stoborough Heath NE | 2 | 0 | 0 | | | | | | | | | | | | | | | | 0 | | | 0 | | | | |
| Stoborough RSPB | 5 | 0 | 2 | | | | | | | | | | | | | | | | 0 | | | 0 | | 2 | 2 | 1 |
| Stoke Heath | 1 | 0 | 0 | | | | 0 | | | | | | | | | | | | | | | | | | | |
| Stokeford Heath | 3 | 1 | 1 | | | | 1 | | | 1 | | | | | | | | | 1 | | | | | | | |
| Tadnoll/Winfrith Heath | 6 | 0 | 1 | | | | 1 | | | | | | | | | | | | 1 | | | 0 | 1 | | 0 | 0 |
| Talbot Heath | 5 | 0 | 0 | | | | 0 | | | | | | | | | | | | 0 | | | 0 | | | 0 | 0 |
| Town Common/St Catherines Hill | 13 | 0 | 1 | 0 | 0 | 0 | 0 | | 0 | 1 | 1 | | | | | | | | 0 | | | 0 | 0 | 0 | 0 | 0 |
| Trigon | 8 | 1 | 4 | 2 | 2 | 2 | | 3 | 1 | 4 | 4 | | | | 1 | | | | | | | | | | | |
| Turbary Common | 2 | 0 | 0 | | | | | | | | | | | | | | | | 0 | | | 0 | | | | |
| Turners Puddle Heath | 3 | 0 | 1 | | | | 0 | | | | | | | | | | | | 1 | | | 0 | | | | |
| Upton Heath | 8 | 0 | 1 | | | | | | | 1 | | | | | 0 | | | | 1 | | | 0 | 0 | 0 | 0 | 0 |
| West Moors | 3 | 5 | 9 | | | | | | | 9 | | | 5 | | | | | | 9 | | | | | | | |
| Whitesheet | 4 | 0 | 1 | | | | 0 | | | 0 | | 1 | | | | | | | | | | | 1 | | | |

## Appendix 3: Dartford warbler data, n=number of surveys, min=minimum number of birds recorded on any survey , max=maximum number of birds recorded on any survey

| Site / Year | n | min | max | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arne | 19 | 19 | 60 | 31 | 39 | 37 | 38 | 32 | 30 | 30 | 48 | 50 | 60 | 50 | | 43 | 43 | 45 | 38 | | | | 53 | 19 | 31 | 29 |
| Avon Common | 3 | 4 | 8 | | | | 8 | 4 | | | 6 | | | | | | | | | | | | | | | |
| Avon Heath Country Park - North | 14 | 3 | 16 | | | | 13 | 12 | 9 | 3 | 7 | 13 | 16 | 7 | | | | | 8 | | | 11 | 15 | 9 | 10 | 11 |
| Avon Heath Country Park - South | 14 | 2 | 21 | | | | 14 | 15 | 13 | 16 | 14 | 21 | 20 | 19 | | | | | 12 | | | 8 | 6 | 2 | 4 | 4 |
| Barnsfield | 15 | 12 | 26 | | | 13 | 19 | 26 | 12 | 23 | | 12 | 15 | | 16 | 18 | 26 | 18 | 14 | 22 | 17 | 17 | | | | |
| Blackhill / Turnerspuddle - Bere Regis | 7 | 4 | 6 | 5 | 6 | 6 | | 5 | 4 | | 6 | | | | | | | | 4 | | | | | | | |
| Bourne Valley | 7 | 0 | 2 | | | | 0 | | | | | | | | | | | | 2 | | 1 | 1 | | 0 | 2 | 0 |
| Canford Heath | 8 | 25 | 73 | | | | 41 | | | | | | | | | | | | 73 | | 50 | 73 | 49 | 25 | 49 | 47 |
| Corfe Hills | 5 | 3 | 11 | 3 | | | 7 | | | | | | | | | | | | 11 | | 4 | 3 | | | | |
| Cranborne Common | 6 | 3 | 9 | | | 9 | 3 | 4 | | 4 | | 7 | | | | | | | 5 | | | | | | | |
| Creech Heath | 6 | 6 | 15 | | 11 | 8 | | | | | | | | | | | | | 15 | | 6 | 7 | 13 | | | |
| Dewlands Common | 4 | 0 | 1 | | | | 1 | | | | | | | | | | | | 0 | | 0 | 0 | | | | |
| Dunyeats Hill | 4 | 2 | 11 | | | | 2 | | | | | | | | | | | | 11 | | 9 | 6 | | | | |
| Ferndown Common | 10 | 5 | 23 | 5 | | 12 | 14 | | | | | | | | | | | | 11 | | 23 | 23 | 18 | 9 | 16 | 11 |
| Gallows Hill | 1 | 1 | 1 | | | | | | | | | | | | | | | | | | | 1 | | | | |
| Gore Heath | 5 | 1 | 2 | | | | | 2 | 1 | | | 2 | | 1 | | | | | 2 | | | | | | | |
| Great Ovens | 14 | 6 | 19 | 18 | | 17 | 18 | 18 | 18 | 19 | | 14 | 7 | | | | | | 6 | | 17 | 14 | 15 | | 15 | 14 |
| Great Ovens Drax | 10 | 1 | 5 | 2 | | 2 | 2 | 5 | 2 | 3 | | 3 | 1 | 2 | | | | | 2 | | | | | | | |
| Ham Common | 4 | 2 | 4 | | | | 4 | | | | | | | | | | | | 4 | | 2 | 2 | | | | |
| Hengistbury just heaths | 3 | 0 | 4 | | | | | | | | | | | | | | | | 4 | | 2 | 0 | | | | |
| Higher Hyde | 7 | 3 | 8 | | 3 | 4 | 8 | 8 | 5 | | | 5 | | | | | | | 3 | | | | | | | |
| Holt Heath | 5 | 36 | 107 | | | | | | | | | | | | | | | | 107 | | | 84 | 55 | | 49 | 36 |
| Holton Heath | 3 | 5 | 11 | | | | 5 | | | | | | 11 | | | | | | 6 | | | | | | | |
| Hurn | 12 | 0 | 4 | | | 0 | 4 | | | 2 | 1 | | 2 | | 1 | 3 | 3 | 1 | | 3 | 3 | 3 | | | | |
| Leybrook Common - Avon Heath | 3 | 1 | 1 | | | | | 1 | | | | | 1 | 1 | | | | | | | | | | | | |
| Lions Hill | 6 | 0 | 5 | | | | 0 | | | | | | | | | | | | 1 | | 5 | 4 | | | 5 | 3 |
| Merritown | 2 | 7 | 7 | 7 | | | 7 | | | | | | | | | | | | | | | | | | | |
| Morden Bog | 6 | 1 | 5 | 1 | | 2 | | | | | | 3 | 1 | 2 | | | | | 5 | | | | | | | |

