



# THE GAME CONSERVANCY TRUST

## **Research Report**

**Contract No: F90-01-708**

### **Participation of the National Gamebag Census in the Mammal Surveillance Network**

**A report to JNCC for the year 2006/07**

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# CONTENTS

	Page No.
1. Introduction.....	4
2. The National Gamebag Census .....	6
3. Temporal trends in bags for NGC mammals .....	7
3.1 Rabbit <i>Oryctolagus cuniculus</i> .....	9
3.2 Brown Hare <i>Lepus europaeus</i> .....	10
3.3 Mountain Hare <i>Lepus timidus</i> .....	11
3.4 Roe Deer <i>Capreolus capreolus</i> .....	12
3.5 Red deer <i>Cervus elaphus</i> .....	13
3.6 Fallow Deer <i>Dama dama</i> .....	14
3.7 Muntjac <i>Muntiacus reevesi</i> .....	15
3.8 Sika Deer <i>Cervus nippon</i> .....	16
3.9 Chinese Water Deer <i>Hydropotes inermis</i> .....	17
3.10 Wild Boar <i>Sus scrofa</i> .....	18
3.11 Hedgehog <i>Erinaceus europaeus</i> .....	19
3.12 Grey Squirrel <i>Sciurus carolinensis</i> .....	20
3.13 Fox <i>Vulpes vulpes</i> .....	21
3.14 Feral Cat <i>Felis catus</i> .....	22
3.15 Weasel <i>Mustela nivalis</i> .....	23
3.16 Stoat <i>Mustela erminea</i> .....	24
3.17 Polecat <i>Mustela putorius</i> .....	25
3.18 Mink <i>Mustela vison</i> .....	26
3.19 Brown Rat <i>Rattus norvegicus</i> .....	27
4. Comparison of trends in Fox, Grey Squirrel and Rabbit with those reported by the BTO from the BBS and WBBS.....	28
4.1 Fox.....	29
4.2 Grey Squirrel .....	30
4.3 Rabbit.....	31
5. Illustrative graphs of Brown Rat, Rabbit and Stoat bag trends since 1961 for each of the environmental zones	
5.1 Brown Rat.....	32
5.2 Rabbit.....	33
5.3 Stoat .....	34
6. Temporal changes in UK geographical distribution for Stoat, Weasel, Polecat and Mink .....	35
6.1 Stoat .....	36
6.2 Weasel .....	37
6.3 Polecat.....	38
6.4 Mink.....	39
7. Historical sample sizes of game and predator species over the period 1801 to 1960 at UK and country level	

## CONTENTS cont.

	<b>Page No.</b>
<b>7.1</b> Number of shoots providing bag data on game and predator species (UK).....	<b>40</b>
<b>7.2</b> Number of shoots providing bag data on game and predator species (England) ..	<b>41</b>
<b>7.3</b> Number of shoots providing bag data on game and predator species (Wales) .....	<b>42</b>
<b>7.4</b> Number of shoots providing bag data on game and predator species (Scotland)..	<b>43</b>
<b>7.5</b> Number of shoots providing bag data on game and predator species (N Ireland) ..	<b>44</b>
 <b>8. Interpretation of results from the National Gamebag Census .....</b>	 <b>45</b>
 <b>9. References.....</b>	 <b>48</b>
 <b>10. Acknowledgements .....</b>	 <b>49</b>

## 1 Introduction

Management measures for conservation or population control rely upon accurate records of a species' distribution and abundance. Monitoring refers to the collection of data on various aspects of a species' ecology or biology; the specific parameters subject to monitoring will depend on its objectives. Monitoring changes in the size of animal populations is an important yet difficult problem for wildlife biologists and managers. In order to manage a population successfully for its conservation it is necessary to have information about its status i.e. absolute abundance and distribution at any point in time and trends in abundance over time. Complete censuses of populations are not feasible for virtually any species of animal, since every individual would have to be detected and counted in order to get a precise figure. For most species, the expense of mark-recapture or mark re-sight estimation programs is prohibitive. The use of count data as indices of abundance and indicators of trends in abundance is therefore the only practical means of monitoring most animal populations, provided that the indices are related in a constant way to abundance over time.

Implicit in the concept of monitoring is an ongoing and regular effort to collect data allowing changes in the parameters of interest to be studied over time. In addition to establishing whether a population has been stable, increasing or decreasing over a given time-scale, long-term monitoring allows the *status quo* to be compared with historical distribution and abundance. This can provide further insight into current population status and act as a starting point for research into the causes of any observed decline in abundance or contraction of a species' geographical range. Repeated monitoring over time also has an important role in setting criteria and thresholds for action and determining when a downward trend constitutes a true decline.

Monitoring wildlife populations is also a legal requirement for a number of species. This is stated explicitly in Article 7 of the 1992 Convention on Biological Diversity, which requires contracting parties to 'monitor through sampling and other techniques the components of biological diversity, paying particular attention to those requiring urgent conservation measures and those offering the potential for sustainable use'. As a signatory to the Convention, the UK published the UK Biodiversity Action Plan (BAP) in January 1995, incorporating separate Action Plans for priority species and habitats, recognizing the importance of the conservation of biological diversity and sustainable use of biological resources.

The National Gamebag Census (NGC) is of considerable interest to the statutory agencies charged by the government with monitoring the status of UK wildlife, particularly with respect to mammals that are difficult to monitor by other means. The Joint Nature Conservation Committee (JNCC) is responsible for assessing and reporting on the state of UK biodiversity on behalf of these agencies. In 2003, JNCC invited The Game Conservancy Trust (GCT) to join the Tracking Mammals Partnership, thereby giving official recognition of the importance of NGC records as a monitoring tool for wildlife management and conservation.

The resulting agreement seeks to improve data collection, collation and analysis of the NGC, which will make it an important part of the Tracking Mammals Partnership. The latter comprises 25 organisations and aims to detect changes in the abundance and distribution of terrestrial and freshwater mammals. Information collected by the Partnership will act as an early warning

system for detecting changes in abundance for species of conservation interest and for pest or problem species.

The following items form part of the GCT NGC work plan within the Tracking Mammals Partnership for 2006/2007 agreed between JNCC and GCT in April 2006. The status of each item is provided in the pages that follow on from the list below.

1. Analyse trends for NGC mammals nationally, by NGC region and by Government Office Region where there are sufficient data.
2. Compare trends in Fox, Grey Squirrel, Stoat and Weasel with those reported by the BTO from the BBS and WBBS.
3. Produce illustrative graphs of Rat, Rabbit and Stoat bag trends since 1961 for each of the six environmental zones.
4. Examine temporal changes in UK geographical distribution of bags for Stoat, Weasel, Polecat and Mink.
5. Tabulate historical sample sizes by species for decades from 1901 to 1960, quarter centuries from 1801 to 1900, and for UK and country level.

## **2 The National Gamebag Census**

The NGC was formally established by the GCT in 1961, and is a voluntary scheme that currently collects bag statistics from over 600 shooting estates annually in England, Wales, Scotland and Northern Ireland. Through the inclusion of data from historical game books, series for several species extend back to the 19<sup>th</sup> century. The GCT believes that the NGC approach, which targets the estate rather than individual shooters, is the best way of assessing bags on driven shoots. The NGC statistics also include bags from rough shooting carried out on the same estates, and much of the mammal bag data held by the NGC is derived from this type of estate activity.

At the end of each shooting season, each participant completes an annual bag survey form detailing the numbers of each species shot, numbers released and numbers of shoot days, estate area and, in the case of upland estates, moorland area. In many cases, additional data extracted from game books extend the time series back to at least the 19th century. Reminders are issued for non-returned forms and the return rate exceeds 85%.

When expressed as the numbers of animals shot per unit area, the data provide temporal and regional trends in bags on shooting estates (Tapper 1992; Aebischer & Baines in press). Overall, the NGC collates data on the shooting bags of 24 huntable species and 19 predator species.

### 3 Temporal trends in bags for NGC mammals

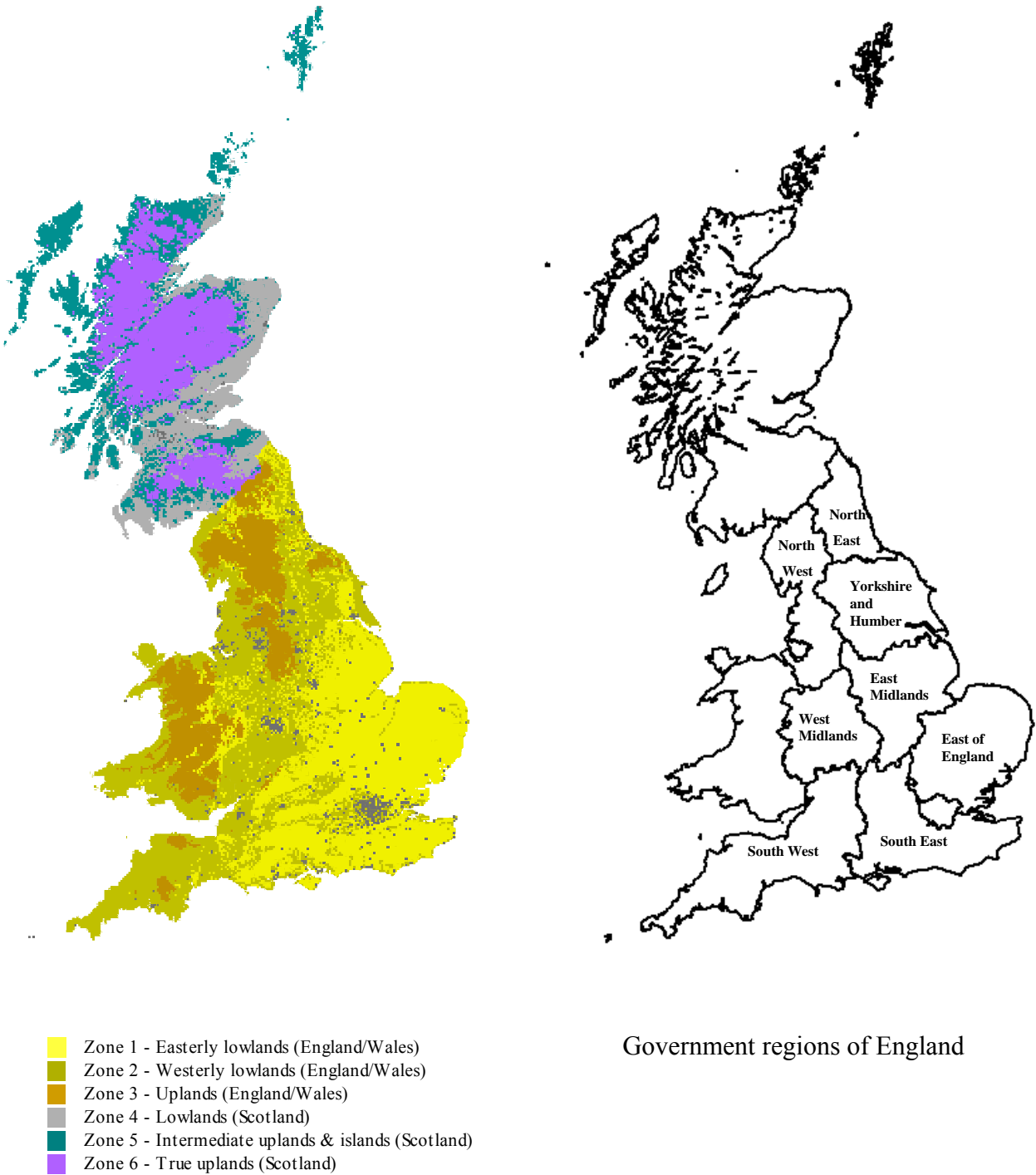
For each species, analysis was based on all annual shoot returns greater than zero. Shoots contributing only one year's data were omitted. Statistical analysis followed the approach adopted by Whitlock, et al. (2003) and was carried out using GenStat (Lawes Agricultural Trust, Rothamsted). For each species, bag data were analysed using a generalised linear model (McCulloch & Nelder 1996) with a Poisson error distribution and logarithmic link function, with shoot and year as factors and the logarithm of shoot area as an offset variable. Data were analysed at the UK, country and environmental zone levels. For most species, the bag data spanned the period from 1961 to 2005, but for several species the start year had to be moved forward because of insufficient sites in early years (five contributing sites in any one year was a minimum requirement). The year coefficients were exponentiated to give an index of bag size on the arithmetic scale. All index values were relative to the start year, which had a value of 1. To obtain index values for the standard Tracking Mammals Partnership period of 1995-2005, the index values from the full analysis were recalibrated by dividing by the 1995 value. The 95% confidence intervals around the index values were obtained by bootstrapping at the shoot level: for each of 199 bootstrap runs, shoots equal in number to the original sample were selected at random with replacement and a new set of indices obtained as described above. For each year, the 95% confidence limits were taken as the lower and upper 95th percentiles of the distribution of all 200 index values.

To measure the percentage change between the first and last years of each time series, a generalized additive model (GAM, Hastie & Tibshirani 1990) was fitted to the bag indices with one degree of freedom per decade or part-decade then the percentage change calculated from the GAM fitted values for the first and last years. The 95% confidence limits were obtained by fitting GAMs to each bootstrap sample, calculating the percentage change, and selecting the lower and upper 95th percentiles of the 200 values that resulted. If the 95% confidence interval did not include zero, then the percentage change was declared significant at  $P < 0.05$ .

This procedure resulted in bag indices and confidence limits from the NGC data for the period 1961 to 2005 and for the period 1995 to 2005, together with estimates of change (and confidence limits of change) across each period. Bag indices were expressed relative to the first year of each period, so the index value for the first year of each series is always one. Analyses were carried out for the UK as a whole, at country level (England, Scotland, Wales), by environmental zone and by government region (Figure 3.0).

Post-1961 and post-1995 UK trends were graphed for all mammals in a similar format to that used within the BTO Research Report No. 404 dated June 2005. The species analysed were Rabbit *Oryctolagus cuniculus*, Brown Hare *Lepus europaeus*, Mountain Hare *Lepus timidus*, Roe Deer *Capreolus capreolus*, Red Deer *Cervus elaphus*, Fallow Deer *Dama dama*, Muntjac *Muntiacus reevesi*, Sika Deer *Cervus nippon*, Chinese Water Deer *Hydropotes inermis*, Wild Boar *Sus scrofa*, Hedgehog *Erinaceus europaeus*, Grey Squirrel *Sciurus carolinensis*, Fox *Vulpes vulpes*, Feral Cat *Felis catus*, Weasel *Mustela nivalis*, Stoat *Mustela erminea*, Polecat *Mustela putorius*, Mink *Mustela vison*, Brown Rat *Rattus norvegicus*. The bag data for Chinese Water Deer and Wild Boar were insufficient for analysis.

Figure 3.0. Breakdown of the UK by environmental zone (left), and of England by government region (right).



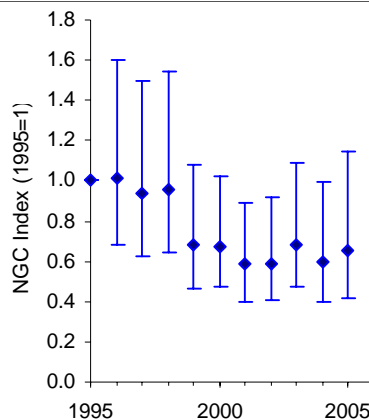
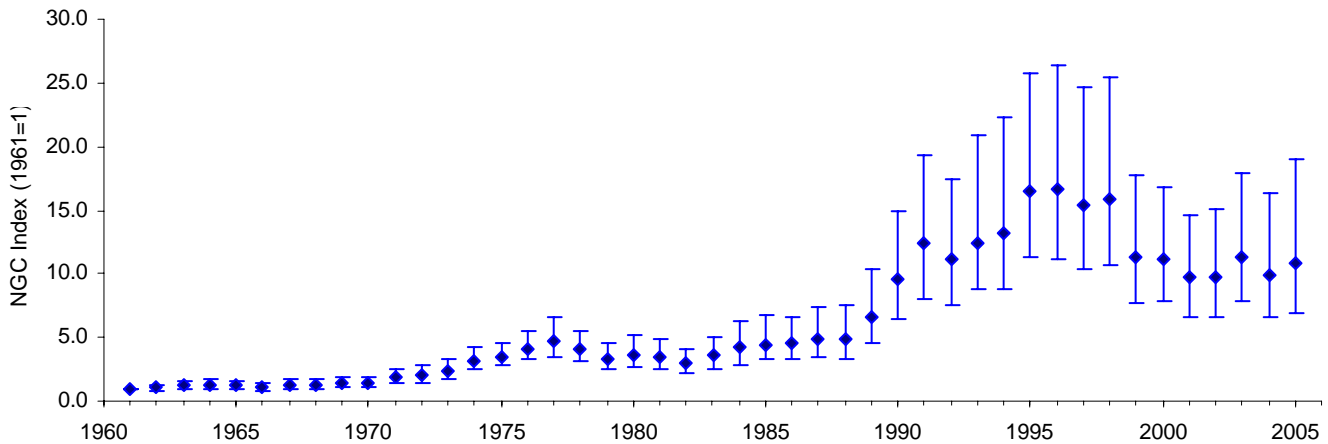
### 3.1 Rabbit *Oryctolagus cuniculus*

**Summary:** A significant increase in the index of bag density across the UK between 1961 and 2005 (although still less than half pre-myxomatosis levels), rapidly so for a time between 1989 and 1995 and a decline thereafter, significantly so in Scotland and for the UK as a whole.

a) Sample size and % change of Rabbit bags.

