Report

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The impacts for stone curlews of increased traffic on the A11.

Model and predictions

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1 Introduction

1.1 This report sets out the results of analyses, conducted for Jacobs Ltd., acting for the Highways Agency. The aim of the work is to determine the likely impacts of increased levels of road traffic on the A11 on the numbers of stone curlews occurring in areas alongside the road, which crosses the Breckland Special Protection Area (SPA).

1.2 Breckland SPA qualifies under Article 4.1 of the Birds Directive (79/409/EEC) by supporting populations of European importance of nightjar, woodlark and stone curlew. Stone curlews are summer migrants, associated with open, bare habitats, such as some heaths, downland and some arable. In 1998 (the year given in the SPA citation), the Breckland SPA supported some 142 pairs of stone curlew, some 75% of the UK population.

1.3 Previous work has shown an avoidance of roads by stone curlews (in particular see Day, 2003). Following concern about the likely significant effects of future development in Breckland, Breckland Council commissioned Footprint Ecology to undertake analysis on the impact of housing and roads on stone curlews. This work (Sharp et al., 2008) used stone curlew data provided by the RSPB. The data involved the spatial distribution (point data in GIS) of stone curlew nests, and contained data for all years from 1988 – 2006 (with the exception of 2001 when fieldwork was limited due to Foot & Mouth).

1.4 Sharp et al looked across a study area that encompassed the whole of the Brecks, with the study area defined by soil data. The focus of the analysis was on arable land, as this habitat was believed to be more consistent across years and in space. Stone curlews also occur on semi-natural habitats, the grass heaths characteristic of the region. The use of such sites by stone curlew is very much dependent on the level of grazing and other management factors, which can vary in time and space. The team used data on housing (derived from OS data in GIS and details from planning applications) to identify the year on year number and distribution of buildings within the entire Breckland Study area, and the distribution of roads was also extracted from the GIS. Road traffic data was provided through the Highways Agency.

1.5 The analysis found a significant avoidance of both buildings and roads by stone curlews, with reduced densities of stone curlews at closer distances to roads and housing. This work, for Breckland Council, was specifically to inform the emerging core strategy, and the focus was therefore very much on buildings and housing. A statistical model was developed and used to predict the impacts of new housing and increased traffic. This model was based on 500m grid cells, and for each grid cell used parameters relating to the area of buildings (calculated from a grid of 50m cells), the amount of road traffic on trunk roads and the presence of non-trunk A roads surrounding each 500m cell. The housing and road variable values for each 500m cell were calculated as weighted sums of the nearby housing or road or traffic density where the weightings with distance were based on half-normal distributions. Different weightings (i.e. different standard deviations (SD) ranging from 250m to 2000m) were tested, and the best fitting model included weighted normal kernel variables for the housing (square root, $\sqrt{X_{H1000}}$) with SD=1000m, daily trunk road traffic with SD=1000m (X_{T1000}) and presence of A-roads with SD=250m (X_{AR250}).

1.6 The original model was used to make specific predictions relating to new housing in the region of Thetford. No predictions were made to determine the impact of increased road traffic alone and therefore the original modelling is of little use in determining the consequences, for the SPA, of increased road traffic alone. This report therefore builds on the previous work and uses the previous model to make predictions for increased traffic, with and without new housing. New housing that we use in the predictions (for arable habitats only) are the same as used in the previous work (Sharp et al 2008), and are used purely for consistency and indicative purposes. Better data on traffic levels has become available[1] (Table 1), and is therefore incorporated into a revised model.

1.7 We also address semi-natural grassland, by simply treating the semi-natural grassland as though the avoidance by stone curlews was the same as that for arable land. It was therefore necessary to determine the amount of housing and to apply the traffic variables to 500m cells containing semi-natural grassland. The average number of stone curlews in each 500m cell containing semi-natural grassland was determined for the period 2002-2006, and the model therefore used to predict the impact of a housing/road scenario on stone curlews in semi-natural grassland.

1.8 The model was run to test a two-way traffic increase on the A11 of 64% over 2009 levels, a figure provided by Jacobs / Highways Agency.

