

Rare and declining bird species benefit most from designating protected areas for conservation in the UK

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Supplementary Table 1 Percentage of bird species influenced by extent of protected area, dividing species into those with significant and non-significant (in parentheses) positive and negative correlations between population measures and area of designation. The χ^2 and P values relate to a two-sided test of proportion, testing the difference in proportion of species with significantly positive or negative correlations with area of designation. Significant results (P < 0.05) are shown in bold.

	All Protected Areas					SSSI					SPA					SAC				
	+	(+)	(-)	-	χ^2 , P	+	(+)	(-)	-	χ^2 , P	+	(+)	(-)	-	χ^2 , P	+	(+)	(-)	-	χ^2 , P
Occurrence (n=179)	47.7	16.9	14.5	21.0	17.16, <0.001	48.8	17.8	11.3	22.0	16.27, <0.001	40.9	13.0	16.6	29.6	2.72, 0.099	27.6	21.8	24.7	25.9	0.04, 0.834
Colonisation (n=165)	24.7	26.5	22.3	26.5	0.05, 0.830	25.2	28.8	20.6	25.3	>0.01, 1	22.4	25.4	26.0	26.0	0.3, 0.581	11.1	30.4	31.0	27.5	11.05, 0.001
Persistence (n=130)	30.4	31.3	18.0	20.3	2.22, 0.137	28.9	32.0	20.3	18.8	2.36, 0.124	18.6	41.1	23.2	17.1	0.02, 0.883	20.0	34.6	30.0	15.4	0.54, 0.461
Abundance (n=133)	48.1	18.0	8.3	25.6	8.58, 0.003	48.1	19.6	7.5	24.8	9.28, 0.002	39.1	21.8	14.3	24.8	3.81, 0.051	36.8	18.0	21.0	24.1	3.16, 0.075
Abundance Trend (n=133)	20.3	27.8	29.3	22.5	0.07, 0.791	20.3	27.8	29.3	22.6	0.07, 0.791	21.8	36.8	29.3	12.0	3.2, 0.074	21.0	21.8	30.8	26.3	0.57, 0.450
Productivity (n=22)	9.9	22.7	22.7	45.5	4.08, 0.043	9.9	22.7	22.7	45.5	4.08, 0.043	13.6	45.5	18.1	22.7	1.26, 0.724	9.8	27.2	22.7	40.9	2.27, 0.070
Productivity Trend (n=22)	13.6	31.8	22.7	31.8	0.9, 0.343	13.6	27.3	27.3	31.8	0.9, 0.34	13.6	27.3	22.7	36.4	1.45, 0.228	18.1	31.8	18.2	31.8	0.36, 0.547

Supplementary Table 2 Mean association between demographic characteristics of individual species and protected area extent within the survey square ($\pm$ standard error), and (final column) the results of the two-sided t-test comparing the mean of SPA with SAC. P values are shown after each statistic and significant results ($P < 0.05$) are shown in bold.

	N Spp	All PA	SSSI	SPA	SAC	SPA vs SAC
Occurrence	179	0.49 ± 0.07, >0.001	0.48 ± 0.07, >0.001	0.31 ± 0.07, >0.001	0.13 ± 0.06, 0.032	$t = 3.5$, >0.001
Colonisations	165	0.27 ± 0.08, 0.001	0.29 ± 0.08, 0.001	0.15 ± 0.08 , 0.073	-0.05 ± 0.08 , 0.566	$t = 3.6$, >0.001
Persistence	130	0.23 ± 0.09, 0.012	0.26 ± 0.1, 0.008	0.15 ± 0.11 , 0.183	0.12 ± 0.09 , 0.198	$t = 1.7$, 0.085
Abundance	133	0.25 ± 0.05, >0.001	0.26 ± 0.05, >0.001	0.19 ± 0.05, 0.001	0.12 ± 0.05, 0.023	$t = 1.7$, 0.098
Abundance trend	133	0.01 ± 0.04 , 0.76	0.02 ± 0.04 , 0.722	0.09 ± 0.05 , 0.075	-0.03 ± 0.06 , 0.682	$t = 2.3$, 0.022
Productivity	22	-0.18 ± 0.07, 0.022	-0.18 ± 0.07, 0.018	-0.11 ± 0.08 , 0.211	-0.25 ± 0.12 , 0.054	$t = -1.0$, 0.319
Productivity trend	22	-0.07 ± 0.07 , 0.294	-0.07 ± 0.07 , 0.308	-0.06 ± 0.1 , 0.549	0.21 ± 0.19 , 0.269	$t = 1.5$, 0.142

Supplementary Table 3. Mean association between the relationship of demographic parameters to PA extent and that of productivity to PA extent for 22 species. The final row compares the association of PA and abundance trend with that of trend in productivity and PA extent. Slope coefficient parameters $\pm$ standard errors from a GLM are shown, and two-sided P values are shown after each value. Significant results ($P < 0.05$) are shown in bold.

Parameter	All PA	SSSI	SPA	SAC
Occupancy	$0.59 \pm 0.44, 0.188$	$0.59 \pm 0.47, 0.222$	$0.57 \pm 0.30, 0.07$	$-0.21 \pm 0.18, 0.267$
Colonisations	$0.61 \pm 0.47, 0.206$	$0.57 \pm 0.51, 0.264$	$0.57 \pm 0.30, 0.075$	$-0.286 \pm 0.2, 0.168$
Persistence	$0.73 \pm 0.45, 0.123$	$0.75 \pm 0.47, 0.131$	$0.46 \pm 0.29, 0.129$	$-0.327 \pm 0.26, 0.227$
Abundance	$0.55 \pm 0.42, 0.207$	$0.57 \pm 0.43, 0.203$	$0.61 \pm 0.26, 0.03$	$-0.40 \pm 0.18, 0.038$
Abundance Trend	$-0.38 \pm 0.19, 0.056$	$-0.39 \pm 0.19, 0.054$	$-0.43 \pm 0.29, 0.065$	$0.12 \pm 0.15, 0.429$
Abundance Trend (vs Trend)	$0.34 \pm 0.21, 0.12$	$0.36 \pm 0.21, 0.101$	$0.40 \pm 0.18, 0.038$	$0.05 \pm 0.10, 0.624$

Supplementary Table 4 Model estimates of the relationship between extent of designated protected area and species population metrics. Estimates are quoted as mean and 95% CI's, significant relationships are in bold.