| Site / Year | n | min | max | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Noon Hill | 2 | 0 | 1 | | | | | | | | | | | | | | | | | | 0 | 1 | | | | |
| Parley Common | 12 | 14 | 38 | | | 26 | 32 | 14 | 22 | | | 20 | | | | | | | 23 | | 21 | 38 | 24 | 17 | 24 | 22 |
| Grange | 16 | 2 | 19 | | 5 | | | 7 | 8 | 5 | 10 | | 19 | | 9 | 14 | 11 | | 10 | 9 | 8 | | 2 | 4 | 12 | 10 |
| Sandford Heath | 8 | 0 | 3 | | | | 0 | | | | | | 0 | | | | | | 3 | | 0 | 2 | 1 | | 0 | 0 |
| Sopely/Ramsdown | 8 | 2 | 18 | 2 | | 4 | 3 | 3 | | | 8 | | | | | | | | 7 | | 18 | 12 | | | | |
| Stephen's Castle | 7 | 0 | 3 | | | | 2 | | | 1 | | | | | | | | | 1 | | 3 | 1 | | | 0 | 0 |
| Stoborough Heath NE | 4 | 6 | 12 | | | | | | | | | | 11 | | | | | | 10 | | 12 | 6 | | | | |
| Stoborough RSPB | 19 | 5 | 38 | 15 | 13 | 15 | 13 | | | 9 | 9 | 19 | 25 | 21 | 28 | 26 | 25 | 24 | 38 | 19 | | | 9 | 5 | 12 | 14 |
| Stoke Heath | 2 | 4 | 5 | | | 4 | 5 | | | | | | | | | | | | | | | | | | | |
| Stokeford Heath | 2 | 5 | 7 | | | | 5 | | | | | | | | | | | | 7 | | | | | | | |
| Tadnoll/Winfrith Heath | 8 | 8 | 23 | | | 8 | 11 | | | | | | | | | | | | 18 | | 23 | 18 | 11 | | 10 | 13 |
| Talbot Heath | 8 | 2 | 6 | 4 | | | 4 | | | | | | | | | | | | 2 | | 4 | 2 | | 4 | 6 | 4 |
| Town Common/St Catherines Hill | 13 | 16 | 39 | 16 | 17 | 25 | 29 | | 36 | | 24 | | | | | | | | 22 | | 23 | 39 | 29 | 16 | 31 | 24 |
| Trigon | 5 | 1 | 7 | | | 2 | | 1 | 2 | | 7 | | | | | | | | 3 | | | | | | | |
| Turbary Common | 3 | 3 | 7 | | | | | | | | | | | | | | | | 7 | | 6 | 3 | | | | |
| Turners Puddle Heath | 2 | 0 | 5 | | | | 5 | | | | | | | | | | | | 0 | | | | | | | |
| Upton Heath | 8 | 19 | 30 | | | | 21 | | | | | | | | | | | | 27 | | 27 | 30 | 22 | 19 | 26 | 25 |
| West Moors | 2 | 7 | 8 | | | | | | | | | | 8 | | | | | | 7 | | | | | | | |
| Whitesheet | 6 | 1 | 8 | | | | 8 | 1 | | 8 | | 8 | | | | | | | | | | 6 | 6 | | | |