[1] We use data provided by R. Green which supplements the raw data by deriving estimates for sections of roads where data are not available.

Table 1 Average daily traffic flows (May-August) on sections of Trunk and other A-roads in the region over the period 1988-2009

Year	A1088 Ixworth	A134 (N) Stoke Ferry Bypass	A1065 Eriswell	A1101 Hengrave	A134 (S) North of Barnham
1988	3652	6641	10920	5433	8043
1989	3665	6696	11062	5370	8264
1990	3682	6625	11705	5316	8479
1991	3721	6735	11446	5258	8325
1992	3339	6993	11799	5208	9187
1993	3752	7056	11997	5162	9331
1994	3782	7122	11907	5328	9262
1995	3815	7217	12361	5082	9509
1996	3854	7151	12791	4975	9597
1997	3940	7389	12682	5018	9748
1998	3941	7196	12788	4936	9887
1999	3948	7238	12953	4968	10014
2000	4044	7501	13067	4861	10128
2001	3951	6521	13173	4934	10229
2002	4165	7303	13396	4865	10315
2003	4260	7459	13299	4980	10134
2004	4323	7532	13461	4961	10382
2005	4419	7624	13196	4951	10559
2006	4444	7675	13418	4911	10518
2007	4543	7879	13557	4961	10445
2008	4602	7604	13497	4797	10500
2009	4750	7803	13536	4912	10599

Year	A1066 Garboldisham	A1075 North Watton / Ovington	A1065 Hilborough	A11 both sites	A14 both sites
1988	3638	5785	5015	12458	26758
1989	3744	5718	5192	13416	27881
1990	3841	5655	5812	14566	28981
1991	4175	5598	5756	15006	30049
1992	4258	5545	5445	16337	31080
1993	4103	5496	5656	17862	32068
1994	4214	5451	5981	18892	33005
1995	4316	5411	6111	20115	33886
1996	4252	5375	6209	20815	34705
1997	4325	5343	6552	22663	35456
1998	4339	5314	6473	22190	36134
1999	4409	5290	6566	23603	35442
2000	4447	5269	6648	24005	34441
2001	4382	5234	6535	23589	36070
2002	4430	5251	6768	24652	36191
2003	4619	5323	7036	26269	36185
2004	4483	5659	6935	27287	37404
2005	4473	5812	6908	28183	36339
2006	4266	5886	6741	27982	36368
2007	4248	5328	6736	28988	36663
2008	4162	5159	6434	28404	35789
2009	4256	5128	6769	29337	37822

2 Revision of original model to incorporate new data

2.1 In Sharp et al (2008), the best predictive Generalised Linear Model (GLM) for stone curlew nest density on suitable arable land within each 500m cell involved the weighted normal kernel variables for the housing (square root, $\sqrt{X_{H1000}}$) with SD=1000m, daily Trunk road traffic with SD=1000m (X_{T1000}) and presence of A-roads with SD=250m (X_{AR250}).

2.2 The estimates of Sharp et al (2008) best fit model's parameters and their standard errors (SE, given in brackets) are repeated here as:

Model Equation E1:

$$\log_e N_{iy} = \log_e A_i + \alpha_y - \underset{(0.00127)}{0.01002} \sqrt{X_{H1000iy}} - \underset{(0.0000001089)}{0.0000008232} X_{T1000i} - \underset{(0.00589)}{0.01335} X_{AR250i}$$

where

N_{iy} = number of nests in 500m cell *i* in year in year *y* (*y* = 1988,..., 2006)
A_i = area (in hectares) of arable land on suitable soil type in cell *i*
$X_{H1000iy}$ = value of the housing variable for cell *i* in year *y*
X_{T1000i} = value of the trunk road traffic variable for cell *i*
X_{Ri} = value of the road/traffic variable for cell *i*
α_y = factor representing average nest density in year y

and where, for example, for the last study year (y=2006), α_y = -3.596.