	All PA	SSSI	SPA	SAC
Occurrence				
Log Mass	-0.213 (-0.527, 0.11)	-0.217 (-0.499, 0.091)	-0.081 (-0.444, 0.237)	-0.326 (-0.534, -0.097)
Log Pop Size	-1.069 (-1.322, -0.804)	-1.009 (-1.274, -0.707)	-0.946 (-1.233, -0.702)	-0.726 (-0.978, -0.498)
Log Pop Change	-0.23 (-0.442, -0.027)	-0.252 (-0.465, -0.029)	-0.223 (-0.425, -0.022)	-0.093 (-0.276, 0.116)
SSI	0.487 (0.252, 0.771)	0.480 (0.185, 0.730)	0.420 (0.159, 0.660)	0.253 (-0.006, 0.455)
STI	0.368 (0.094, 0.627)	0.366 (0.105, 0.670)	0.249 (-0.024, 0.509)	-0.062 (-0.283, 0.181)
Wetland	0.575 (0.083, 1.021)	0.585 (0.161, 0.989)	0.352 (-0.214, 0.856)	0.178 (-0.111, 0.464)
Upland	0.235 (-0.181, 0.686)	0.291 (-0.009, 0.668)	0.155 (-0.368, 0.657)	0.133 (-0.095, 0.358)
Coastal	0.457 (-0.074, 0.945)	0.522 (0.090, 0.918)	0.321 (-0.282, 0.857)	-0.065 (-0.382, 0.237)
Farmland	0.387 (-0.058, 0.803)	0.363 (0, 0.751)	0.285 (-0.256, 0.807)	0.148 (-0.096, 0.392)
Woodland	0.508 (0.076, 0.957)	0.449 (0.100, 0.810)	0.214 (-0.300, 0.729)	0.216 (-0.003, 0.435)
Urban	-0.222 (-0.859, 0.375)	-0.296 (-0.900, 0.304)	-0.200 (-0.831, 0.491)	-0.347 (-0.810, 0.127)
Unclassified	0.579 (0.100, 1.032)	0.601 (0.192, 0.978)	0.297 (-0.252, 0.796)	0.238 (-0.020, 0.509)
Colonisations				
Log Mass	-0.215 (-0.532, 0.050)	-0.214 (-0.461, 0.048)	-0.084 (-0.418, 0.213)	-0.276 (-0.463, -0.097)
Log Pop Size	-1.143 (-1.410, -0.914)	-1.121 (-1.378, -0.864)	-0.990 (-1.250, -0.743)	-0.835 (-1.051, -0.645)
Log Pop Change	-0.187 (-0.403, 0.015)	-0.235 (-0.460, -0.036)	-0.215 (-0.436, -0.015)	-0.100 (-0.275, 0.09)
SSI	0.477 (0.238, 0.748)	0.529 (0.268, 0.758)	0.517 (0.258, 0.756)	0.344 (0.150, 0.557)
STI	0.280 (0.037, 0.563)	0.237 (-0.023, 0.491)	0.175 (-0.090, 0.428)	-0.141 (-0.354, 0.060)
Wetland	0.274 (-0.151, 0.648)	0.317 (-0.012, 0.644)	0.121 (-0.351, 0.561)	-0.005 (-0.229, 0.233)
Upland	0.064 (-0.286, 0.423)	0.046 (-0.218, 0.334)	-0.010 (-0.445, 0.417)	-0.100 (-0.266, 0.075)
Coastal	0.262 (-0.159, 0.646)	0.389 (0.011, 0.737)	0.213 (-0.292, 0.671)	-0.260 (-0.529, 0.001)
Farmland	0.301 (-0.041, 0.688)	0.334 (0.025, 0.671)	0.301 (-0.127, 0.731)	0.188 (0.003, 0.392)
Woodland	0.301 (-0.053, 0.682)	0.261 (-0.003, 0.582)	0.151 (-0.258, 0.564)	0.125 (-0.051, 0.313)
Urban	-0.319 (-0.850, 0.201)	-0.338 (-0.816, 0.147)	-0.218 (-0.744, 0.343)	-0.316 (-0.64, 0.005)
Unclassified	0.326 (-0.069, 0.688)	0.375 (0.066, 0.672)	0.187 (-0.247, 0.584)	0.097 (-0.073, 0.284)