	Sample	1961-2005		1995-2005	
		Change	95% CI	Change	95% CI
UNITED KINGDOM	1186	1045*	648 – 1760	-24*	-41 – -3
COUNTRIES					
England	847	1104*	561 – 2038	18	-11 – 63
Scotland	282	1160*	686 – 2521	-65*	-74 – -53
Wales	41	6125*	738 – 23416	-21	-57 – 34
ENVIRONMENTAL ZONES					
1 - Easterly lowlands (England/Wales)	491	1256*	633 – 3175	20	-22 – 89
2 - Westerly lowlands (England/Wales)	173	468*	195 – 1374	-28	-48 – 1
3 - Uplands (England/Wales)	102	2747*	598 – 18700	27	-17 – 114
4 - Lowlands (Scotland)	99	1226*	305 – 4369	-66*	-85 – -25
5 - Intermediate uplands/islands (Scotland)	47	3883	-15084 – 55784	-69*	-84 – -35
6 - True uplands (Scotland)	138	1051*	560 – 2626	-162*	-173 – -147
GOVERNMENT REGIONS					
South West	144	474*	46 – 8260	-43	-79 – 51
South East	168	688*	361 – 1513	-26	-42 – 2
East of England	186	1689*	382 – 9613	54	-15 – 152
East Midlands	89	1096*	215 – 7198	100	-17 – 217
West Midlands	80	1017*	439 – 2303	-25*	-54 – -9
North West	43	541	-1371 – 19410	-4	-59 – 75
Yorkshire and Humber	106	1982*	839 – 6065	30	-27 – 168
North East	31	1151	99 – 23763	-39	-90 – 55

b) Change in relative bag density in the UK from 1961 to 2005 and from 1995 to 2005, respectively. Error bars represent 95% confidence intervals.



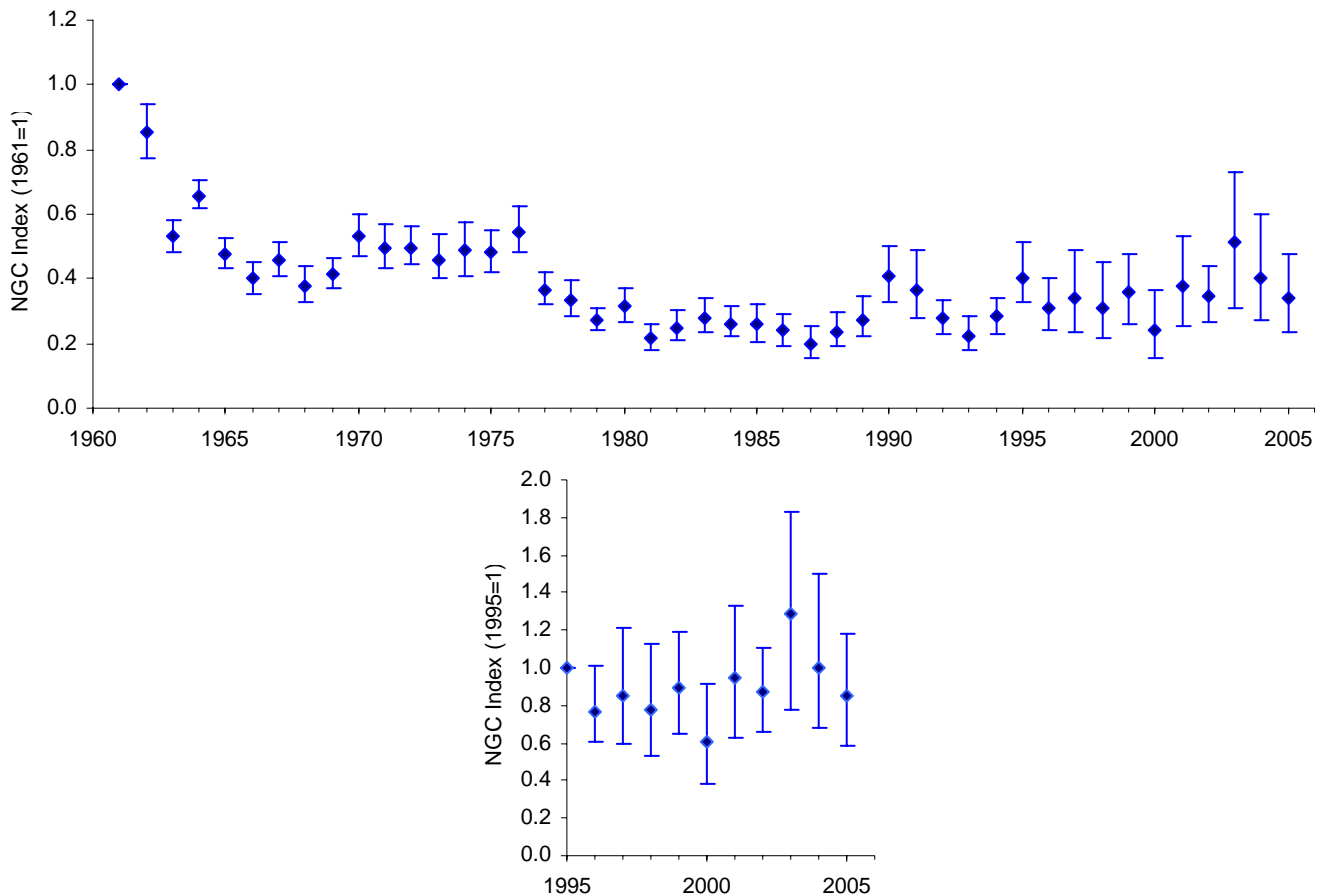
### 3.2 Brown Hare *Lepus europaeus*

**Summary:** A significant decline in the index of bag density across the UK between 1961 and 2005, but a reversal in trend since the 1980s (significant increase of 53% since 1985). There have been significant regional increases in the index in England between 1995 and 2005, but also a decline in south-east England and the Scottish uplands.

a) Sample size and % change of Brown Hare bags.

	Sample	1961-2005		1995-2005	
		Change	95% CI	Change	95% CI
UNITED KINGDOM	1089	-50*	-66 – -29	26	-3 – 55
COUNTRIES					
England	825	-45*	-65 – -18	31	-1 – 62
Scotland	221	-82*	-89 – -71	-16	-53 – 23
Wales	34				
ENVIRONMENTAL ZONES					
1 - Easterly lowlands (England/Wales)	491	-44*	-63 – -20	31*	1 – 65
2 - Westerly lowlands (England/Wales)	152	-66*	-89 – -38	15	-44 – 75
3 - Uplands (England/Wales)	83	-69*	-87 – -8	32	-50 – 283
4 - Lowlands (Scotland)	90	-82*	-93 – -65	2	-52 – 59
5 - Intermediate uplands/islands (Scotland)	30	-78*	-95 – -47	-8	-85 – 105
6 - True uplands (Scotland)	101	-86*	-95 – -65	-43*	-80 – -2
GOVERNMENT REGIONS					
South West	126	-59	-93 – 63	19	-60 – 293
South East	166	-60*	-79 – -35	-38*	-63 – -10
East of England	186	-37	-63 – 2	51*	4 – 89
East Midlands	95	-60*	-83 – -36	25	-25 – 114
West Midlands	79	-38	-75 – 0	288*	113 – 543
North West	41	-76	-95 – 33	-7	-86 – 414
Yorkshire and Humber	102	-32	-68 – 8	57	-9 – 135
North East	30	-39	-82 – 5	17	-57 – 91

b) Change in relative bag density in the UK from 1961 to 2005 and from 1995 to 2005, respectively. Error bars represent 95% confidence intervals.



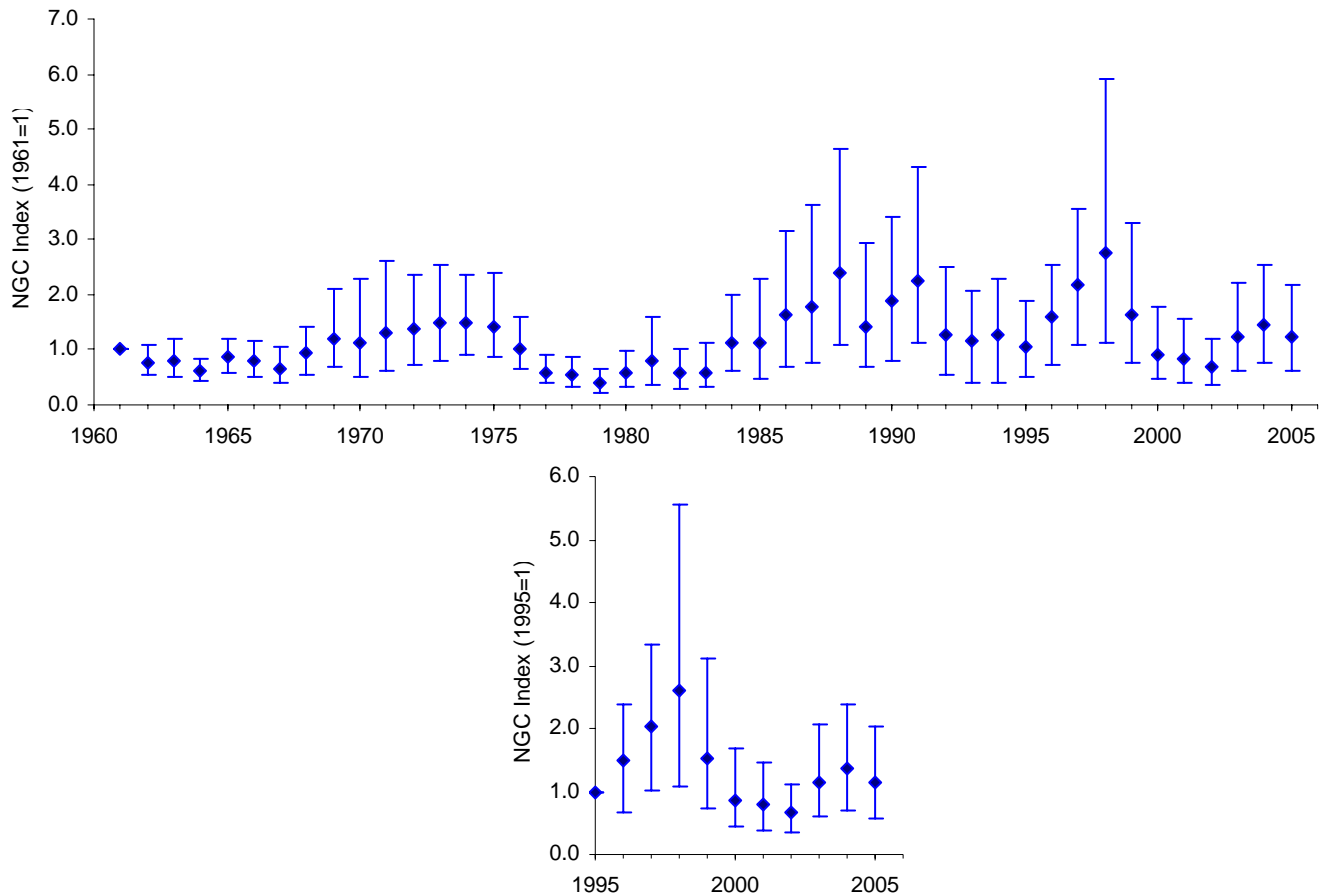
### 3.3 Mountain Hare *Lepus timidus*

**Summary:** A cyclic trend in the index of bag density in the UK between 1961 and 2005, with increases from 1967 to 1974, 1983 to 1988, and 1995 to 1998 alternating with poor seasons. Overall, there was no significant long-term trends.

a) Sample size and % change of Mountain Hare bags.

	Sample	1961-2005		1995-2005	
		Change	95% CI	Change	95% CI
UNITED KINGDOM	189	46	-27 – 158	-31	-61 – 37
COUNTRIES					
England	Too few sites				
Scotland	184	34	-34 – 174	-29	-62 – 34
Wales	Too few sites				
ENVIRONMENTAL ZONES					
1 - Easterly lowlands (England/Wales)	Too few sites				
2 - Westerly lowlands (England/Wales)	Too few sites				
3 - Uplands (England/Wales)	Too few sites				
4 - Lowlands (Scotland)	28	-9	-86 – 386	45	-24 – 435
5 - Intermediate uplands/islands (Scotland)	22	-44	-993 – 2343	-24	-47 – 239
6 - True uplands (Scotland)	133	41	-40 – 251	-34	-62 – 26
GOVERNMENT REGIONS					
South West	Too few sites				
South East	Too few sites				
East of England	Too few sites				
East Midlands	Too few sites				
West Midlands	Too few sites				
North West	Too few sites				
Yorkshire and Humber	Too few sites				
North East	Too few sites				

b) Change in relative bag density in the UK from 1961 to 2005 and from 1995 to 2005, respectively. Error bars represent 95% confidence intervals.



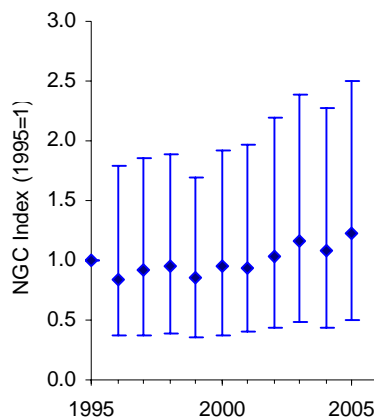
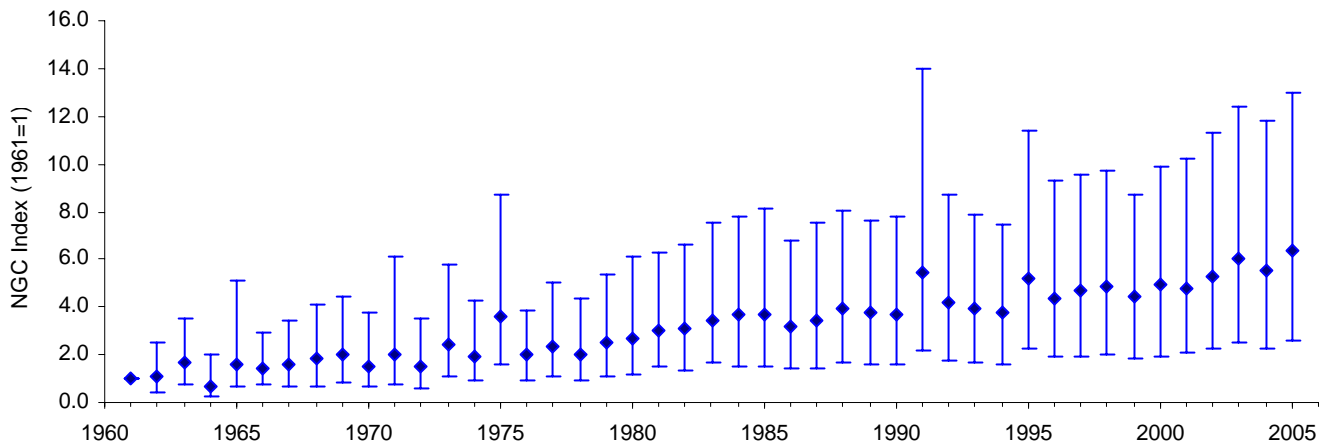
### 3.4 Roe Deer *Capreolus capreolus*

**Summary:** A significant and sustained increase in the index of bag density between 1961 and 2005 in England and Scotland. Regionally, increases in the bag index continue to be significant across the lowlands of England and Scotland, and the uplands of Scotland. A single site in Wales reported Roe Deer in the years 1993, 1997 and 2005.

a) Sample size and % change of Roe Deer bags.