2.3 Model equation E1 was based on the best GLM fit (with Poisson error distribution) to the whole data set covering the period 1988-2006, relating observed nests numbers in each cell in each year to the year-specific values of the housing and road traffic variables. Very similar predictions to those from E1 were obtained from a model (M1 in Sharp et al 2008) relating total nest numbers over the period 1988-2006 to average housing density for the period and the same road data.

2.4 The previously available trunk road traffic data was merely an average over the period 2002-06. For our 2009 analyses, the traffic data has been updated with new March to August inclusive average daily two-way traffic flows for sections of the A11, A14 and other non-trunk A roads in the study region for each year from 1998 onwards (Table 1).

2.5 In order to be able to make predictions of the potential impact of a scenario of a specified increase in traffic on the A11 within the study region, the 2008 model was re-calibrated using the new trunk road traffic data (i.e. the sum of the A11 and A14 traffic). This gave the following Generalised Linear Model (GLM) fit:

Model Equation E2:

$$\log_e N_{iy} = \log_e A_i + \alpha_y - 0.01011 \sqrt{X_{H1000iy}} - 0.0000008710\, X_{T1000iy} - 0.01342\, X_{AR250i}$$

where, for the most recent study period of 2002-06, α_{2002} = -4.092, α_{2003} = -4.021, α_{2004} = -3.814, α_{2005} = -3.718, α_{2006} = -3.573; with an average of $\alpha_{2002\text{-}06}$ = -3.844 which can be used in equation E2 to predict the average nest density during 2002-06 on arable land within any cell.

2.6 This is very similar to the previous Sharp et al (2008) model equation E1 above.

2.7 The effect on model parameters, their standard errors and statistical significance, of potential lack of statistical independence of the nest observations in different years at the same 500m cell was assessed. Specifically, the optimum model was re-fitted using each of a range of assumed inter-year error correlation structures using the Generalised Estimating Equations (GEE) procedure in the SPSS statistics package, treating 500m cells as ‘subjects’ and years as a repeated measures (within-subject) factor. The fits of the assumed model error structures were compared using the quasi-likelihood information criteria (QIC, lower is better fit).

2.8 On assuming a first-order auto-regressive correlation structure between years, the average correlation between model residuals for nest density in successive years at the same 500m cell was only 0.23. Based on minimising QIC, the best fitting model was one assuming independent observations between years within each 500m cell. This is not particularly surprising given the high annual turnover and change in which 500m cells have any nests that was found by Sharp et al (2008).

3 Predictions relating to trunk road traffic and housing

3.1 The above best predictive model equation can be used to obtain predictions of nest densities on suitable arable land within each of the 2142 500m grid cells in the study region. This was done for the latest study period of 2002-06 using the average levels and spatial distribution of housing in the same 2002-06 period in each 50m grid cell and hence using the values of the housing variable for 2002-06 based on a SD of 1000m. It also used the average 2002-06 data for Traffic flows as the best estimate of 'current' flows.

3.2 The predictions can then be re-run by adding in any scenario for additional traffic in the study area. The proposed additional traffic on the A11 will increase the traffic values for the 50m grid cells through which it passes, which will lead to increases in the trunk road (A11+A14) traffic variable values for some 500m cells, which will lead to decreases in the predicted stone curlew nest number and density in those 500m cells.

3.3 The predictions can also be re-run by adding in any proposed additional housing in the study area. The additional housing will increase the area of houses/buildings in some 50m grid cells, which will lead to increases in the housing variable values for some 500m cells, which will lead to decreases in the predicted stone curlew nest number and density in those 500m cells.

3.4 By summing the predicted number of nests on suitable arable land across all 500m cells in the study region based on both current and future traffic (and housing) levels, the proportional reduction in predicted total nests can be used to estimate the potential impact of the proposed increases in traffic (and housing) on stone curlew nesting numbers.

3.5 For this report, we have been requested to make predictions of the potential effect of a 64% increase in two-way traffic on the A11 in the study region above current 2009 levels. The March-August average daily traffic flows on the A11 were 29337 in 2009, which is 9.2% higher than the average 26875 flows over 2002-06. Therefore predictions were made for the effect of a 70% (64% x 1.092) increase in A11 traffic relative to the average 2002-06 traffic levels, combined with:

either	average 2002-06 housing distribution and density,
or allowing for	(a) Thetford North housing extension
	(b) Thetford South housing extension
	(c) Thetford North and South housing extensions

a, b and c allow direct comparisons with the previous predictions.