Persistence

Log Mass	-0.328 (-0.64, 0.009)	-0.359 (-0.688, -0.043)	-0.251 (-0.569, 0.049)	-0.406 (-0.702, -0.108)
Log Pop Size	-0.576 (-0.863, -0.294)	-0.565 (-0.844, -0.282)	-0.375 (-0.662, -0.107)	-0.441 (-0.688, -0.191)
Log Pop Change	-0.303 (-0.568, -0.064)	-0.339 (-0.591, -0.072)	-0.245 (-0.523, -0.004)	-0.440 (-0.696, -0.200)
SSI	0.448 (0.122, 0.785)	0.486 (0.135, 0.812)	0.565 (0.249, 0.862)	0.369 (0.061, 0.696)
STI	-0.009 (-0.348, 0.303)	0.059 (-0.297, 0.393)	0.011 (-0.326, 0.326)	-0.141 (-0.456, 0.183)
Wetland	0.671 (0.239, 1.119)	0.678 (0.241, 1.116)	0.583 (0.137, 1.007)	0.48 (0.071, 0.898)
Upland	0.166 (-0.158, 0.535)	0.242 (-0.073, 0.589)	0.093 (-0.249, 0.441)	0.252 (-0.021, 0.548)
Coastal	0.136 (-0.325, 0.596)	0.23 (-0.215, 0.666)	0.122 (-0.329, 0.559)	0.014 (-0.412, 0.46)
Farmland	0.240 (-0.073, 0.602)	0.198 (-0.124, 0.563)	0.302 (-0.025, 0.659)	0.250 (-0.036, 0.563)
Woodland	0.384 (0.069, 0.719)	0.354 (0.060, 0.677)	0.280 (-0.032, 0.596)	0.229 (-0.05, 0.519)
Urban	-0.42 (-0.927, 0.116)	-0.458 (-0.952, 0.069)	-0.445 (-0.947, 0.038)	-0.336 (-0.774, 0.119)
Unclassified	0.319 (-0.018, 0.676)	0.345 (0.015, 0.687)	0.380 (0.032, 0.728)	0.378 (0.084, 0.684)

Abundance

Log Mass	-0.100 (-0.325, 0.108)	-0.094 (-0.308, 0.138)	-0.096 (-0.326, 0.140)	-0.136 (-0.350, 0.093)
Log Pop Size	-0.401 (-0.617, -0.188)	-0.387 (-0.595, -0.142)	-0.388 (-0.614, -0.151)	-0.411 (-0.626, -0.194)
Log Pop Change	-0.053 (-0.222, 0.149)	-0.048 (-0.249, 0.131)	0.004 (-0.108, 0.205)	0.032 (-0.140, 0.232)
SSI	0.412 (0.203, 0.642)	0.427 (0.188, 0.644)	0.466 (0.231, 0.693)	0.374 (0.164, 0.613)
STI	0.051 (-0.154, 0.291)	0.0440 (-0.200, 0.260)	-0.113 (-0.353, 0.131)	0.034 (-0.175, 0.256)
Wetland	0.494 (0.174, 0.799)	0.493 (0.188, 0.787)	0.339 (0.030, 0.647)	0.125 (-0.174, 0.412)
Upland	0.236 (-0.003, 0.482)	0.266 (0.032, 0.531)	0.142 (-0.108, 0.414)	0.214 (-0.018, 0.446)
Coastal	0.500 (0.128, 0.864)	0.485 (0.096, 0.870)	0.263 (-0.132, 0.663)	0.483 (0.112, 0.846)
Farmland	-0.017 (-0.265, 0.229)	-0.008 (-0.266, 0.256)	0.111 (-0.135, 0.366)	-0.004 (-0.236, 0.235)
Woodland	0.336 (0.126, 0.564)	0.351 (0.133, 0.594)	0.212 (0.001, 0.444)	0.161 (-0.039, 0.365)
Urban	-0.684 (-1.088, -0.242)	-0.683 (-1.127, -0.241)	-0.303 (-0.747, 0.109)	-0.802 (-1.21, -0.415)
Unclassified	0.429 (0.181, 0.691)	0.446 (0.182, 0.718)	0.394 (0.136, 0.677)	0.398 (0.163, 0.649)

Trend

Log Mass	-0.215 (-0.402, -0.040)	-0.212 (-0.396, -0.033)	-0.153 (-0.367, 0.079)	-0.468 (-0.735, -0.169)
Log Pop Size	-0.037 (-0.224, 0.145)	-0.025 (-0.214, 0.159)	-0.024 (-0.236, 0.175)	-0.107 (-0.353, 0.166)
Log Pop Change	-0.282 (-0.430, -0.126)	-0.290 (-0.45, -0.132)	-0.332 (-0.504, -0.142)	-0.215 (-0.44, 0.017)
SSI	-0.022 (-0.213, 0.152)	-0.012 (-0.206, 0.167)	0.022 (-0.188, 0.237)	-0.069 (-0.304, 0.201)
STI	-0.169 (-0.353, 0.023)	-0.158 (-0.369, 0.022)	-0.022 (-0.242, 0.194)	-0.382 (-0.650, -0.107)
Wetland	0.216 (-0.031, 0.476)	0.201 (-0.044, 0.477)	0.329 (0.019, 0.640)	0.280 (-0.099, 0.686)

Upland	-0.071 (-0.261, 0.125)	-0.061 (-0.268, 0.151)	0.053 (-0.166, 0.290)	-0.15 (-0.459, 0.189)
Coastal	-0.043 (-0.344, 0.263)	-0.017 (-0.344, 0.300)	0.110 (-0.254, 0.489)	-0.237 (-0.674, 0.27)
Farmland	0.038 (-0.167, 0.232)	0.033 (-0.178, 0.238)	-0.005 (-0.238, 0.257)	0.062 (-0.234, 0.354)
Woodland	-0.141 (-0.311, 0.043)	-0.140 (-0.318, 0.058)	-0.010 (-0.231, 0.222)	-0.202 (-0.479, 0.085)
Urban	0.328 (0.005, 0.659)	0.309 (-0.037, 0.667)	0.414 (0.023, 0.853)	0.747 (0.25, 1.248)
Unclassified	0.209 (0.006, 0.413)	0.204 (0.002, 0.438)	0.221 (-0.027, 0.464)	0.11 (-0.209, 0.415)

Supplementary Table 5 Mean effect of extent of protected areas on population metrics of species of conservation concern (BoCC) or which are legally protected (Annex/Schedule 1). Asterisks indicate the significance of the difference in response to PA between species of conservation concern (red/amber-listed) and those not (green-listed) or for those designated under Annex 1 ('Birds' Directive) and Schedule 1 (UK Wildlife & Countryside Act) and those not so designated (exact P values are after the brackets, and significant results, $P < 0.05$, are shown in bold).