	Sample		1961-2005		1995-2005	
			Change	95% CI	Change	95% CI
UNITED KINGDOM	459		480*	209 – 871	34*	11 – 53
COUNTRIES						
England	75 - 05	212	312*	221 – 852	45*	23 – 78
Scotland		241	359*	167 – 686	30*	3 – 60
Wales	Too few sites					
ENVIRONMENTAL ZONES						
1 - Easterly lowlands (England/Wales)	77 - 05	132	344*	159 – 941	50*	17 – 86
2 - Westerly lowlands (England/Wales)	77 - 05	46	151*	56 – 463	8	-19 – 51
3 - Uplands (England/Wales)	95 - 05	27			204*	90 – 378
4 - Lowlands (Scotland)	77 - 05	63	87*	22 – 292	27	-12 – 108
5 - Intermediate uplands/islands (Scotland)	77 - 05	32	125	-29 – 372	0	-37 – 67
6 - True uplands (Scotland)	77 - 05	143	218*	25 – 791	39	-6 – 95
GOVERNMENT REGIONS						
South West	77 - 05	54	204*	61 – 592	15	-5 – 43
South East	77 - 05	60	821*	399 – 1794	75*	17 – 167
East of England	77 - 05	32	348	-2118 – 5846	52	-5 – 106
East Midlands	Too few sites					
West Midlands	Too few sites					
North West	Too few sites					
Yorkshire and Humber	84 - 05	32	371*	104 – 981	33	-15 – 98
North East	95 - 05	13			70	-30 – 285

b) Change in relative bag density in the UK from 1961 to 2005 and from 1995 to 2005, respectively. Error bars represent 95% confidence intervals.



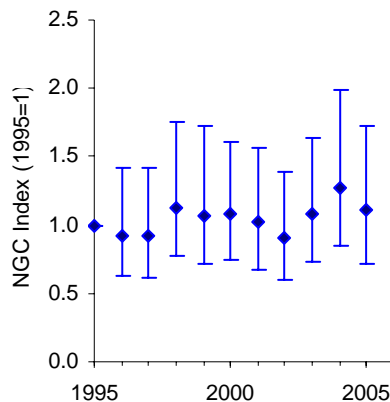
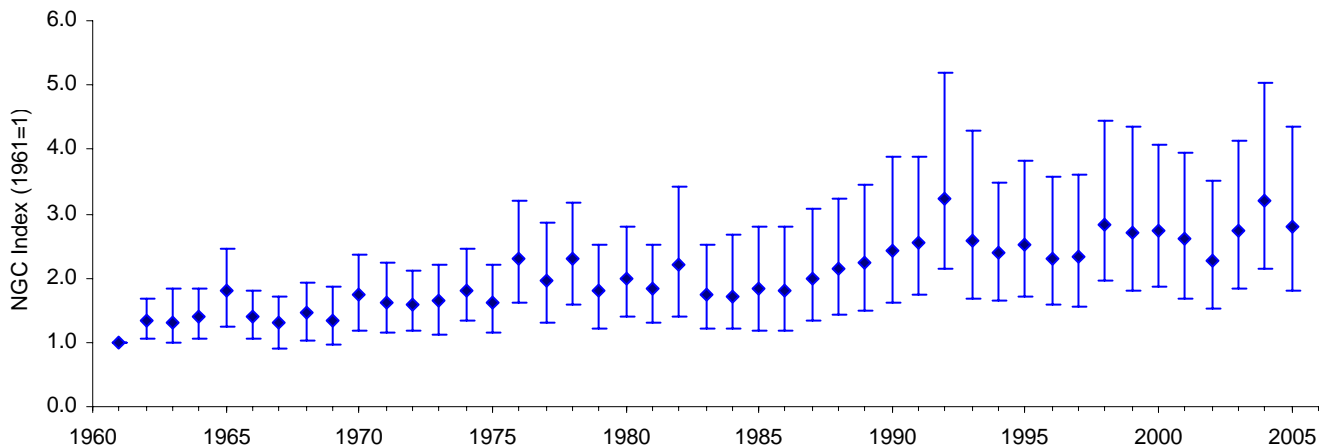
### 3.5 Red Deer *Cervus elaphus*

**Summary:** A significant increase in the index of bag density across the UK between 1961 and 2005 with stabilisation between 1995 and 2005. The majority of sites reporting Red Deer are from Scotland. Regionally, the true uplands of Scotland continue to have significant increases in the bag index. Although no sites in England reported Red Deer during the 1960s, two sites reported the animal during the 1970s.

a) Sample size and % change of Red Deer bags.

	Sample	1961-2005		1995-2005	
				Change	95% CI
UNITED KINGDOM	216		Change 162*	82 – 301	Change 12
COUNTRIES					95% CI -2 – 28
England	83 - 05	26	172*	46 – 540	13
Scotland	188		161*	75 – 292	12*
Wales	Too few sites				0 – 28
ENVIRONMENTAL ZONES					
1 - Easterly lowlands (England/Wales)	95 - 05	16			-20
2 - Westerly lowlands (England/Wales)	95 - 05	5			-44 – 115
3 - Uplands (England/Wales)	Too few sites				55
4 - Lowlands (Scotland)			375*	135 – 4104	-36 – 119
5 - Intermediate uplands/islands (Scotland)			9	-78 – 277	-12
6 - True uplands (Scotland)			137*	48 – 311	-41 – 31
GOVERNMENT REGIONS					
South West	Too few sites				
South East	Too few sites				
East of England	95 - 05	13			74
East Midlands	Too few sites				-38 – 28
West Midlands	Too few sites				
North West	Too few sites				
Yorkshire and Humber	Too few sites				
North East	Too few sites				

b) Change in relative bag density in the UK from 1961 to 2005 and from 1995 to 2005, respectively. Error bars represent 95% confidence intervals.



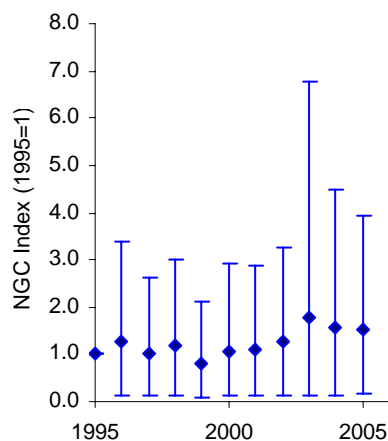
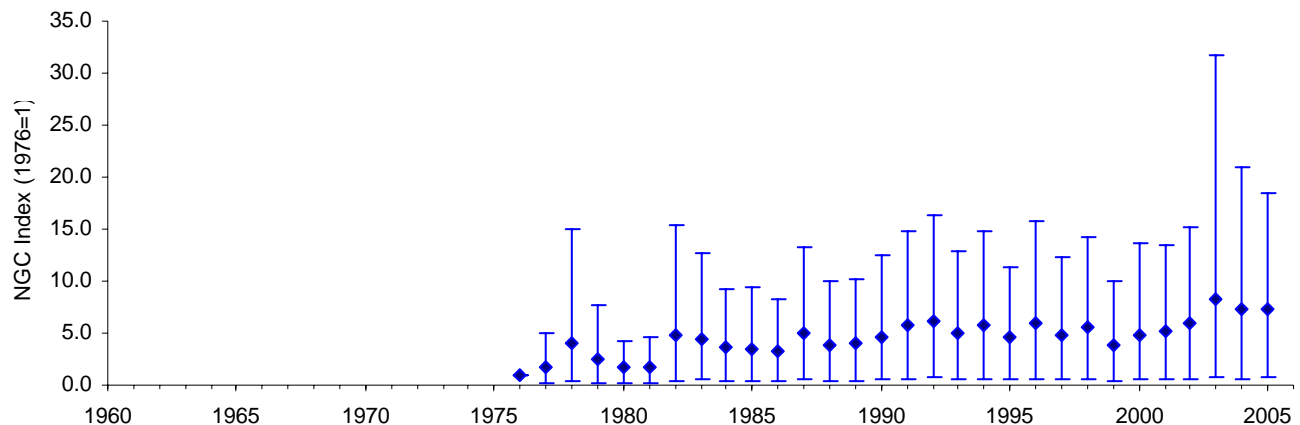
### 3.6 Fallow Deer *Dama dama*

**Summary:** A significant increase in the index of bag density in Scotland between 1976 and 2005 and in England between 1995 and 2005. These increases were primarily in the Scottish and English lowlands. Just seven sites in England reported Fallow Deer between 1961 and 1975.

a) Sample size and % change of Fallow Deer bags.

	Sample		1976-2005		1995-2005	
			Change	95% CI	Change	95% CI
UNITED KINGDOM	76 - 05	114	376*	25 – 828	44*	8 – 119
COUNTRIES						
England	76 - 05	93	124	-30 – 427	47*	19 – 89
Scotland	76 - 05	16	742*	318 – 2224	29	-12 – 407
Wales	Too few sites					
ENVIRONMENTAL ZONES						
1 - Easterly lowlands (England/Wales)	76 - 05	78	125	-27 – 381	53*	23 – 123
2 - Westerly lowlands (England/Wales)	95 - 05	11			12	-67 – 382
3 - Uplands (England/Wales)	Too few sites					
4 - Lowlands (Scotland)	Too few sites					
5 - Intermediate uplands/islands (Scotland)	Too few sites					
6 - True uplands (Scotland)	Too few sites					
GOVERNMENT REGIONS						
South West	84 - 05	18	52	-6 – 202	19	-45 – 105
South East	76 - 05	34	-16	-57 – 92	102*	13 – 183
East of England	84 - 05	24	141*	87 – 3930	76*	32 – 300
East Midlands	Too few sites					
West Midlands	Too few sites					
North West	Too few sites					
Yorkshire and Humber	Too few sites					
North East	Too few sites					

b) Change in relative bag density in the UK from 1976 to 2005 and from 1995 to 2005, respectively. Error bars represent 95% confidence intervals.



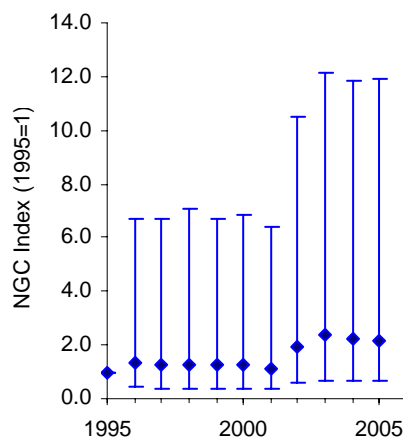
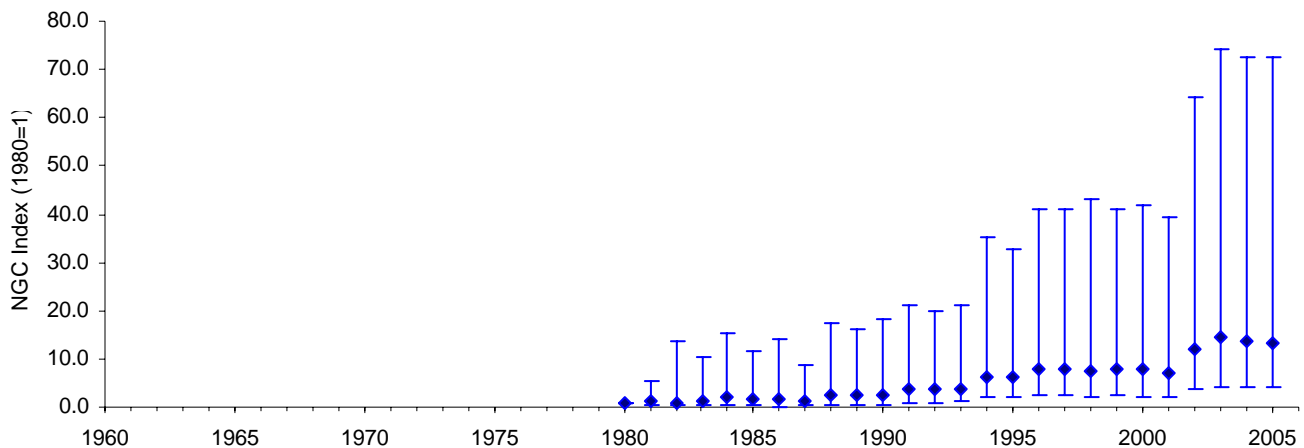
### 3.7 Muntjac *Muntiacus reevesi*

**Summary:** A rapid increase in the index of bag density between 1980 and 2005 in England, with average gains of 12% per annum across the period. The increase continued at a similar rate between 1995 and 2005. No muntjac were reported from Scotland or Wales. Regionally, the majority of Muntjac reports were from the easterly lowlands of England.

a) Sample size and % change of Muntjac bags.

	Sample		1980-2005		1995-2005	
			Change	95% CI	Change	95% CI
UNITED KINGDOM	80 - 05	97	1328*	189 – 3802	129*	80 – 230
COUNTRIES						
England	80 - 05	97	1328*	189 – 3802	129*	80 – 230
Scotland	Too few sites					
Wales	Too few sites					
ENVIRONMENTAL ZONES						
1 - Easterly lowlands (England/Wales)	80 - 05	88	1339*	230 – 3723	129*	80 – 227
2 - Westerly lowlands (England/Wales)	Too few sites					
3 - Uplands (England/Wales)	Too few sites					
4 - Lowlands (Scotland)	Too few sites					
5 - Intermediate uplands/islands (Scotland)	Too few sites					
6 - True uplands (Scotland)	Too few sites					
GOVERNMENT REGIONS						
South West	Too few sites					
South East	95 - 05	28			64	-12 – 238
East of England	84 - 05	46	746*	304 – 5721	125*	59 – 260
East Midlands	95 - 05	12			287*	111 – 428
West Midlands	Too few sites					
North West	Too few sites					
Yorkshire and Humber	Too few sites					
North East	Too few sites					

b) Change in relative bag density in the UK from 1980 to 2005 and from 1995 to 2005, respectively. Error bars represent 95% confidence intervals.



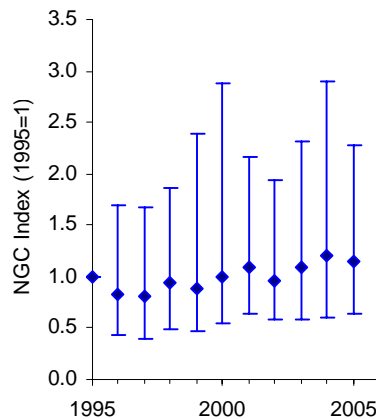
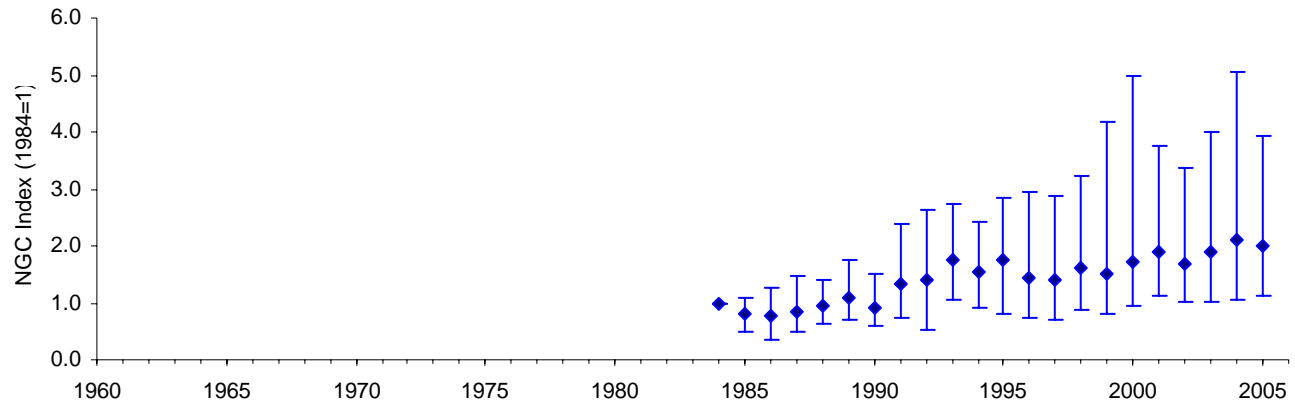
### 3.8 Sika Deer *Cervus nippon*

**Summary:** A significant increase in the index of bag density between 1984 and 2005 in the UK. Regionally, populations are disjunct and are restricted to the easterly lowlands of England and the true uplands of Scotland. The increase was significant in the uplands of Scotland between 1995 and 2005. Two sites reported Sika Deer in Scotland between 1961 and 1983, and no sites in England reported the animal between 1961 and 1975.

a) Sample size and % change of Sika Deer bags.