3.6 Based purely on model E2 predictions for current (2002-06 average) and future total nest numbers on arable land, the 70% increase in A11 traffic is predicted to lead to a 3.4% reduction in nest numbers on suitable arable land Table 2(i).

3.7 For each 500m cell (k) the ratio $R_K = P_{K1} / P_{K0}$ of predicted nest number under increased traffic (P_{K1}) to model predictions of current nest number (P_{K0}) provides an estimate of the expected proportional reduction in nests for each cell; R_K will be lower for cells near high densities of housing and/or high traffic levels.

3.8 To make a prediction of the effect of increased traffic on the actual recent stone curlew nest distribution, we multiplied the predicted cell-specific proportional reduction R_K by the observed 2002-06 average nest numbers (M_{K0}) in the cell and summed across all cells. This second prediction method suggested the effect of 70% more traffic on the A11 would reduce nest numbers (from a 2002-06 average annual total of 150.4) by 3.6%, trivially more than the previous estimate Table 2(ii).

Table 2: Predictions from model equation E2 of Scenarios for 70% increases in A11 traffic and/or housing developments on changes to Stone curlew numbers on suitable arable land starting from (i) predicted and (ii) observed average stone curlew numbers over the recent period 2002-06.

A11 Traffic increase	Housing levels			
	Current	(a) + Thetford North	(b) + Thetford South	(c) + Thetford N&S
(I) Starting from model predictions for 2002-06 average nest number				
Current Traffic	147.2	146.7 (0.3%)	147.0 (0.2%)	146.5 (0.5%)
70% traffic increase	142.2 (3.4%)	142.0 (3.6%)	142.0 (3.6%)	141.7 (3.7%)
(II) Starting from observed stone curlew nest average (2002-06) distribution data				
Current Traffic	150.4	150.4 (0.0%)	148.6 (1.2%)	148.6 (1.2%)
70% traffic increase	145.0 (3.6%)	145.0 (3.6%)	143.2 (4.8%)	143.2 (4.8%)

3.9 Equivalent models to equations E1-E2 were not developed by Sharp et al (2008) for stone curlews on semi-natural grassland because it was considered that the quality of semi-natural grassland for nesting stone curlew habitat was too variable in space and time for the observed nest distribution to be adequately predicted by the extent of nearby housing and/or roads and traffic.

3.10 However, it may be reasonable to assume that the model E2 predictions of proportional impact (R_K) of increase traffic on nest density, developed for arable land, would apply to stone curlews on semi-natural grassland. Therefore we applied model equation E2, with current housing levels and either current or 70% increased A11 traffic, to derive a value of R_K for each cell with semi-natural grassland, multiplied this by the actual (2002-06 average) observed nest density in the cell and summed across all 500m cells with some semi-natural grassland.

3.11 Over the period 2002-06, there were, on average, 71 stone curlews nests on semi-natural grassland within the region; a 70% increase in A11 traffic was predicted to reduce this to an average annual total of 65.9 nests, a reduction of 7.1%.

3.12 Useful though they can be, one should always be wary of all models and any perceived precision of their predictions. As one check on the form of the relationship between nest density, housing and trunk road traffic suggested by model equation E2, the values of the two main predictor variables, X_{H1000} for housing and X_{T1000} for trunk road traffic were classified into four or five classes to give roughly equal numbers of observations in each (non-zero-valued) class. Table 3 shows the mean observed stone curlew nest density (per km^2) over the period 2002-06 on arable land in cells classified by their values of X_{H1000} and X_{T1000}.

3.13 In the absence of any nearby trunk road traffic (i.e. $X_{T1000} = 0$) and with only the lowest levels of nearby housing (i.e. $X_{H1000} < 7000$), average stone curlew nest density over the period 2002-06 was 1.200 per km^2 (n=284 cells). It can be seen from the marginal 'overall' row and column that average nest density declines with the level of 'nearby' housing and with the level of 'nearby' trunk road traffic.