	All PA	SSSI	SPA	SAC
Occurrence				
BoCC Green	-0.08 (-0.18, 0.02)	-0.07 (-0.18, 0.04)	-0.242 (-0.35, -0.14)	-0.141 (-0.23, -0.05)
BoCC Amber	0.235 (0.08, 0.39), 0.001	0.273 (0.11, 0.44), 0.001	0.196 (0.04, 0.35), < 0.001	0.08 (-0.05, 0.21), 0.008
BoCC Red	0.077 (-0.17, 0.32), 0.249	0.147 (-0.12, 0.41), 0.142	-0.026 (-0.28, 0.22), 0.122	0.005 (-0.22, 0.23), 0.23
Not Annex 1	-0.004 (-0.09, 0.08)	0.017 (-0.07, 0.11)	-0.135 (-0.22, -0.05)	-0.091 (-0.16, -0.02)
Annex 1	0.563 (0.2, 0.93), 0.003	0.652 (0.25, 1.05), 0.003	0.605 (0.26, 0.95), < 0.001	0.41 (0.11, 0.71), 0.002
Not Schedule 1	0.001 (-0.08, 0.08)	0.024 (-0.07, 0.11)	-0.122 (-0.21, -0.04)	-0.082 (-0.15, -0.01)
Schedule 1	0.639 (0.21, 1.07), 0.004	0.688 (0.22, 1.16), 0.007	0.58 (0.16, 1), 0.001	0.399 (0.03, 0.77), 0.013
Colonisation				
BoCC Green	-0.336 (-0.44, -0.23)	-0.342 (-0.45, -0.23)	-0.397 (-0.51, -0.29)	-0.366 (-0.45, -0.28)
BoCC Amber	0.054 (-0.11, 0.21), < 0.001	0.086 (-0.08, 0.25), < 0.001	0.087 (-0.07, 0.25), < 0.001	-0.098 (-0.23, 0.03), 0.001
BoCC Red	-0.088 (-0.36, 0.18), 0.1	-0.026 (-0.31, 0.26), 0.044	-0.103 (-0.38, 0.17), 0.055	-0.164 (-0.39, 0.06), 0.099

Not Annex 1	-0.238 (-0.32, -0.15)	-0.229 (-0.32, -0.14)	-0.272 (-0.36, -0.18)	-0.297 (-0.37, -0.23)
Annex 1	0.622 (0.21, 1.03), < 0.001	0.677 (0.25, 1.11), < 0.001	0.655 (0.26, 1.05), < 0.001	0.29 (-0.03, 0.61), 0.001
Not Schedule 1	-0.236 (-0.32, -0.15)	-0.226 (-0.32, -0.14)	-0.263 (-0.35, -0.17)	-0.294 (-0.36, -0.22)
Schedule 1	0.672 (0.24, 1.11), < 0.001	0.727 (0.27, 1.18), < 0.001	0.594 (0.17, 1.02), < 0.001	0.319 (-0.03, 0.67), 0.001

Persistence

BoCC Green	-0.066 (-0.2, 0.07)	-0.047 (-0.19, 0.1)	-0.085 (-0.22, 0.05)	-0.066 (-0.19, 0.06)
BoCC Amber	0.034 (-0.18, 0.25), 0.445	0.062 (-0.16, 0.29), 0.423	0.221 (0.02, 0.42), 0.013	0.125 (-0.07, 0.32), 0.103
BoCC Red	0.049 (-0.29, 0.39), 0.533	0.091 (-0.26, 0.44), 0.474	-0.041 (-0.36, 0.27), 0.803	0.155 (-0.15, 0.46), 0.193
Not Annex 1	-0.041 (-0.15, 0.07)	-0.016 (-0.13, 0.1)	-0.013 (-0.12, 0.09)	-0.009 (-0.11, 0.09)
Annex 1	0.625 (-0.15, 1.4), 0.1	0.628 (-0.2, 1.45), 0.132	0.709 (0.04, 1.37), 0.037	0.69 (0.07, 1.32), 0.032
Not Schedule 1	-0.031 (-0.14, 0.08)	-0.007 (-0.12, 0.11)	0.003 (-0.1, 0.11)	0.006 (-0.09, 0.11)
Schedule 1	0.543 (-0.88, 1.97), 0.431	0.538 (-0.97, 2.05), 0.481	0.26 (-1.04, 1.56), 0.701	0.343 (-0.9, 1.59), 0.596

Abundance

BoCC Green	-0.13 (-0.23, -0.04)	-0.13 (-0.23, -0.03)	-0.21 (-0.31, -0.12)	-0.18 (-0.27, -0.09)
BoCC Amber	-0.22 (-0.39, -0.05), 0.391	-0.22 (-0.40, -0.04), 0.393	-0.14 (-0.31, 0.02), 0.481	-0.18 (-0.33, -0.03), 0.994