	Sample		1984-2005		1995-2005	
			Change	95% CI	Change	95% CI
UNITED KINGDOM	84 - 05	44	135*	35 – 370	30*	9 – 82
COUNTRIES						
England	95 - 05	10			14	-11 – 572
Scotland	84 - 05	31	365*	9 – 838	92*	8 – 143
Wales	Too few sites					
ENVIRONMENTAL ZONES						
1 - Easterly lowlands (England/Wales)	95 - 05	6			-3	-6 – 98
2 - Westerly lowlands (England/Wales)	Too few sites					
3 - Uplands (England/Wales)	Too few sites					
4 - Lowlands (Scotland)	Too few sites					
5 - Intermediate uplands/islands (Scotland)	Too few sites					
6 - True uplands (Scotland)	95 - 05	19			120*	53 – 294
GOVERNMENT REGIONS						
South West	Too few sites					
South East	Too few sites					
East of England	Too few sites					
East Midlands	Too few sites					
West Midlands	Too few sites					
North West	Too few sites					
Yorkshire and Humber	Too few sites					
North East	Too few sites					

b) Change in relative bag density in the UK from 1984 to 2005 and from 1995 to 2005, respectively. Error bars represent 95% confidence intervals.



### 3.9 Chinese Water Deer *Hydropotes inermis*

**Summary:** Just four sites reported Chinese Water Deer between 1990 and 2005, and all of these were from the easterly lowlands in England

a) Sample size and % change of Chinese Water Deer bags.		1961-2005		1995-2005	
	Sample	Change	95% CI	Change	95% CI
UNITED KINGDOM	Too few sites				
COUNTRIES					
England	Too few sites				
Scotland	Too few sites				
Wales	Too few sites				
ENVIRONMENTAL ZONES					
1 - Easterly lowlands (England/Wales)	Too few sites				
2 - Westerly lowlands (England/Wales)	Too few sites				
3 - Uplands (England/Wales)	Too few sites				
4 - Lowlands (Scotland)	Too few sites				
5 - Intermediate uplands/islands (Scotland)	Too few sites				
6 - True uplands (Scotland)	Too few sites				
GOVERNMENT REGIONS					
South West	Too few sites				
South East	Too few sites				
East of England	Too few sites				
East Midlands	Too few sites				
West Midlands	Too few sites				
North West	Too few sites				
Yorkshire and Humber	Too few sites				
North East	Too few sites				

### 3.10 Wild Boar *Sus scrofa*

**Summary:** Just five sites reported Wild Boar since 2000. Four of these were from the English lowlands and one from Aberdeenshire.

a) Sample size and % change of Wild Boar bags.

	Sample	1961-2005		1995-2005	
		Change	95% CI	Change	95% CI
UNITED KINGDOM	Too few sites				
COUNTRIES					
England	Too few sites				
Scotland	Too few sites				
Wales	Too few sites				
ENVIRONMENTAL ZONES					
1 - Easterly lowlands (England/Wales)	Too few sites				
2 - Westerly lowlands (England/Wales)	Too few sites				
3 - Uplands (England/Wales)	Too few sites				
4 - Lowlands (Scotland)	Too few sites				
5 - Intermediate uplands/islands (Scotland)	Too few sites				
6 - True uplands (Scotland)	Too few sites				
GOVERNMENT REGIONS					
South West	Too few sites				
South East	Too few sites				
East of England	Too few sites				
East Midlands	Too few sites				
West Midlands	Too few sites				
North West	Too few sites				
Yorkshire and Humber	Too few sites				
North East	Too few sites				

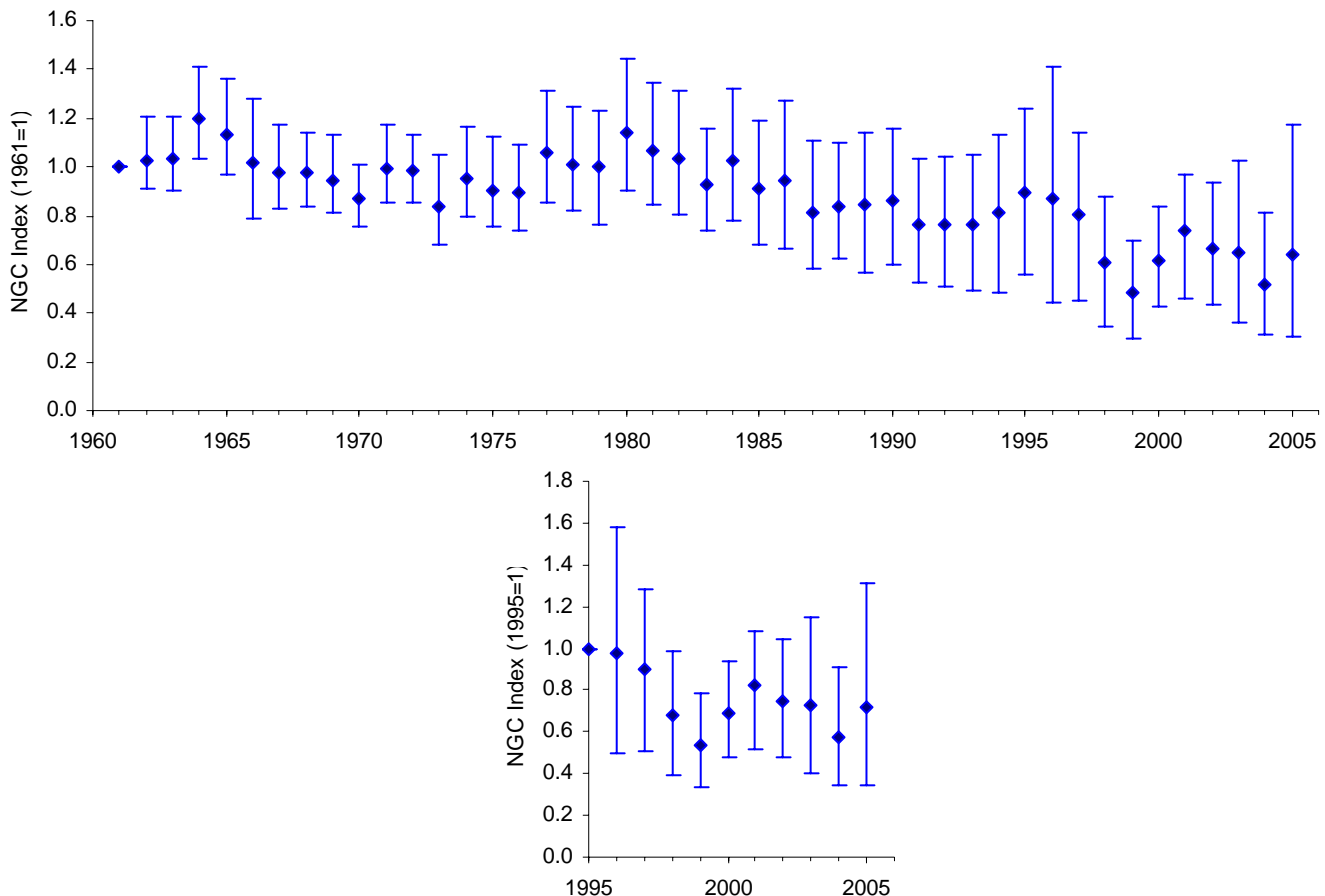
### 3.11 Hedgehog *Erinaceus europaeus*

**Summary:** A significant decline in the index of bag density between 1961 and 2005 in Wales and northern England especially, ongoing since 1995. The uplands of England and Wales in particular show a significant decrease in bag index.

a) Sample size and % change of Hedgehog bags.

	Sample	1961-2005		1995-2005	
		Change	95% CI	Change	95% CI
UNITED KINGDOM	662	-45*	-68 – -12	-24	-45 – 9
COUNTRIES					
England	523	-49	-76 – 13	-22	-52 – 19
Scotland	118	10	-49 – 114	-20	-53 – 33
Wales	19	-72*	-83 – -62	-43*	-50 – -42
ENVIRONMENTAL ZONES					
1 - Easterly lowlands (England/Wales)	312	-40	-75 – 34	-15	-46 – 31
2 - Westerly lowlands (England/Wales)	93	-67	-87 – 1	130	-39 – 622
3 - Uplands (England/Wales)	55	-75*	-84 – -40	-61*	-76 – -21
4 - Lowlands (Scotland)	43	-37	-81 – 74	-66*	-83 – -16
5 - Intermediate uplands/islands (Scotland)	19	47	-31 – 320	37	-25 – 110
6 - True uplands (Scotland)	55	-22	-66 – 17	26	-26 – 90
GOVERNMENT REGIONS					
South West	Too few sites				
South East	105	-86*	-97 – -74	-53*	-87 – -20
East of England	131	-25	-70 – 71	-10	-48 – 38
East Midlands	52	-12	-83 – 58	-33	-83 – 62
West Midlands	54	-84*	-95 – -73	4	-45 – 26
North West	25	-93*	-97 – -64	-70	-88 – 85
Yorkshire and Humber	68	-86*	-92 – -21	-47*	-64 – -7
North East	19	-80*	-95 – -73	-60*	-68 – -53

b) Change in relative bag density in the UK from 1961 to 2005 and from 1995 to 2005, respectively. Error bars represent 95% confidence intervals.



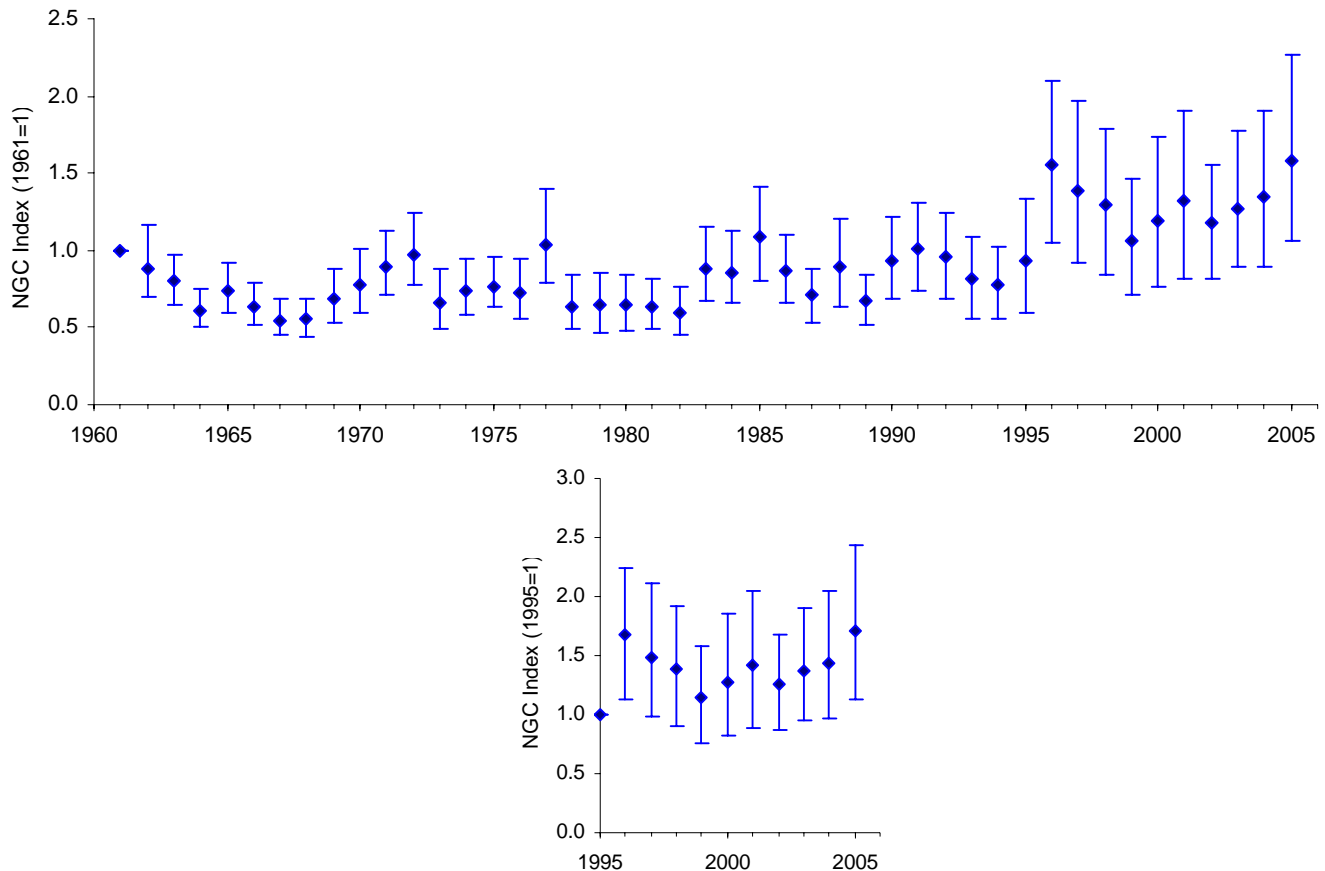
### 3.12 Grey Squirrel *Sciurus carolinensis*

**Summary:** A significant increase in the index of bag density across the UK between 1961 and 2005, with a noticeable step-up in the index post-1995. Regionally, the bag index has increased significantly across the lowlands of England and Wales, and across much of Scotland. Between 1961 and 1976, there were just nine reports of Grey Squirrel from six sites in Scotland.

a) Sample size and % change of Grey Squirrel bags.

a) Sample size and % change of Grey Squirrel bags.	1961-2005			1995-2005	
	Sample	Change	95% CI	Change	95% CI
UNITED KINGDOM	775	69*	19 – 123	34*	19 – 53
COUNTRIES					
England	661	69*	19 – 124	32*	16 – 48
Scotland	77 - 05 75	189*	24 – 544	34	-4 – 95
Wales	33	-6	-73 – 266	64	-18 – 166
ENVIRONMENTAL ZONES					
1 - Easterly lowlands (England/Wales)	380	67*	7 – 128	29*	15 – 47
2 - Westerly lowlands (England/Wales)	150	87*	21 – 164	40*	17 – 83
3 - Uplands (England/Wales)	81	43	-60 – 134	65*	28 – 101
4 - Lowlands (Scotland)	77 - 05 33	183*	15 – 835	47	-20 – 144
5 - Intermediate uplands/islands (Scotland)	95 - 05 13			361*	228 – 1257
6 - True uplands (Scotland)	84 - 05 27	107*	-17 – 306	11	-47 – 98
GOVERNMENT REGIONS					
South West	133	91*	15 – 189	62*	20 – 118
South East	140	-33*	-53 – -6	9	-10 – 37
East of England	135	276*	94 – 583	23	-5 – 47
East Midlands	65	217*	88 – 463	82*	12 – 192
West Midlands	72	103*	10 – 254	110*	41 – 202
North West	84 - 05 19	59	-10 – 436	15	-2 – 90
Yorkshire and Humber	81	222*	123 – 552	46*	21 – 78
North East	95 - 05 11			111	-5 – 342

b) Change in relative bag density in the UK from 1961 to 2005 and from 1995 to 2005, respectively. Error bars represent 95% confidence intervals.