3.14 In suitable arable areas not near any trunk road traffic, average nest density declines consistently with increasing housing from 1.200 per km^2 down 84% to 0.194 per km^2.

Table 3: Average observed stone curlew nest density per 500m cell classified by the weighted normal kernel variables (both using SD=1000m) for housing (average 2002-06) and combined A11+A14 average (2002-06) traffic; nest densities (per km^2) are average 2002-06 observed densities weighted by area of suitable arable land per 500m cell (number of cells involved given in brackets).

		Average combined traffic (A11 + A14)				**Overall**
		0	1-470000	470001-1700000	1700000-5100000	
Housing	0-7000	1.200 (284)	0.940 (52)	0.865 (58)	0.198 (43)	1.006 (437)
	7001-13000	0.865 (344)	0.182 (37)	0.288 (25)	0.000 (31)	0.716 (437)
	13001-22000	0.542 (333)	0.254 (26)	0.217 (27)	0.083 (20)	0.482 (406)
	22001-44000	0.225 (312)	0.237 (46)	0.178 (40)	0.000 (38)	0.204 (436)
	44001-50000	0.194 (209)	0.318 (40)	0.073 (50)	0.000 (67)	0.157 (426)
	Overall	0.615 (1542)	0.462 (201)	0.379 (200)	0.055 (199)	0.529 (2142)

3.15 More importantly in the current context of expected increasing trunk road traffic, in areas near only low levels of housing (i.e. (i.e. $X_{H1000} < 7000$), increases in 'nearby' trunk road traffic are associated with consistent but moderate decreases in nest density but with a sharp fall in nest density in areas with the highest current levels of 'nearby' trunk road traffic.

3.16 Nest density is consistently very low or zero in the areas of the highest levels of nearby trunk road traffic regardless of the level of nearby housing (Table 3).

3.17 Interestingly, moderate levels of the trunk road traffic variable (i.e. X_{T1000} = 1-470000) have variable effects on nest density depending on the level of nearby housing. These not completely consistent patterns may be a result of the geographic spread and clumping of the different combinations of levels of nearby housing and nearby trunk road traffic.

3.18 This merits more detailed spatial analysis of the raw data and residual patterns beyond the scope of this very time-constrained analysis and reporting.

4 Additional modelling of recent data over the period 2002-06

4.1 In addition to variables representing the density of nearby housing and the nearby trunk-road traffic levels, the best fitting model of Sharp et al (2008) involved a kernel density variable (with SD=250m) representing the extent of nearby non-trunk A-roads.

4.2 As a follow-up investigation of the strength of any association of traffic levels on all non-trunk A-roads with stone curlew nest density, we restricted our analysis to those 1542 cells with suitable arable land which were not ‘near’ either the All or A14 (i.e. where integer value of X_{T1000} = 0) and assessed the pattern of average nest density for the these cells classified by both the ‘nearby’ housing density (variable X_{H1000}) and the level of ‘nearby’ non-trunk road traffic defined by a range of kernel density SD from 250m up to 2000m (Table 4).

Table 4: Average 2002-06 stone curlew nest density (per km^2 arable land) in cells classified by the weighted normal kernel variables for average 2002-06 housing (SD=1000m) and average 2002-06 non-trunk road traffic for (a) SD=250m and (b) SD=500m; number of cells involved given in brackets.

(a)		Non-trunk road traffic variable (SD=250m)			**Overall**
		0	1-100000	100001-520000	
Housing	0-7000	1.204 (255)	1.436 (13)	1.036 (16)	1.200 (284)
	7001-13000	0.818 (291)	1.322 (29)	0.903 (24)	0.865 (344)
	13001-22000	0.640 (257)	0.101 (38)	0.199 (38)	0.542 (333)
	22001-44000	0.111 (221)	0.851 (45)	0.250 (46)	0.225 (312)
	44001-50000	0.202 (185)	0.467 (32)	0.029 (52)	0.194 (269)
	Overall	0.636 (1209)	0.757 (157)	0.363 (176)	0.615 (1542)