BoCC Red	-0.04 (-0.32, 0.23), 0.539	-0.05 (-0.33, 0.23), 0.599	-0.03 (-0.29, 0.23), 0.210	-0.04 (-0.28, 0.21), 0.276
Not Annex 1	-0.15 (-0.23, -0.07)	-0.15 (-0.23, -0.07)	-0.19 (-0.27, -0.11)	-0.18 (-0.25, -0.11)
Annex 1	0.56 (-0.18, 1.30), 0.063.	0.59 (-0.18, 1.35), 0.061	0.57 (-0.04, 1.17), 0.017	0.61 (0.04, 1.17), 0.008
Not Schedule 1	-0.15 (-0.23, -0.07)	-0.15 (-0.23, -0.07)	-0.19 (-0.27, -0.11)	-0.18 (-0.25, -0.10)
Schedule 1	0.47 (-0.35, 1.29), 0.139	0.48 (-0.36, 1.32), 0.147	0.47 (-0.21, 1.16), 0.061	0.54 (-0.11, 1.19), 0.035

Trend

BoCC Green	-0.03 (-0.09, 0.02)	-0.03 (-0.09, 0.02)	0.05 (-0.01, 0.11)	-0.08 (-0.15, -0.00)
BoCC Amber	0.01 (-0.09, 0.10), 0.474	0.01 (-0.08, 0.10), 0.445	0.07 (-0.03, 0.17), 0.676	-0.03 (-0.16, 0.09), 0.536
BoCC Red	0.10 (-0.04, 0.25), 0.083	0.09 (-0.05, 0.24), 0.114	0.10 (-0.06, 0.26), 0.533	0.11 (-0.09, 0.31), 0.084
Not Annex 1	-0.01 (-0.05, 0.03)	-0.01 (-0.06, 0.03)	0.06 (0.01, 0.11)	-0.05 (-0.11, 0.02)
Annex 1	-0.13 (-0.50, 0.24), 0.524	-0.13 (-0.51, 0.24), 0.535	0.06 (-0.30, 0.41), 0.993	-0.16 (-0.60, 0.28), 0.611
Not Schedule 1	-0.01 (-0.05, 0.04)	-0.01 (-0.05, 0.03)	0.06 (0.01, 0.11)	-0.04 (-0.10, 0.02)
Schedule 1	-0.31 (-0.71, 0.09), 0.140	-0.35 (-0.75, 0.06), 0.105	-0.19 (-0.58, 0.20), 0.208	-0.37 (-0.86, 0.13), 0.205

Supplementary Table 6 Mean effect of extent of protected areas on population metrics of species of conservation concern (BoCC) or which are legally protected (Annex/Schedule 1), adjusted for the mean population size of species within the group. Asterisks indicate the significance of the difference in response to PA between species of conservation concern (red/amber-listed) and those not (green-listed) or for those designated under Annex 1 ('Birds' Directive) and Schedule 1 (UK Wildlife & Countryside Act) and those not so designated, after taking differences in population size into account (Exact P values after brackets and significant results, $P < 0.05$, are shown in bold).

	All PA	SSSI	SPA	SAC
Occurrence				
BoCC Green	-0.252 (-0.35, -0.16)	-0.274 (-0.38, -0.17)	-0.438 (-0.54, -0.34)	-0.271 (-0.36, -0.18)
BoCC Amber	0.467 (0.33, 0.61), 0.065	0.535 (0.38, 0.68), 0.057	0.477 (0.34, 0.62), 0.002	0.234 (0.11, 0.36), 0.23
BoCC Red	0.744 (0.49, 1), 0.155	0.858 (0.59, 1.13), 0.076	0.575 (0.33, 0.82), 0.078	0.495 (0.25, 0.73), 0.185
Not Annex 1	-1.44 (-1.78, -1.1)	-1.671 (-2.07, -1.27)	-1.651 (-2.01, -1.29)	-1.145 (-1.47, -0.82)
Annex 1	1.987 (1.54, 2.44), 0.861	2.306 (1.8, 2.81), 0.913	2.09 (1.63, 2.55), 0.405	1.448 (1.03, 1.86), 0.61
Not Schedule 1	-2.036 (-2.51, -1.56)	-2.272 (-2.79, -1.75)	-2.301 (-2.79, -1.81)	-1.571 (-2.01, -1.14)
Schedule 1	2.488 (1.93, 3.04), 0.472	2.762 (2.15, 3.37), 0.378	2.538 (1.98, 3.1), 0.537	1.74 (1.23, 2.25), 0.621
Colonisation				
BoCC Green	-0.577 (-0.67, -0.48)	-0.597 (-0.7, -0.5)	-0.627 (-0.73, -0.53)	-0.521 (-0.61, -0.44)
BoCC Amber	0.39 (0.25, 0.53), 0.007	0.437 (0.29, 0.58), 0.003	0.39 (0.25, 0.53), < 0.001	0.12 (0, 0.24), 0.04

BoCC Red	0.629 (0.38, 0.88), 0.038	0.726 (0.47, 0.99), 0.01	0.504 (0.25, 0.76), 0.038	0.314 (0.09, 0.54), 0.068
Not Annex 1	-2.05 (-2.42, -1.68)	-2.134 (-2.52, -1.75)	-2.011 (-2.4, -1.62)	-1.463 (-1.78, -1.15)
Annex 1	2.311 (1.84, 2.78), 0.611	2.455 (1.96, 2.95), 0.584	2.242 (1.76, 2.72), 0.282	1.392 (0.99, 1.8), 0.565
Not Schedule 1	-2.692 (-3.19, -2.19)	-2.811 (-3.33, -2.29)	-2.59 (-3.09, -2.09)	-1.91 (-2.34, -1.48)
Schedule 1	2.865 (2.3, 3.43), 0.936	3.036 (2.45, 3.62), 0.951	2.632 (2.08, 3.19), 0.837	1.767 (1.28, 2.25), 0.999