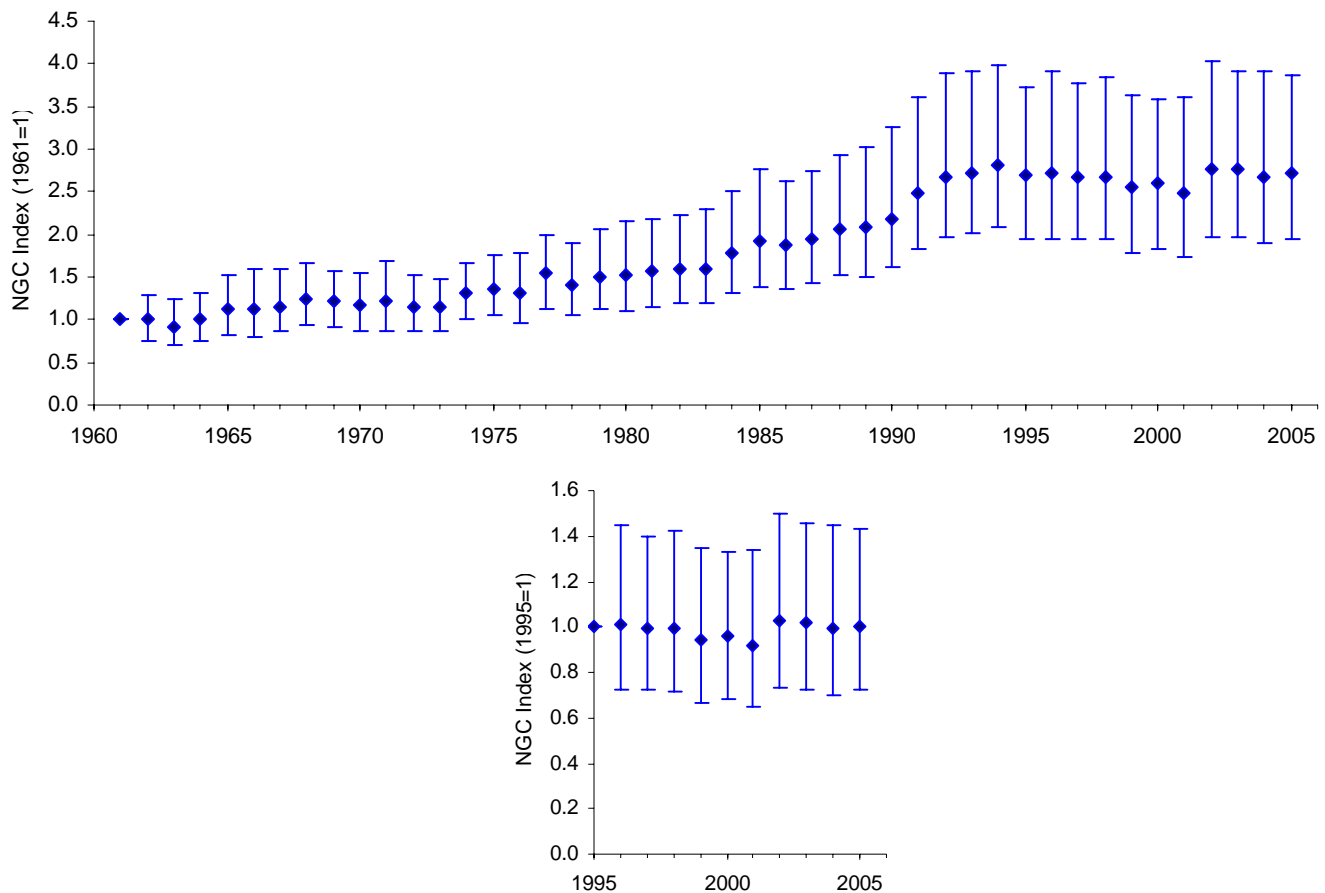
### 3.13 Fox *Vulpes vulpes*

**Summary:** A significant increase in the index of bag density across the UK between 1961 and 1994, continuing in England during the period 1995 to 2005. Regionally, increases continue to be significant to the present day across the westerly lowlands of England and Wales.

a) Sample size and % change of Fox bags.

	Sample	1961-2005		1995-2005	
		Change	95% CI	Change	95% CI
UNITED KINGDOM	962	180*	116 – 272	3	-4 – 9
COUNTRIES					
England	635	218*	130 – 357	12*	2 – 21
Scotland	279	154*	71 – 283	-14*	-26 – -1
Wales	34	9	-53 – 177	13	-14 – 51
ENVIRONMENTAL ZONES					
1 - Easterly lowlands (England/Wales)	376	353*	194 – 599	9	-2 – 22
2 - Westerly lowlands (England/Wales)	149	68	-14 – 202	31*	12 – 56
3 - Uplands (England/Wales)	108	87*	46 – 467	5	-9 – 22
4 - Lowlands (Scotland)	81	224	-15 – 476	-5	-23 – 23
5 - Intermediate uplands/islands (Scotland)	45	27	-44 – 142	-15	-40 – 12
6 - True uplands (Scotland)	153	140*	38 – 292	-17	-36 – 5
GOVERNMENT REGIONS					
South West	112	59	-2 – 168	-4	-26 – 20
South East	121	221*	97 – 487	13	-4 – 30
East of England	138	853*	319 – 1606	17	-5 – 43
East Midlands	59	240*	2 – 581	19	-8 – 53
West Midlands	56	274*	28 – 815	9	-6 – 38
North West	39	138*	98 – 368	36*	9 – 77
Yorkshire and Humber	79	-13	-30 – 9	6	-12 – 25
North East	31	298*	78 – 1030	3	-26 – 29

b) Change in relative bag density in the UK from 1961 to 2005 and from 1995 to 2005, respectively. Error bars represent 95% confidence intervals.



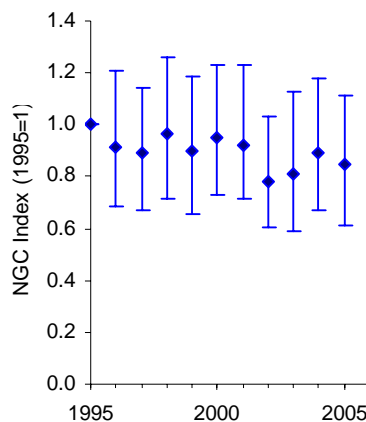
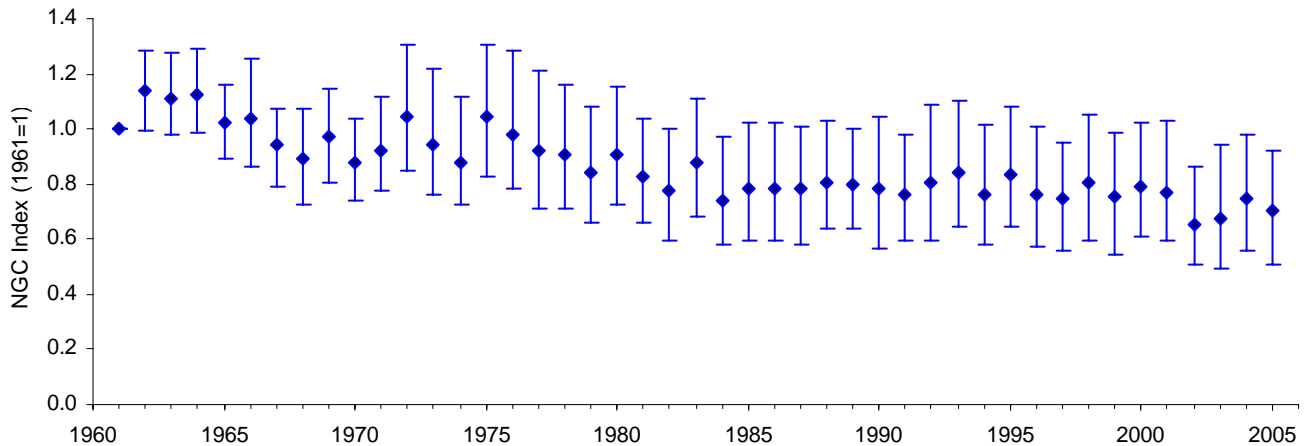
### 3.14 Feral Cat *Felis catus*

**Summary:** A significant decrease in the index of bag density across the UK between 1961 and 2005. Regionally, the decrease has been significant in eastern England and in the Scottish uplands.

a) Sample size and % change of Feral Cat bags.

	Sample	1961-2005		1995-2005	
		Change	95% CI	Change	95% CI
UNITED KINGDOM	724	-36*	-51 – -14	-11	-25 – 5
COUNTRIES					
England	510	-38*	-53 – -11	-5	-22 – 11
Scotland	179	-39	-71 – 76	-16	-41 – 14
Wales	24	-58	-98 – 35	26	-95 – 202
ENVIRONMENTAL ZONES					
1 - Easterly lowlands (England/Wales)	288	-52*	-64 – -31	-18	-42 – 7
2 - Westerly lowlands (England/Wales)	105	-30	-64 – 40	26	-16 – 67
3 - Uplands (England/Wales)	81	-37	-72 – 122	0	-14 – 24
4 - Lowlands (Scotland)	55	-34	-59 – 47	-26	-56 – 16
5 - Intermediate uplands/islands (Scotland)	25	-67	-86 – 22	2	-58 – 60
6 - True uplands (Scotland)	100	-58*	-79 – -43	-14	-39 – 15
GOVERNMENT REGIONS					
South West	77	-88	-108 – 58	-90	-104 – 24
South East	88	-59*	-74 – -34	-20	-45 – 12
East of England	118	-46*	-63 – -20	5	-25 – 40
East Midlands	47	-82*	-86 – -78	-46*	-71 – -26
West Midlands	52	-17	-67 – 38	24	-26 – 63
North West	34	27*	3 – 149	-3	-18 – 54
Yorkshire and Humber	68	-27	-65 – 51	5	-15 – 37
North East	26	-61	-83 – 83	-25	-59 – 3

b) Change in relative bag density in the UK from 1961 to 2005 and from 1995 to 2005, respectively. Error bars represent 95% confidence intervals.



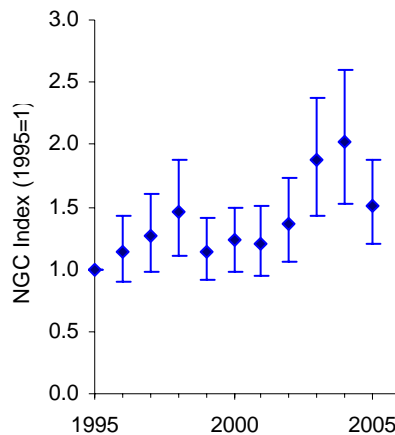
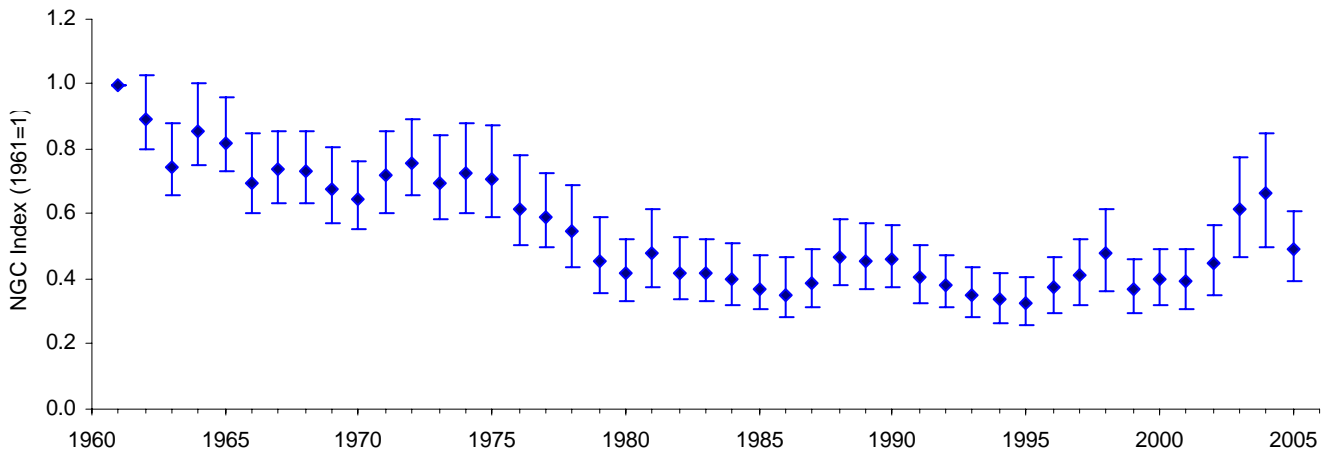
### 3.15 Weasel *Mustela nivalis*

**Summary:** A significant decrease in the index of bag density across the UK between 1961 and 2005, but a significant increase since 1995. Regionally, the long-term decrease occurred across the southern half of England and Wales and southern Scotland. Recent increases are most marked in upland areas.

a) Sample size and % change of Weasel bags.

	Sample	1961-2005		1995-2005	
		Change	95% CI	Change	95% CI
UNITED KINGDOM	935	-38*	-51 – -24	47*	24 – 74
COUNTRIES					
England	674	-42*	-56 – -26	55*	21 – 99
Scotland	231	0	-39 – 73	38*	10 – 73
Wales	29	-86	-92 – 65	-40	-77 – 61
ENVIRONMENTAL ZONES					
1 - Easterly lowlands (England/Wales)	379	-69*	-79 – -59	-14	-35 – 6
2 - Westerly lowlands (England/Wales)	134	-70*	-83 – -47	-12	-43 – 26
3 - Uplands (England/Wales)	97	-24	-73 – 939	146*	82 – 234
4 - Lowlands (Scotland)	70	-61*	-86 – -7	-43	-72 – 5
5 - Intermediate uplands/islands (Scotland)	31	-73*	-81 – -33	7	-29 – 108
6 - True uplands (Scotland)	129	76	-17 – 232	75*	43 – 112
GOVERNMENT REGIONS					
South West	104	-83*	-90 – -61	-40	-64 – 4
South East	136	-79*	-88 – -65	-23	-50 – 29
East of England	140	-60*	-76 – -41	-5	-37 – 22
East Midlands	72	-71*	-81 – -53	2	-25 – 45
West Midlands	64	-64	-91 – 27	-3	-66 – 75
North West	36	23	-67 – 618	109*	27 – 170
Yorkshire and Humber	89	5	-49 – 126	196*	87 – 307
North East	33	-32	-81 – 580	17	-37 – 102

b) Change in relative bag density in the UK from 1961 to 2005 and from 1995 to 2005, respectively. Error bars represent 95% confidence intervals.



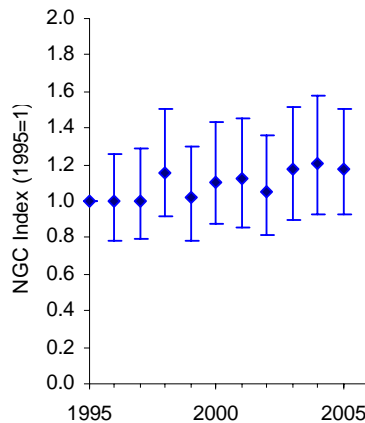
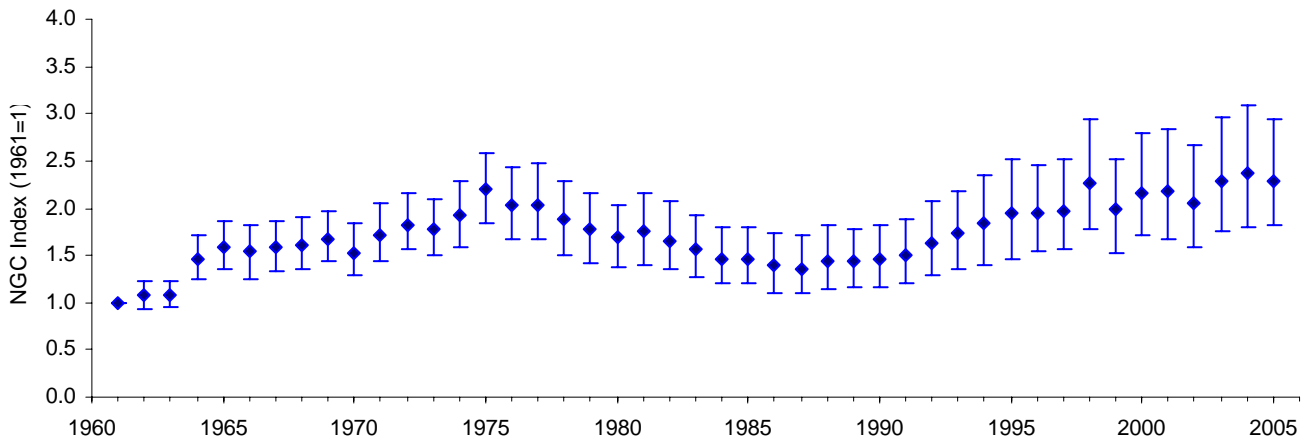
### 3.16 Stoat *Mustela erminea*

**Summary:** A significant increase in the index of bag density across the UK between 1961 and 2005 (although still less than half pre-myxomatosis levels), but with a notable broad-based dip during the 1980s followed by recovery during the 1990s. Since 1995, increases have been significant in upland areas.

a) Sample size and % change of Stoat bags.