(b)		Non-trunk road traffic variable (SD=500m)			**Overall**
		0	1-200000	200001-1100000	
Housing	0-7000	1.145 (229)	1.657 (31)	1.235 (24)	1.200 (284)
	7001-13000	0.764 (231)	1.177 (80)	0.918 (33)	0.865 (344)
	13001-22000	0.636 (211)	0.467 (70)	0.188 (52)	0.542 (333)
	22001-44000	0.130 (179)	0.432 (61)	0.346 (72)	0.225 (312)
	44001-50000	0.222 (152)	0.111 (48)	0.182 (69)	0.194 (269)
	Overall	0.623 (1002)	0.738 (290)	0.457 (250)	0.615 (1542)

4.3 Amongst cells not ‘near’ either the A11 or A14, although the nest decreases markedly with the level of nearby housing, within each level of housing, average nest density is often highest in cells with intermediate levels of the non-trunk road traffic variables whether based a kernel density SD of 250m or 500m. However, for a SD of 250m, the lowest average nest density usually occurred at the highest levels on the non-trunk road traffic variable (Table 4).

4.4 GLM models (with Poisson error distribution) relating total nest numbers per 500m cell (i) over the period 2002-06 to average housing and road traffic data over the same period were refitted. These models no longer have a separate term for each year and avoid any problems of temporal auto-correlation. The standard errors (SE) and test probabilities p for the partial regression coefficients were adjusted for model mean residual deviance to allow for over-dispersion.

4.5 In models with terms for housing (SD=1000) and trunk traffic (SD=1000m) akin to model E2, the additional term for the effect of being 'near' non-trunk A-roads (SD=250m) was no longer statistically significant (test $p = 0.174$). When the variable representing the presence of 'nearby' non-trunk A-roads was replaced by a variable representing the extent of 'nearby' non-trunk A-roads traffic (SD=250m) using the newly supplied data, the term was also not statistically significant ($p = 0.312$).

4.6 Our analyses (Table 4 and GLMs for 2002-06) suggest that any effect of current levels of non-trunk A-road traffic on nest density is negligible and inconsistent and, if present, may only occur at the highest recorded levels of traffic within 200-300m of the potential nesting area

4.7 The best fitting Poisson GLM that we obtained for total nest densities (N_{Si}) over 2002-06 for each nest i involved average housing (SD=1000m, X_{H1000i}) and average A11+A14 trunk road traffic (SD=1000m, X_{T1000i}) for each cell over the same period, as given by (mean deviance adjusted SE given in brackets):

Model Equation E3:

$$\log_e N_{Si} = \log_e A_i - 2.225 \; - 0.01029 \sqrt{X_{H1000i}} \; - 0.0000008948 \, X_{T1000i}$$

$$(0.146) \quad (0.00125) \qquad (0.0000001878)$$

4.8 Both the housing and trunk road traffic terms in model E3 are highly statistically significant (both $p < 0.001$). This is further support to suggest a real association between current trunk road traffic and stone curlew nest density, even after allowing for the association between nest and housing density distribution.

4.9 The predictions using model equation E3 for the potential effect of 70% increases in A11 traffic and/or housing developments on changes to average 2002-06 stone curlew numbers on suitable arable land are given in Table 5.

4.10 The predictions of percentage reductions in nest numbers from equation E3 are almost identical to those derived from model equation E2 (as given in Table 2). This is not surprising because we have shown that the last term in E2 for the effect of being near non-trunk A roads and their traffic is not statistically significant once based on just recent average data (i.e. no replication over time).

Table 5: Predictions from model equation E3 of Scenarios for 70% increases in A11 traffic and/or housing developments on changes to Stone curlew numbers on suitable arable land starting from (i) predicted and (ii) observed average stone curlew numbers over the recent period 2002-06.