Persistence

BoCC Green	-0.121 (-0.25, 0)	-0.104 (-0.23, 0.03)	-0.128 (-0.25, -0.01)	-0.095 (-0.21, 0.02)
BoCC Amber	0.509 (0.26, 0.76), 0.79	0.567 (0.3, 0.83), 0.816	0.602 (0.37, 0.84), 0.122	0.486 (0.26, 0.71), 0.542
BoCC Red	0.292 (-0.02, 0.6), 0.188	0.345 (0.02, 0.67), 0.156	0.16 (-0.14, 0.46), 0.432	0.346 (0.05, 0.64), 0.055
Not Annex 1	-0.796 (-1.09, -0.5)	-0.82 (-1.13, -0.51)	-0.698 (-0.98, -0.41)	-0.579 (-0.85, -0.31)
Annex 1	1.308 (0.56, 2.06), 0.617	1.353 (0.56, 2.14), 0.741	1.329 (0.67, 1.98), 0.362	1.216 (0.59, 1.84), 0.278
Not Schedule 1	-1.149 (-1.56, -0.74)	-1.192 (-1.62, -0.77)	-1.056 (-1.45, -0.66)	-0.886 (-1.26, -0.51)
Schedule 1	1.277 (-0.03, 2.58), 0.743	1.316 (-0.06, 2.69), 0.674	0.945 (-0.26, 2.15), 0.426	0.928 (-0.24, 2.1), 0.616

Abundance

BoCC Green	-0.17 (-0.25, -0.09)	-0.17 (-0.25, -0.08)	-0.24 (-0.32, -0.16)	-0.21 (-0.29, -0.14)
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BoCC Amber	0.20 (0.02, 0.38), 0.029	0.21 (0.03, 0.39), 0.027*	0.22 (0.05, 0.38), 0.481	0.17 (0.01, 0.32), 0.136
BoCC Red	0.58 (0.30, 0.85), 0.670	0.58 (0.30, 0.86), 0.753	0.52 (0.26, 0.78), 0.286	0.51 (0.26, 0.75), 0.328
Not Annex 1	-1.29 (-1.61, -0.97)	-1.31 (-1.64, -0.99)	-1.25 (-1.55, -0.95)	-1.16 (-1.44, -0.88)
Annex 1	1.64 (0.94, 2.33), 0.879	1.68 (0.97, 2.40), 0.889	1.59 (0.99, 2.18), 0.791	1.56 (1.01, 2.11), 0.539
Not Schedule 1	-1.52 (-1.90, -1.15)	-1.55 (-1.93, -1.17)	-1.48 (-1.84, -1.13)	-1.38 (-1.71, -1.04)
Schedule 1	1.67 (0.91, 2.44), 0.472	1.71 (0.93, 2.49), 0.453	1.61 (0.96, 2.27), 0.602	1.58 (0.96, 2.21), 0.847

Trend

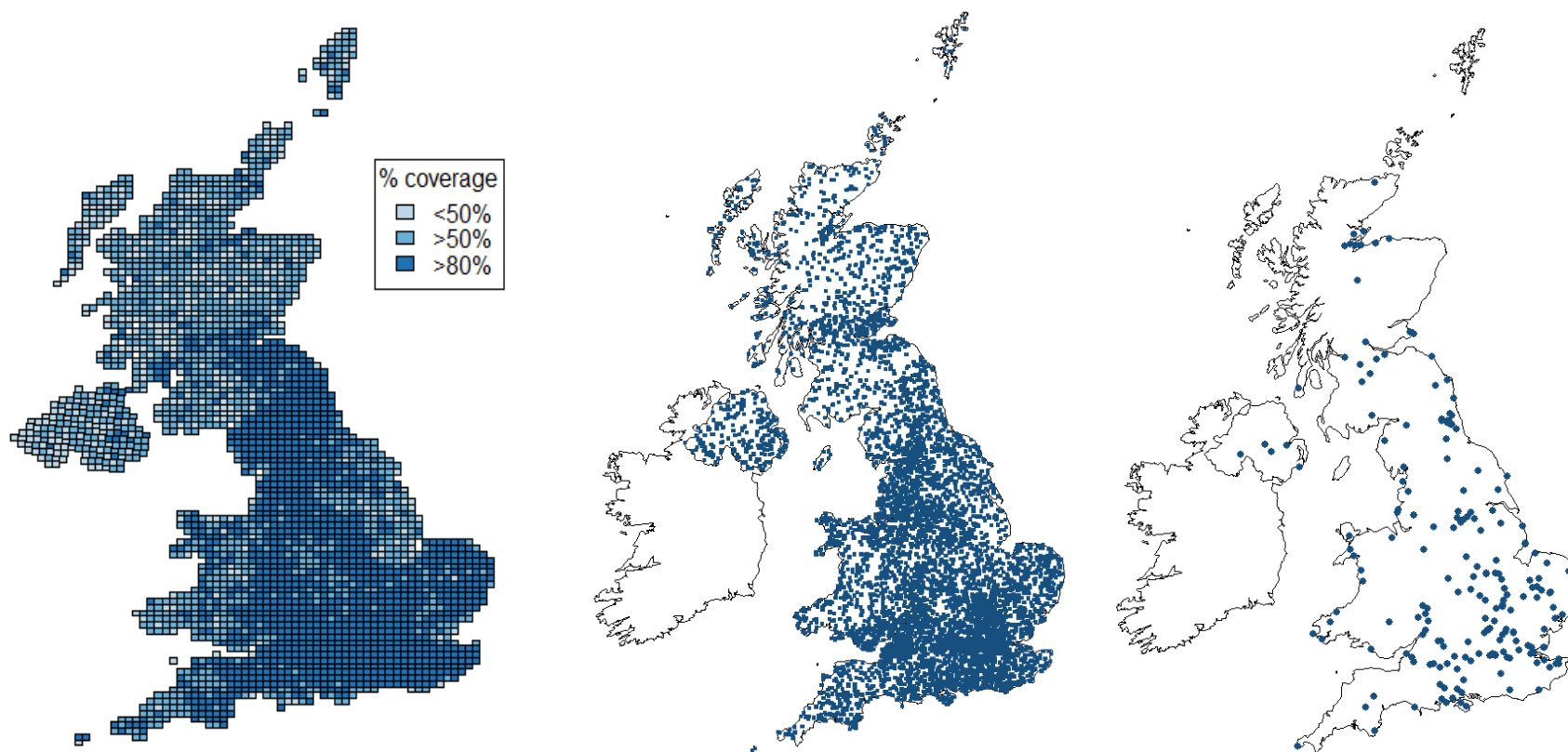
BoCC Green	-0.03 (-0.08, 0.02)	-0.03 (-0.09, 0.02)	0.05 (-0.01, 0.11)	-0.07 (-0.15, 0.00)
BoCC Amber	-0.01 (-0.12, 0.10), 0.436	-0.01 (-0.12, 0.10), 0.404	0.07 (-0.05, 0.19), 0.681	-0.06 (-0.21, 0.09), 0.44
BoCC Red	0.08 (-0.09, 0.25), 0.082	0.07 (-0.11, 0.24), 0.111	0.10 (-0.09, 0.29), 0.534	0.06 (-0.18, 0.29), 0.079.
Not Annex 1	-0.00 (-0.20, 0.20)	0.00 (-0.20, 0.21)	0.05 (-0.18, 0.27)	0.02 (-0.26, 0.30)
Annex 1	-0.14 (-0.55, 0.27), 0.567	-0.14 (-0.56, 0.28), 0.589	0.07 (-0.35, 0.48), 0.968	-0.22 (-0.74, 0.29), 0.756
Not Schedule 1	-0.04 (-0.27, 0.20)	-0.04 (-0.28, 0.20)	-0.02 (-0.28, 0.24)	-0.02 (-0.35, 0.31)
Schedule 1	-0.29 (-0.73, 0.16), 0.144	-0.32 (-0.77, 0.13), 0.109	-0.12 (-0.57, 0.33), 0.164	-0.39 (-0.96, 0.18), 0.265