	Sample	1961-2005		1995-2005	
		Change	95% CI	Change	95% CI
UNITED KINGDOM	977	120*	77 – 179	28*	15 – 41
COUNTRIES					
England	699	130*	76 – 198	28*	10 – 50
Scotland	237	84*	14 – 232	29*	11 – 47
Wales	30	-38	-57 – 396	-20*	-47 – -7
ENVIRONMENTAL ZONES					
1 - Easterly lowlands (England/Wales)	397	39	-3 – 84	-12	-31 – 9
2 - Westerly lowlands (England/Wales)	137	5	-35 – 84	-7	-34 – 23
3 - Uplands (England/Wales)	101	277	-2 – 729	61*	38 – 95
4 - Lowlands (Scotland)	73	80	-16 – 225	-16	-43 – 31
5 - Intermediate uplands/islands (Scotland)	34	6	-46 – 131	24	-30 – 78
6 - True uplands (Scotland)	130	100*	3 – 327	44*	27 – 63
GOVERNMENT REGIONS					
South West	112	-19	-61 – 74	-24	-57 – 33
South East	139	-33	-61 – 19	-29	-50 – 4
East of England	147	145*	75 – 240	-6	-27 – 25
East Midlands	71	65*	29 – 135	13	-17 – 40
West Midlands	66	-13	-57 – 99	-18	-44 – 20
North West	38	171	-7 – 532	78*	20 – 110
Yorkshire and Humber	93	238*	40 – 486	76*	40 – 112
North East	33	320*	8 – 1057	1	-35 – 37

b) Change in relative bag density in the UK from 1961 to 2005 and from 1995 to 2005, respectively. Error bars represent 95% confidence intervals.



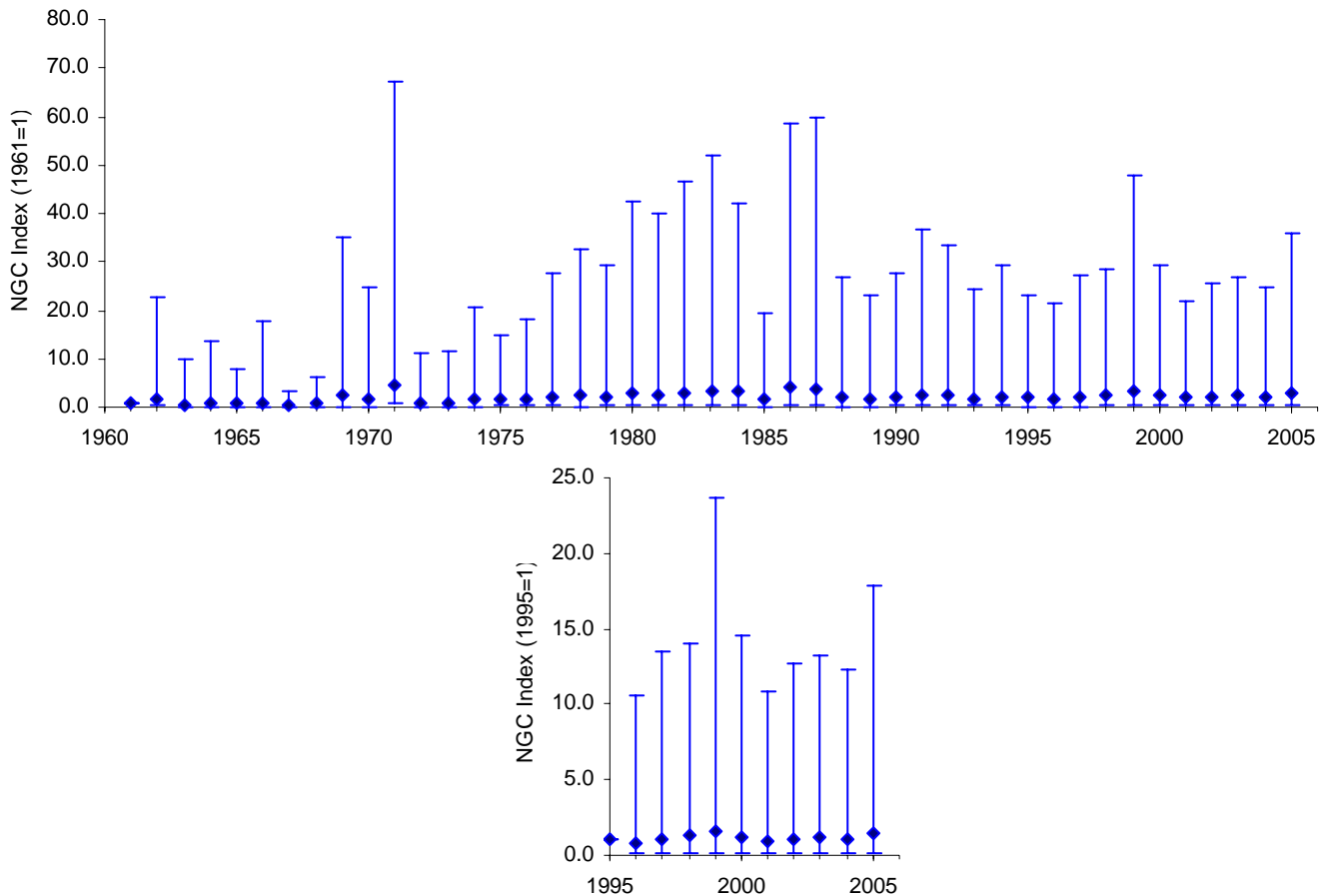
### 3.17 Polecat *Mustela putorius*

**Summary:** Overall no significant changes, although 13 out of all 14 change values that can be calculated were positive. No sites reported Polecat from Scotland between 1961 and 1978.

a) Sample size and % change of Polecat bags.

	Sample		1961-2005		1995-2005	
			Change	95% CI	Change	95% CI
UNITED KINGDOM	145		194	-44 – 3446	15	-14 – 76
COUNTRIES						
England	76 - 05	77	60	-39 – 916	65	-2 – 217
Scotland	95 - 05	31			91	-45 – 586
Wales	76 - 05	18	23	-90 – 99	-7	-75 – 27
ENVIRONMENTAL ZONES						
1 - Easterly lowlands (England/Wales)	77 - 05	34	65	-71 – 1201	37	-60 – 405
2 - Westerly lowlands (England/Wales)	76 - 05	25	18	-73 – 122	40	-47 – 142
3 - Uplands (England/Wales)	77 - 05	36	65	-73 – 118	49	-11 – 197
4 - Lowlands (Scotland)	Too few sites					
5 - Intermediate uplands/islands (Scotland)	Too few sites					
6 - True uplands (Scotland)	95 - 05	18			33	-62 – 758
GOVERNMENT REGIONS						
South West	Too few sites					
South East	Too few sites					
East of England	Too few sites					
East Midlands	Too few sites					
West Midlands	76 - 05	26	7	-66 – 288	47	-51 – 243
North West	Too few sites					
Yorkshire and Humber	Too few sites					
North East	Too few sites					

b) Change in relative bag density in the UK from 1961 to 2005 and from 1995 to 2005, respectively. Error bars represent 95% confidence intervals.



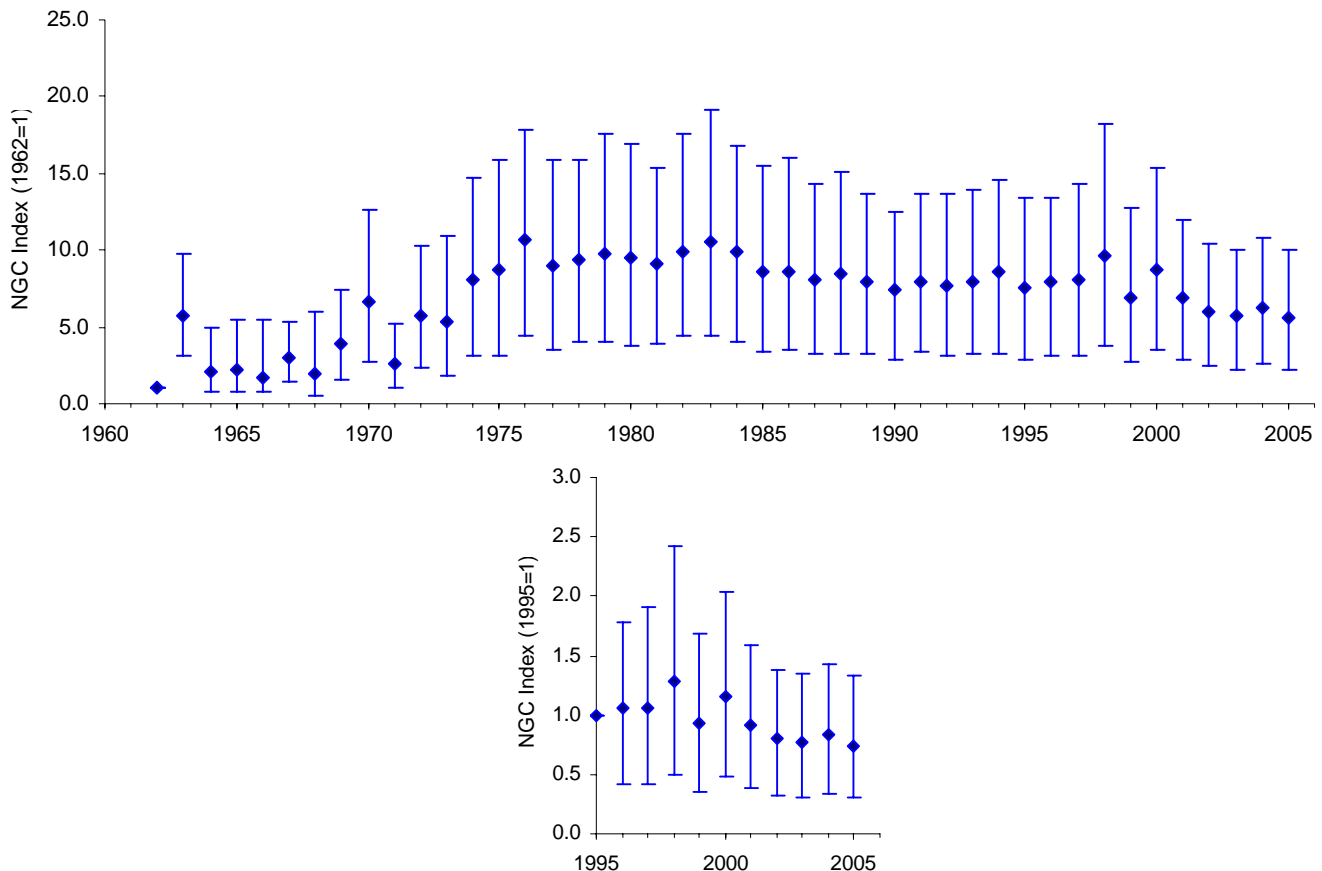
### 3.18 Mink *Mustela vison*

**Summary:** A significant increase in the index of bag density across the UK between 1961 and 2005 (the increase was rapid between 1962 and 1976), but a significant decrease between 1995 and 2005. Regionally, adequate data for trend analysis were available only from 1976 or 1980. This showed a decline in bag index for mainland Scotland, particularly over the last 10 years.

a) Sample size and % change of Mink bags.

	Sample	1962-2005		1995-2005	
		Change	95% CI	Change	95% CI
UNITED KINGDOM	468	197*	51 – 375	-28*	-38 – -17
COUNTRIES					
England	263	279*	27 – 504	-14	-31 – 8
Scotland	76 - 05 154			-36*	-52 – -20
Wales	95 - 05 11			-23	-77 – 55
ENVIRONMENTAL ZONES					
1 - Easterly lowlands (England/Wales)	76 - 05 123	38	-12 – 131	-8	-39 – 55
2 - Westerly lowlands (England/Wales)	76 - 05 68	-48	-71 – 1	-26	-47 – 3
3 - Uplands (England/Wales)	80 - 05 70	-51	-75 – 17	-26	-54 – 6
4 - Lowlands (Scotland)	76 - 05 57	-71*	-84 – -34	-58*	-72 – -40
5 - Intermediate uplands/islands (Scotland)	80 - 05 24	-59	-88 – 124	-14	-52 – 71
6 - True uplands (Scotland)	76 - 05 104	-46	-77 – 119	-47*	-64 – -20
GOVERNMENT REGIONS					
South West	Too few sites				
South East	76 - 05 40	-27	-70 – 37	-47	-82 – 24
East of England	95 - 05 30	36	-40 – 151	12	-39 – 198
East Midlands	95 - 05 12			36	-40 – 151
West Midlands	80 - 05 22	201*	34 – 593	12	-32 – 95
North West	80 - 05 24	-66*	-83 – -3	24	-18 – 172
Yorkshire and Humber	80 - 05 45	0	-60 – 125	-27	-60 – 14
North East	95 - 05 15	-39	-73 – 32	-39	-73 – 32

b) Change in relative bag density in the UK from 1961 to 2005 and from 1995 to 2005, respectively. Error bars represent 95% confidence intervals.



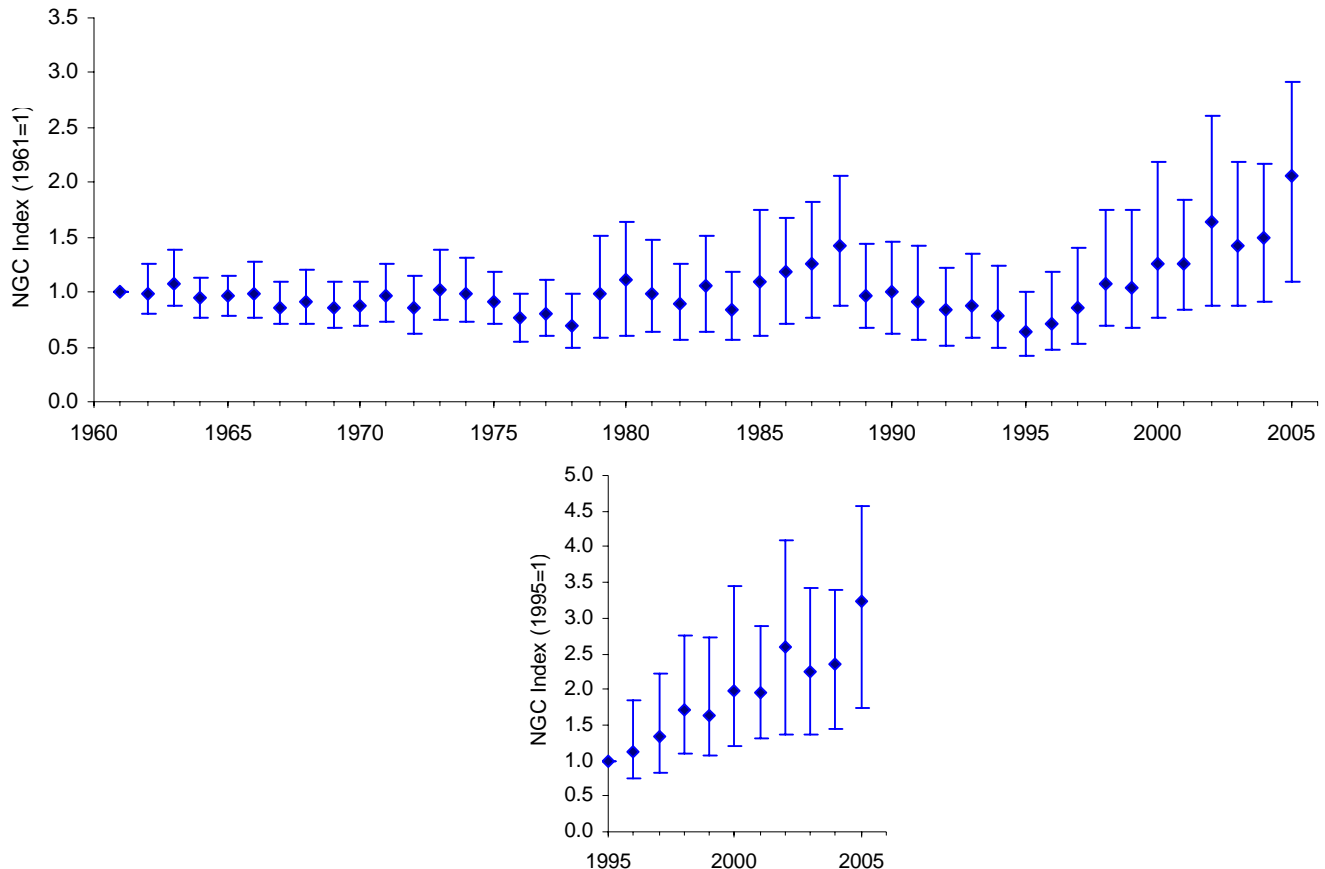
### 3.19 Brown Rat *Rattus norvegicus*

**Summary:** Broad stability in the index of bag density across the UK between 1961 and 1990, but a significant increase overall between 1995 and 2005 because of a doubling of the index since 1995. A rather cyclic pattern includes declines in bag index during the mid 1970s and again in the early 1990s. Regionally, there have been recent increases in the uplands and easterly lowlands of England and Wales.

a) Sample size and % change of Brown Rat bags.