A11 Traffic increase	**Housing levels**			
	Current	**(a)** **+ Thetford North**	**(b)** **+ Thetford South**	**(c)** **+ Thetford N&S**
(I) Starting from model predictions for 2002-06 average nest number				
Current Traffic	145.4	144.9 (0.3%)	145.2 (0.2%)	144.7 (0.5%)
70% traffic increase	140.5 (3.4%)	140.2 (3.6%)	140.3 (3.5%)	140.0 (3.7%)
(II) Starting from observed stone curlew nest average (2002-06) distribution data				
Current Traffic	150.4	150.4 (0.0%)	148.6 (1.2%)	148.6 (1.2%)
70% traffic increase	144.9 (3.7%)	144.9 (3.7%)	143.1 (4.9%)	143.1 (4.9%)

4.11 Applying model E3 to semi-natural habitats results in a predicted percentage reduction in the number of stone curlew nests of 7.3% following a 70% increase in A11 traffic.

4.12 As a check on the practical fit of our model E3 to the observed stone curlew nest distribution in relation to distance from the All, all of the 2142 500m cells with some suitable arable land were classified according the distance from the cell centre to the A11, using 500m distance classes up to 3000m, 3001-5000m and greater than 5000m.

4.13 Figure 1 shows the observed average nest density over the period 2002-06 for the arable area in each distance class. Also shown is the predicted average nest density in each class over the same period based on model equation E3 using current (average 2002-06) housing levels and either current traffic levels or using 70% higher A11 traffic levels. It can be seen that the predictions agree fairly closely with the observed pattern of increasing nest density with increasing distance from the A11 (up to at least 2km). The slight fall in average predicted nest density for areas greater than 2.5km from the All must be due to these areas have relatively higher levels of nearby housing (and maybe influence from A14 traffic), which equation E3 predicts will reduce nest density.

4.14 These predictive relationships are based on a best-fit to the road traffic data based on a weighted kernel density variable of nearby housing and nearby trunk road traffic, both using a standard deviation (SD) of 1000m, which is why the predicted influences of the A11 trunk road extend up to about 2000m (i.e. two SD) – see Sharp et al (2008) for further details of kernel density estimators.

4.15 Figure 1 also shows how a 70% increase in traffic on the A11 during the stone curlew breeding season(Mar-Aug) is predicted to further reduce nest density in arable areas up to 2km from the A11 road.

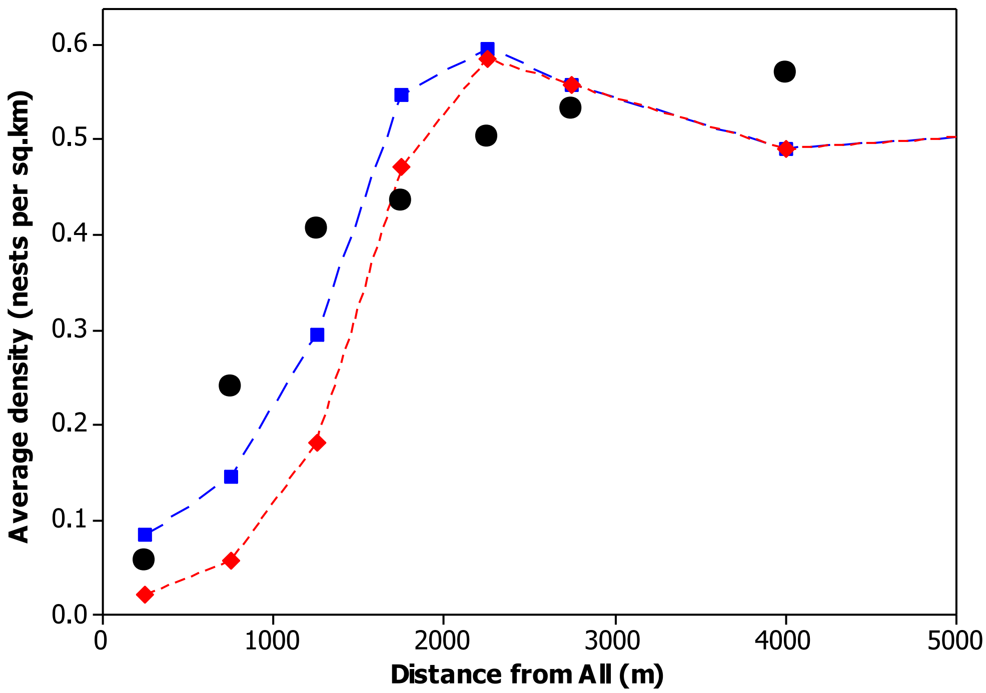

Figure 1 Observed (solid circle) and predicted average stone curlew nest density (per km2) over the period 2002-06 on arable land in 500m cells classified by cell centre distance to the A11. Predictions based on model equation E3 using current housing levels and either current traffic (blue) or with a 70% increase in A11 (Mar-Aug) traffic (red).