Supplementary Table 7 Percentage of bird species influenced by extent of protected area, dividing species into those with significant and non-significant (in parentheses) positive and negative correlations between population measures and area of designation based on the matched sample analysis. The χ^2 and P values relate to a two-sided test of proportion, testing the difference in proportion of species with significantly positive or negative correlations with area of designation. Significant results ($P < 0.05$) are shown in bold.

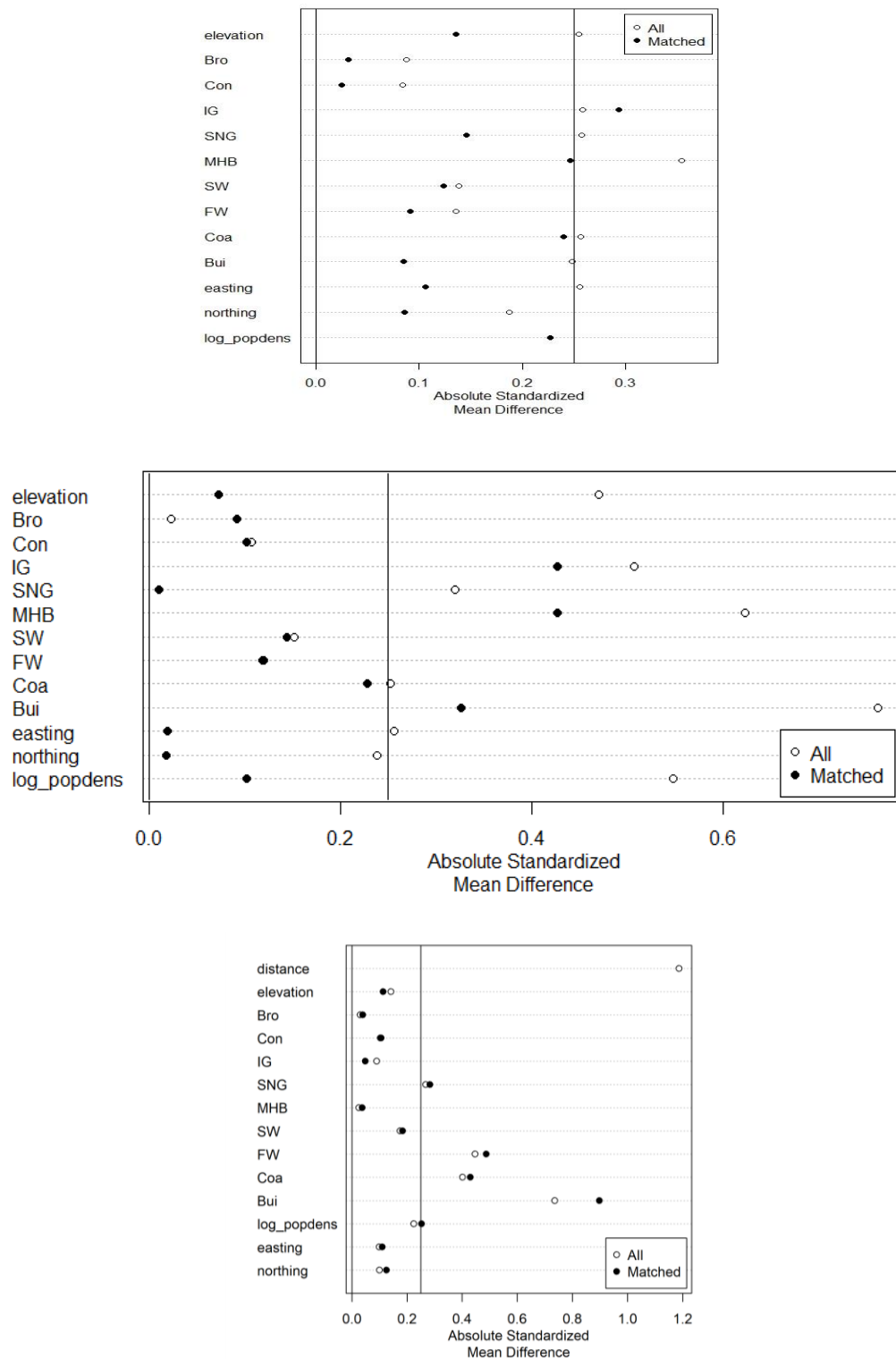
	All Protected Areas					SSSI					SPA					SAC				
	+	(+)	(-)	-	χ^2 , P	+	(+)	(-)	-	χ^2 , P	+	(+)	(-)	-	χ^2 , P	+	(+)	(-)	-	χ^2 , P
Occurrence (n=179)	69	19.5	10.3	1.1	112.2, < 0.001	70.2	20.8	8.4	0.6	120.07, < 0.001	50.9	21.1	16.6	11.4	42.42, < 0.001	44.9	39.3	11.8	3.9	59.59, < 0.001
Colonisation (n=165)	38.7	31.2	24.3	5.8	40.73, < 0.001	38.1	33	23.3	5.7	40.73, < 0.001	29	35.8	21	14.2	8.22, 0.004	18	37.1	37.1	7.9	6.28, 0.012
Persistence (n=130)	24.6	45.9	22.1	7.4	10.26, 0.001	26	43.9	22	8.1	10.5, 0.001	18	41	33.6	7.4	4.65, 0.031	18.3	40.8	37.5	3.3	11.12, 0.001
Abundance (n=133)	47.4	19.6	7.2	25.8	5.63, 0.018	51	15.6	6.2	27.1	6.45, 0.011	30.1	19.2	19.2	31.5	0, 1	36.8	22.4	11.8	28.9	0.5, 0.48
Abundance Trend (n=133)	11.3	39.2	33	16.5	0.59, 0.441	12.5	38.5	33.3	15.6	0.15, 0.7	23.3	34.2	31.5	11	2.56, 0.11	11.8	27.6	31.6	28.9	4.65, 0.031
Productivity (n=22)	13.6	27.3	18.2	40.9	2.08, 0.149	13.6	27.3	13.6	45.5	2.77, 0.096	11.8	29.4	35.3	23.5	0.17, 0.683	6.2	12.5	31.2	50	4, 0.046
Productivity Trend (n=22)	13.6	22.7	31.8	31.8	0.9, 0.343	9.1	27.3	31.8	31.8	1.78, 0.182	11.8	11.8	35.3	41.2	1.78, 0.182	6.2	31.2	31.2	31.2	1.5, 0.221