## Appendix 4: Sites

Sites used in analysis and categories used as covariates in the analysis.

| Site | Area | Urban/rural | Area | Big | Small |
|---|---|---|---|---|---|
| Arne | 313.69 | rural | Purbeck | 2 | 1 |
| Avon Common | 23.64 | rural | E. of Poole | 1 | 2 |
| Avon Heath Country Park - North | 122.78 | rural | E. of Poole | 2 | 1 |
| Avon Heath Country Park - South | 80.13 | rural | E. of Poole | 1 | 1 |
| Barnsfield | 131.15 | rural | E. of Poole | 2 | 1 |
| Blackhill / Turnerspuddle - Bere Regis | 70.36 | rural | Purbeck | 1 | 1 |
| Bourne Valley | 27.83 | urban | Poole | 1 | 2 |
| Canford Heath | 382.94 | urban | Poole | 2 | 1 |
| Corfe Hills | 33.03 | urban | Poole | 1 | 1 |
| Cranborne Common | 42.1 | rural | E. of Poole | 1 | 1 |
| Creech Heath | 90.98 | rural | Purbeck | 1 | 1 |
| Dewlands Common | 12.51 | urban | E. of Poole | 1 | 2 |
| Dunyeats Hill | 31.66 | urban | Poole | 1 | 1 |
| Ferndown Common | 68.13 | urban | E. of Poole | 1 | 1 |
| Gallows Hill | 10.85 | rural | Purbeck | 1 | 2 |
| Gore Heath | 77.06 | rural | Purbeck | 1 | 1 |
| Great Ovens | 43.2 | rural | Purbeck | 1 | 1 |
| Great Ovens Drax | 41.49 | rural | Purbeck | 1 | 1 |
| Ham Common | 22.3 | urban | Poole | 1 | 2 |
| Hengistbury just heaths | 39.17 | rural | E. of Poole | 1 | 1 |
| Higher Hyde | 74.71 | rural | Purbeck | 1 | 1 |
| Holt Heath | 435.32 | rural | E. of Poole | 2 | 1 |
| Holton Heath | 83.46 | rural | Purbeck | 1 | 1 |
| Hurn | 101.95 | rural | E. of Poole | 2 | 1 |
| Leybrook Common - Avon Heath | 6.76 | rural | E. of Poole | 1 | 2 |
| Lions Hill | 52.48 | urban | E. of Poole | 1 | 1 |
| Merritown | 57.31 | rural | E. of Poole | 1 | 1 |
| Morden Bog | 65.91 | rural | Purbeck | 1 | 1 |
| Noon Hill | 4.22 | urban | E. of Poole | 1 | 2 |
| Parley Common | 145.25 | urban | E. of Poole | 2 | 1 |
| Grange | 58.35 | rural | Purbeck | 1 | 1 |
| Sandford Heath | 39.8 | rural | Purbeck | 1 | 1 |
| Sopely/Ramsdown | 50.92 | rural | E. of Poole | 1 | 1 |
| Stephen's Castle | 21.13 | urban | E. of Poole | 1 | 2 |
| Stoborough Heath NE | 108.65 | rural | Purbeck | 2 | 1 |
| Stoborough RSPB | 129.82 | rural | Purbeck | 2 | 1 |
| Stoke Heath | 23.84 | rural | Purbeck | 1 | 2 |

| Site | Area | Urban/rural | Area | Big | Small |
|---|---|---|---|---|---|
| Stokeford Heath | 24.91 | rural | Purbeck | 1 | 2 |
| Tadnoll/Winfrith Heath | 151.19 | rural | Purbeck | 2 | 1 |
| Talbot Heath | 34.01 | urban | Poole | 1 | 1 |
| Town Common/St Catherines Hill | 172.04 | rural | E. of Poole | 2 | 1 |
| Trigon | 92.25 | rural | Purbeck | 1 | 1 |
| Turbary Common | 38.78 | urban | Poole | 1 | 1 |
| Turners Puddle Heath | 30.32 | rural | Purbeck | 1 | 1 |
| Upton Heath | 197.88 | urban | Poole | 2 | 1 |
| West Moors | 153.42 | rural | E. of Poole | 2 | 1 |
| Whitesheet | 76.86 | rural | E. of Poole | 1 | 1 |