	Sample	1961-2005		1995-2005	
		Change	95% CI	Change	95% CI
UNITED KINGDOM	821	74*	3 – 152	98*	44 – 138
COUNTRIES					
England	620	81*	29 – 162	112*	62 – 162
Scotland	161	133	-28 – 659	12	-30 – 108
Wales	30	-82*	-92 – -45	10	-53 – 80
ENVIRONMENTAL ZONES					
1 - Easterly lowlands (England/Wales)	347	82*	13 – 184	116*	53 – 167
2 - Westerly lowlands (England/Wales)	134	51	-49 – 146	74	-20 – 215
3 - Uplands (England/Wales)	86	-59	-92 – 243	92*	38 – 179
4 - Lowlands (Scotland)	57	148	-44 – 870	-33	-63 – 31
5 - Intermediate uplands/islands (Scotland)	30	-5	-36 – 16	40	-5 – 75
6 - True uplands (Scotland)	75	-61	-145 – 140	-18	-126 – 259
GOVERNMENT REGIONS					
South West	108	135	-24 – 233	84*	45 – 167
South East	124	317*	47 – 618	57	-15 – 97
East of England	127	32	-22 – 88	171*	38 – 237
East Midlands	60	-84*	-96 – -19	69	-11 – 213
West Midlands	58	161	-34 – 442	385*	13 – 601
North West	34	221	-58 – 755	44*	6 – 231
Yorkshire and Humber	82	-7	-62 – 101	142*	73 – 235
North East	27	-15	-91 – 341	87	-40 – 194

b) Change in relative bag density in the UK from 1961 to 2005 and from 1995 to 2005, respectively. Error bars represent 95% confidence intervals.



#### **4 Comparison of trends in Fox, Grey Squirrel and Rabbit with those reported by the BTO from the BBS and WBBS**

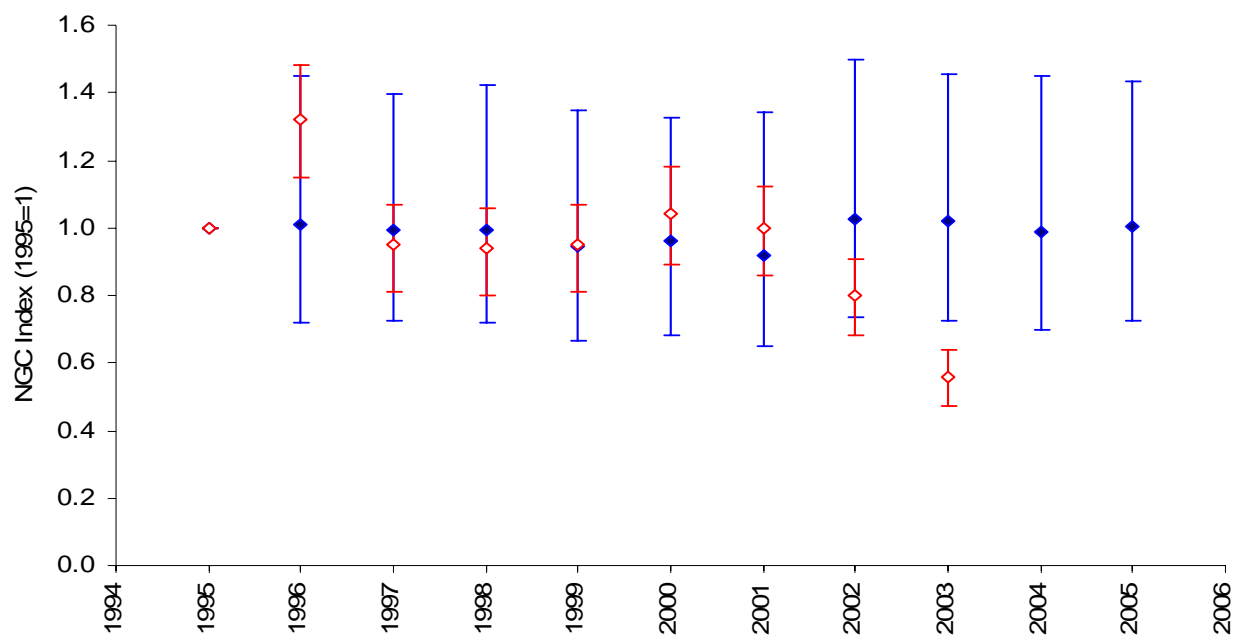
A comparison was made between the trends in Fox, Grey Squirrel and Rabbit reported in the BTO Research Report No. 404 'The production of population trends for UK mammals using BBS mammal data: 1995-2003 update' (June 2005), and the GCT trends for these species reproduced in Section 3 above. The BTO and GCT trends are superimposed for each species in Sections 4.1 to 4.3 below. One main difference between the BTO and the GCT analyses is the bootstrapping technique used by the GCT routine to produce confidence intervals. This may account for the difference in the respective error bar sizes.

## 4.1 Fox

The BTO reported a significant decline in abundance for Fox across the UK. The GCT reported a significant increase across the western lowlands of England and Wales but a significant decline across Scotland, resulting in a stable statistic for the UK as a whole.

	BTO 1995-2003				NGC 1995-2005		
	Sample	Change	P≤.05		Sample	Change	P≤.05
UNITED KINGDOM	227	-44	*		962	3	
COUNTRIES							
England	183	-42			635	12	*
Scotland					279	-14	*
Wales					34	13	
ENVIRONMENTAL ZONES							
Zone 1 - Easterly lowlands (England/Wales)	98	-45	*		376	9	
Zone 2 - Westerly lowlands (England/Wales)	81	-33	*		149	31	*
Zone 3 - Uplands (England/Wales)					108	5	
Zone 4 - Lowlands (Scotland)					81	-5	
Zone 5 - Intermediate uplands, islands (Scot)					45	-15	
Zone 6 - True uplands (Scotland)					153	-17	

The UK trend for Fox between 1995 and 2005 is depicted below. The mean and error bars in blue are those reported by the GCT and the mean and error bars in red reported by the BTO (to 2003 only). The two trends begin to diverge markedly from 2002.

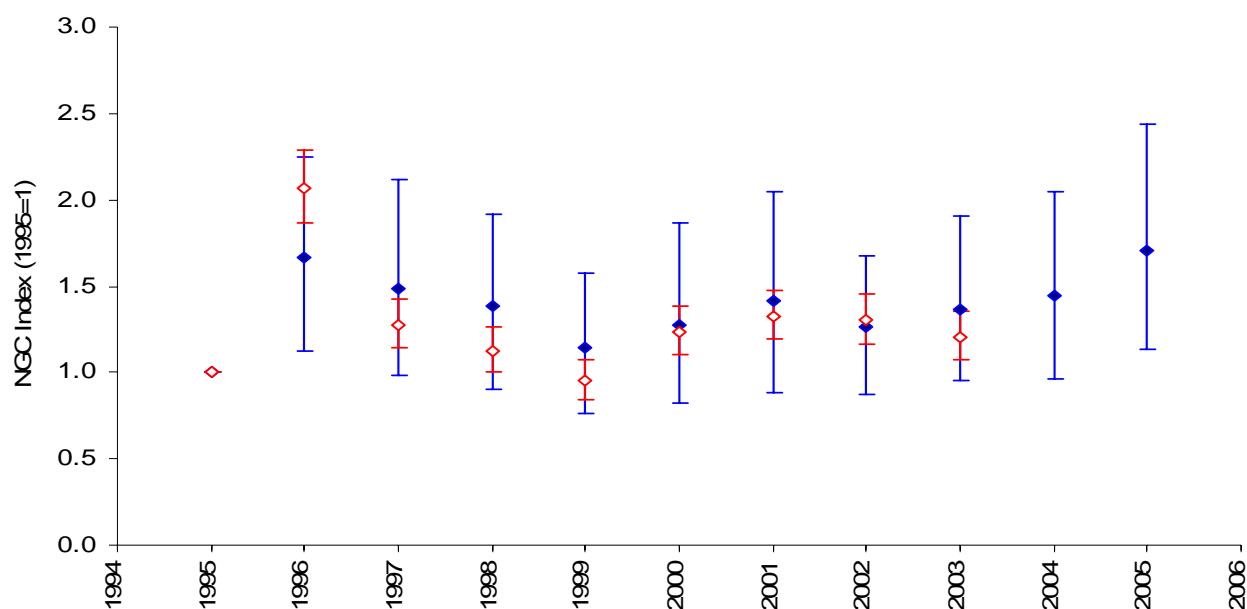


## 4.2 Grey Squirrel

The BTO and the GCT reported a significant increase in abundance from 1995.

	BTO 1995-2003				NGC 1995-2005		
	Sample	Change	P≤.05		Sample	Change	P≤.05
UNITED KINGDOM	472	20	*		775	34	*
COUNTRIES							
England	422	14	*		661	32	*
Scotland	39	37			75	34	
Wales					33	64	
ENVIRONMENTAL ZONES							
Zone 1 - Easterly lowlands (England/Wales)	235	5			380	29	*
Zone 2 - Westerly lowlands (England/Wales)	192	23	*		150	40	*
Zone 3 - Uplands (England/Wales)					81	65	*
Zone 4 - Lowlands (Scotland)					33	47	
Zone 5 - Intermediate uplands, islands (Scot)					13	361	*
Zone 6 - True uplands (Scotland)					27	11	

The UK trend for Grey Squirrel between 1995 and 2005 is depicted below. The mean and error bars in blue are those reported by the GCT and the mean and error bars in red reported by the BTO (to 2003 only). The BTO and GCT trends follow a similar path.

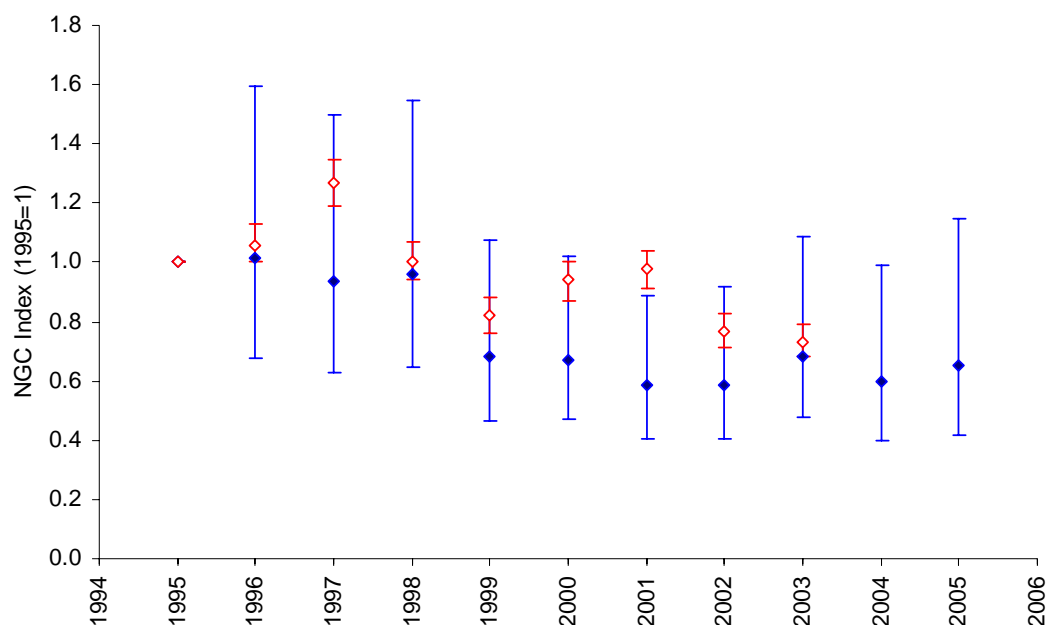


### 4.3 Rabbit

The BTO reported a significant decline in abundance between 1995 and 2003 across England and Scotland. The GCT reported a significant decline in bag density across the whole of Scotland.

	BTO 1995-2003				NGC 1995-2005		
	Sample	Change	P≤.05		Sample	Change	P≤.05
UNITED KINGDOM	1057	-27			1186	-24	*
COUNTRIES							
England	849	-11	*		847	18	
Scotland	99	-60	*		282	-65	*
Wales	73	11			41	-21	
ENVIRONMENTAL ZONES							
Zone 1 - Easterly lowlands (England/Wales)	465	-6			491	20	
Zone 2 - Westerly lowlands (England/Wales)	357	-6			173	-28	
Zone 3 - Uplands (England/Wales)	103	-19			102	27	
Zone 4 - Lowlands (Scotland)	58	-70	*		99	-66	*
Zone 5 - Intermediate uplands, islands (Scot)					47	-69	*
Zone 6 - True uplands (Scotland)					138	-162	*

The UK trend for Rabbit between 1995 and 2005 is depicted below. The mean and error bars in blue are those reported by the GCT and the mean and error bars in red reported by the BTO (to 2003 only). The BTO and GCT indices show similar declining trends.

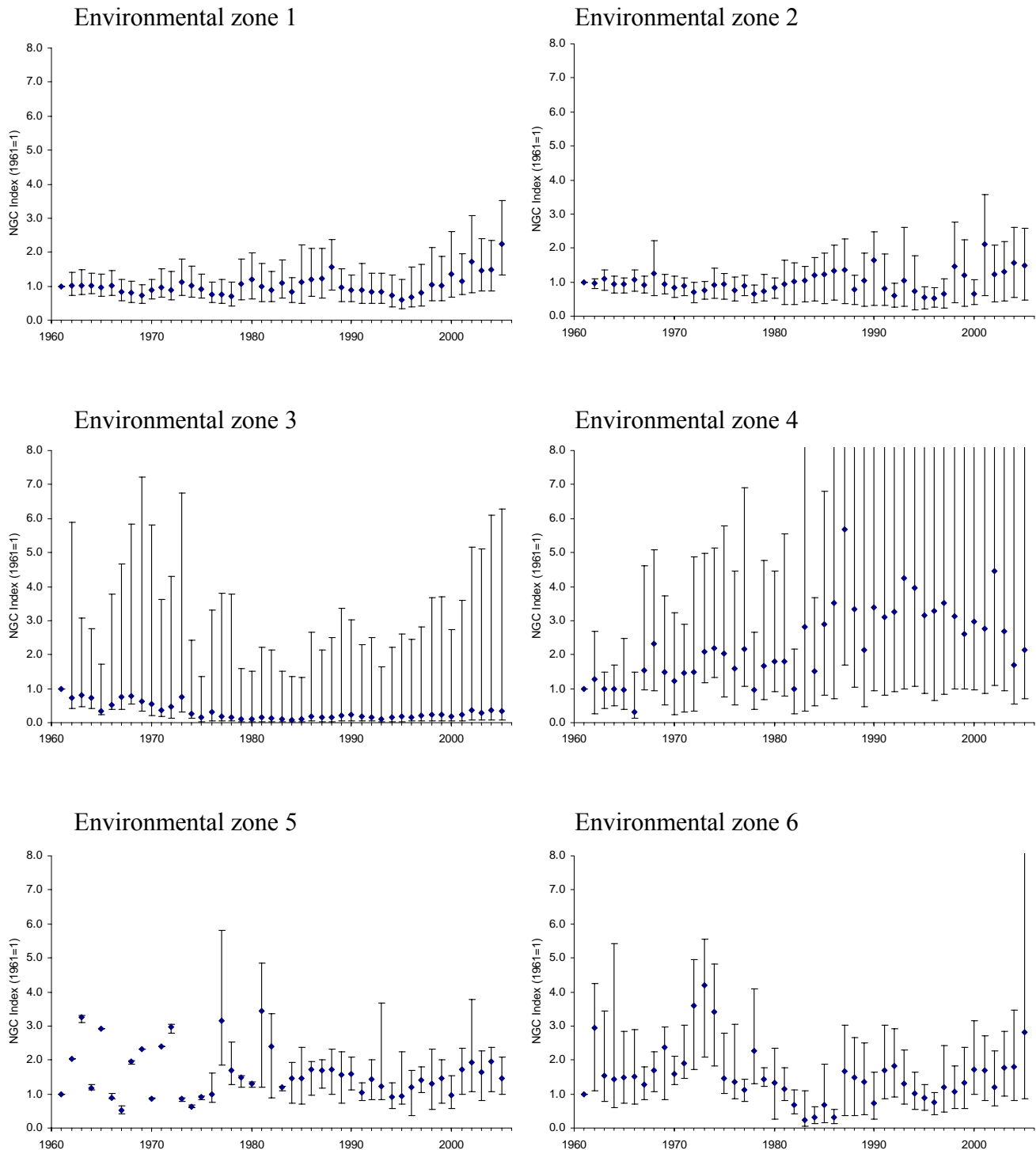


## 5 Illustrative graphs of Brown Rat, Rabbit and Stoat bag trends since 1961 for each of the environmental zones

The map in Section 3 (Figure 3.0) shows the distribution of the six environmental zones across the UK.