Supplementary Table 8 Mean association between demographic characteristics of individual species and protected area extent within the survey square ($\pm$ standard error) from the statistically matched analysis, and (final column) the results of the two-sided t-test comparing the mean of SPA with SAC. P values are shown after each statistic and significant results ($P < 0.05$) are shown in bold.

	N Spp	All PA	SSSI	SPA	SAC	SPA vs SAC
Occurrence	178	0.39 +/- 0.04, < 0.001	0.41 +/- 0.04, < 0.001	0.37 +/- 0.04, < 0.001	0.25 +/- 0.03, < 0.001	t = 4.2, >0.001
Colonisations	178	0.26 +/- 0.04, < 0.001	0.29 +/- 0.05, < 0.001	0.25 +/- 0.05, < 0.001	0.12 +/- 0.04, 0.001	t = 2.8, 0.005
Persistence	122	0.14 +/- 0.03, < 0.001	0.14 +/- 0.03, < 0.001	0.12 +/- 0.04, 0.003	0.1 +/- 0.05, 0.038	t = 0.49, 0.622
Abundance	133	0.15 +/- 0.03, < 0.001	0.14 +/- 0.03, < 0.001	0.07 +/- 0.04, 0.083	0.06 +/- 0.02, 0.024	t = 0.03, 0.977
Abundance trend	133	0 +/- 0.02, 0.89	0 +/- 0.02, 0.801	0.03 +/- 0.03, 0.24	-0.05 +/- 0.03, 0.054	t = 3.4, 0.001
Productivity	22	-0.11 +/- 0.05, 0.038	-0.11 +/- 0.05, 0.031	-0.07 +/- 0.07, 0.29	-0.27 +/- 0.11, 0.031	t = 1.5, 0.153
Productivity trend	22	-0.04 +/- 0.04, 0.268	-0.04 +/- 0.04, 0.318	-0.08 +/- 0.08, 0.379	-0.11 +/- 0.06, 0.097	t = 0.22, 0.832



Supplementary Figure 1 Survey coverage. Percent of available 2km tetrads within each 10km square surveyed in either Atlas period (1988-91 or 2007-11, left), BBS survey squares (middle) and CES sites (right) contributing to the data. Contains Ordnance Survey data © Crown Copyright and database right 2022.



Supplementary Figure 2 Matching balance. The balance of samples along each variable axis before (open dots) and after (filled dots) matching for all PA in the Atlas (top), BBS (middle) and CES (bottom) datasets. Matching generally resulted in standardized mean differences below 0.25 (vertical line), which we considered well matched (Ho et al. 2007), however, because some imbalances were retained after matching we used covariate adjustments in the analysis of the

matched sample In some cases, the balance of samples was the same before and after matching so only one dot is visible.