4.16 Potential confounding effect of nearby housing on apparent effect of nearby road traffic: In regression modelling, if two predictor variables (X1 and X2, here roads and housing) are positively correlated (i.e. when X1 is high X2 also tends to be high and thus part of their explanatory power is shared) then in regressions involving only one of them, say X1, the estimated regression coefficient for X1 is 'trying' to represent the combined effect of both variables and thus tends to over-estimate the true size of the effect of X1.

4.17 This is why our approach and equations E1-E3 was based on simultaneously modelling the joint effect of nearby housing and road traffic.

4.18 However, across all suitable arable land in the Breckland study region (our 2142 500m cells), there was no overall Pearson correlation between the values of our housing kernel variables and any of the Trunk road (A11+A14) traffic kernel variables (e.g. for the two variables used in our model E3, correlation between $\sqrt{X_{H1000i}}$ and X_{T1000i} is only 0.047). Furthermore, If we restrict analysis to only those squares for which the value of the kernel variable for A11 traffic with SD=1000 (denoted $X_{A11.1000}$) is greater than one (i.e. only squares 'near' the A11), then there is no correlation (*r* = -0.005) between $\sqrt{X_{H1000i}}$ and $X_{A11.1000}$.

4.19 Thus across areas ‘near the A11' over the whole, there is no confounding correlation between level of nearby housing and our measure of level of nearby A11 traffic (i.e. $X_{A11.1000}$). Also across the region as a whole there is no overall correlation amongst 500m cells with arable land in their levels of nearby housing and trunk road traffic.

5 Summary

5.1 Stone curlew nest density in the study region was shown to be negatively related to 'nearby' housing density and 'nearby' trunk road traffic (based on new traffic data for the period 1988-2006). However, no statistically significant additional relationship with non-trunk A-road traffic could be detected.

5.2 We recommend using the predictions in Table 5 as the best currently available estimates of the potential effect of a 70% increase in A11 average daily (March-August) two-way traffic above the average All traffic levels in 2002-06.

5.3 The predicted effect of a 70% increase in A11 traffic is for a reduction from current observed nest numbers on suitable arable land of 3.7% with no changes in housing density or 4.9% when combined with the predicted effect of housing options.

5.4 A reduction of 7.3% is predicted for semi-natural grassland habitats. Taking both semi-natural and grassland habitats together, the observed total average nest numbers for the period 2002-2006 was 221.4, and the prediction following a 70% increase in traffic on the A11 is 210.8, a reduction of 4.8% (Table 6).

Table 6: Summary of predictions of stone curlew nest numbers following a 70% increase in traffic on the A11.

	Semi-Natural	Arable	Both habitats combined
2002-2006 average number of nests	71.0	150.4	221.4
Predicted no. of nests following 70% traffic increase	65.9	144.9	210.8
% reduction	7.3	3.7	4.8

5.5 Further detailed data analyses are still needed to:

(i) Assess any implications of spatial auto-correlation in the housing, road and nest data.

(ii) Assess hypothesis that there may be more woodland near major roads and traffic which could cause, or at least partly explain, the observed negative associations between nest density and trunk road traffic (and housing distribution).

6 References

Day, T. C. F. (2003) The effects of disturbance from roads on stone curlews in southern England., pp. 228. Darwin College, University of Cambridge, Cambridge.

Sharp, J., Clarke, R. T., Liley, D. & Green, R. E. (2008) The effect of housing development and roads on the distribution of stone curlews in the Brecks. Footprint Ecology.