### 5.1 Brown Rat

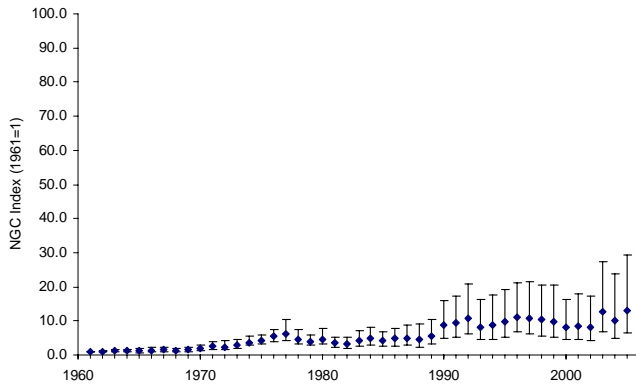
The table below show the trends in the Brown Rat bag index for each of the six environmental zones between 1961 and 2005. It shows recent increases in the index of bag density in the uplands and easterly lowlands of England and Wales.



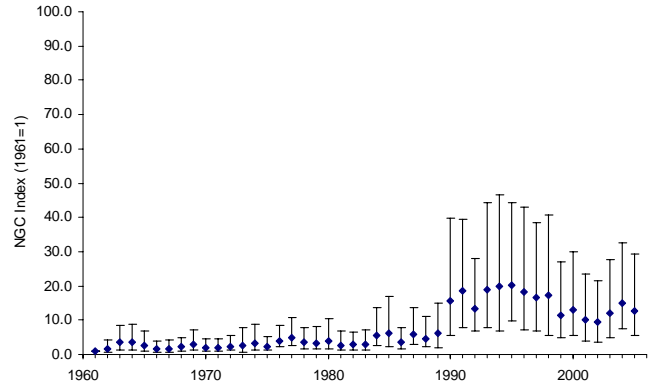
## 5.2 Rabbit

The table below show the trends in the Rabbit bag index for each of the six environmental zones between 1961 and 2005. It shows significant increases in the index of bag density across all zones until the mid-1990s but some retracing thereafter across the UK, particularly so across Scotland.

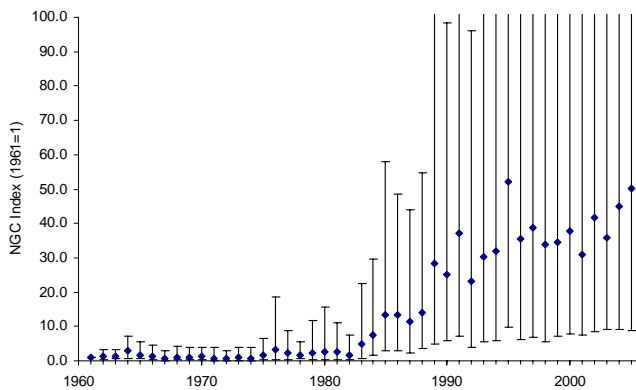
Environmental zone 1



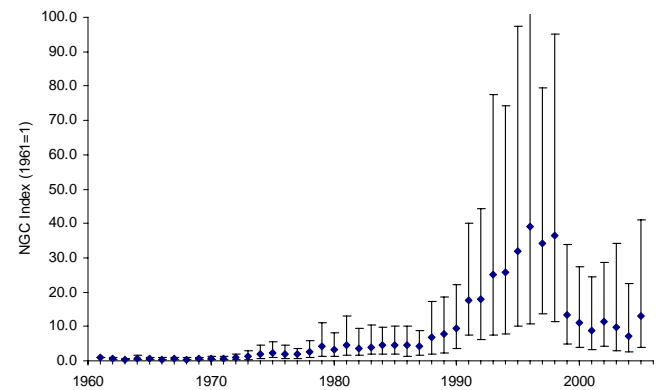
Environmental zone 2



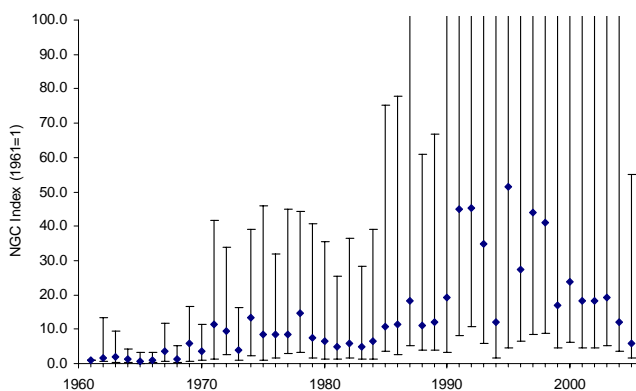
Environmental zone 3



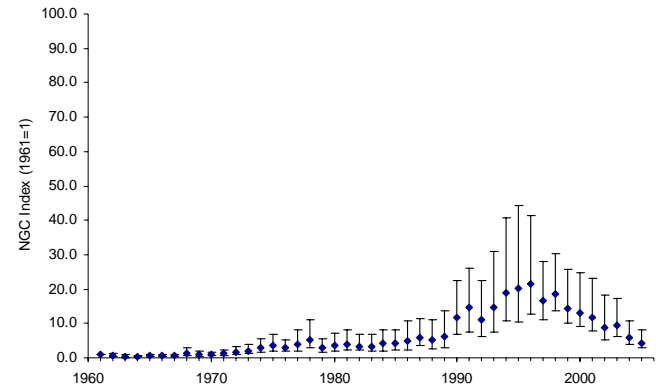
Environmental zone 4



Environmental zone 5



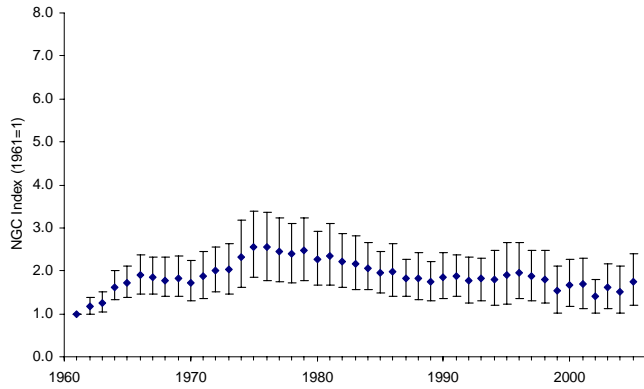
Environmental zone 6



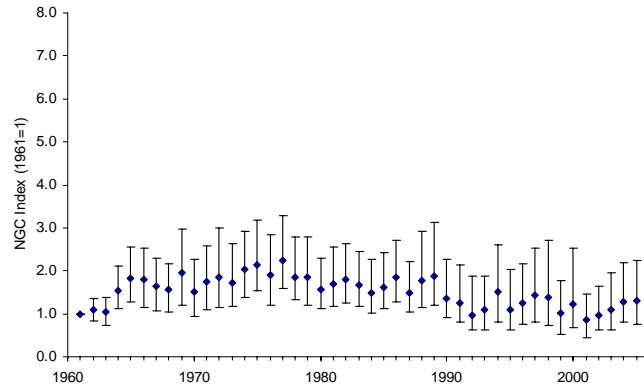
### 5.3 Stoat

The table below show the trends in the Stoat bag index for each of the six environmental zones between 1961 and 2005. It shows significant increases in the index of bag density across upland areas from the mid-1990s.

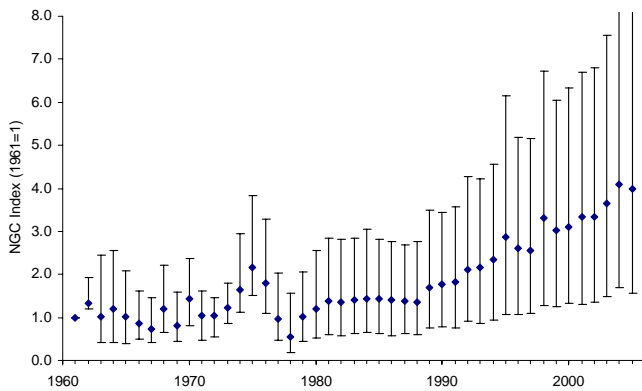
Environmental zone 1



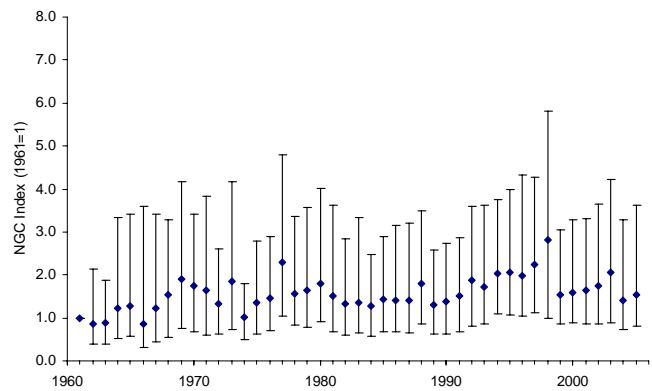
Environmental zone 2



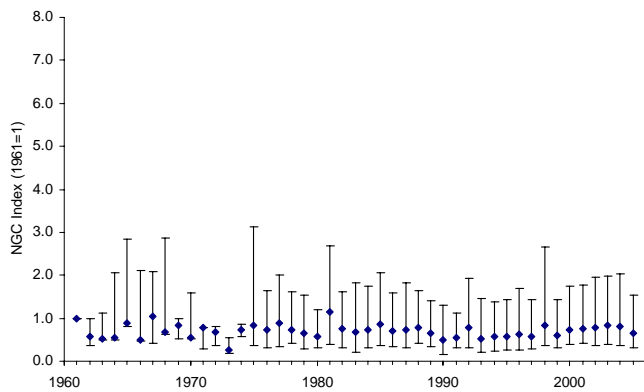
Environmental zone 3



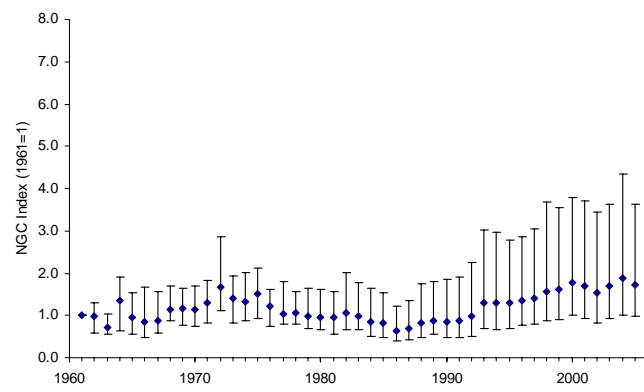
Environmental zone 4



Environmental zone 5



Environmental zone 6



## **6 Temporal changes in UK geographical distribution for Stoat, Weasel, Polecat and Mink**

Data were extracted for 1194 estates submitting bag records between 1960 and 1999 inclusive. The spatial and temporal changes in mustelid bag density were examined by calculating the mean bag density for each vice-county and each of the ten decades 1960-69, 1970-79, 1980-89 and 1990-99. The mean was a weighted average of all corresponding annual density values, using annual estate area as the weight. The results of the analysis are reproduced on four maps, each corresponding to a decade. Within each map, the vice-counties are shaded according to their mean bag density in that decade; the palest shade represents the lowest density, the darkest one the highest density (logarithmic scale).

### **6.1 Stoat**

There is no large variation in the county distribution of Stoat across Britain. The maps (Figure 4.1) indicate increases in the bag densities across eastern and southern Scotland and northern England, but with fluctuating densities elsewhere across England and in Wales.

### **6.2 Weasel**

Weasel too shows no large variation in the county distribution across Britain. However, the maps (Figure 4.2) suggest that increases in southern Scotland are offset by decreases elsewhere across southern England and in Wales.

### **6.3 Polecat**

Polecat, historically widespread and abundant across England, Scotland and Wales, declined in the 18<sup>th</sup> and 19<sup>th</sup> centuries in response to the development of driven game shooting and its pest status among country people who kept poultry. By the beginning of the 20<sup>th</sup> century Polecat was restricted to a small area around Aberystwyth. Since the Second World War, the species has spread dramatically and at the present time occupies much of Scotland and central and northern England (Figure 4.3).

### **6.4 Mink**

Feral Mink became established during the 1950s following the post-war activity of mink farming and inevitable escapes plus intentional releases. The maps (Figure 4.4) show the spread of Mink reaching nearly every corner of England, Scotland and Wales by the final decade of the century.

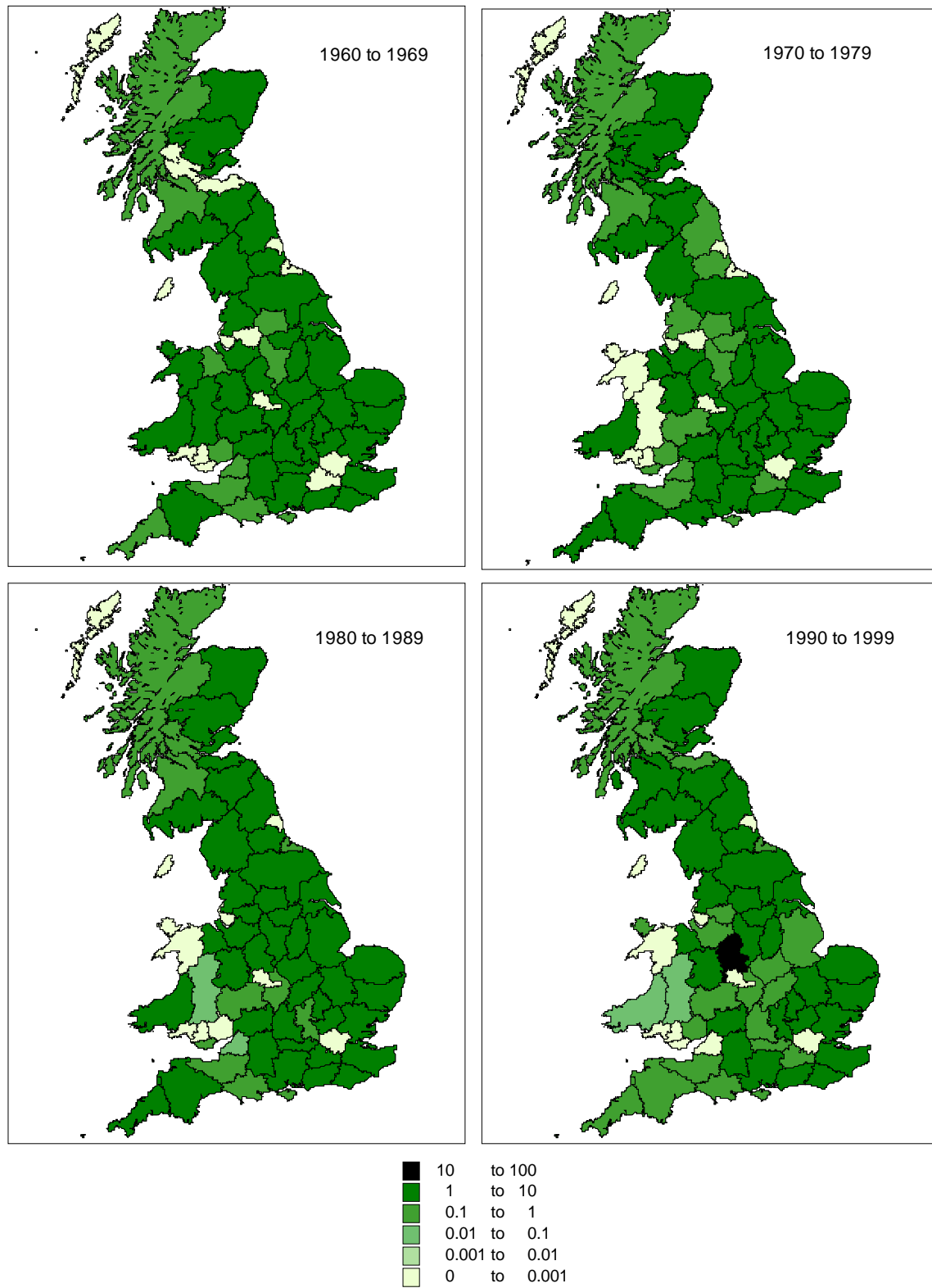


Figure 6.1. Stoat bag density (number shot per 100 ha) synoptically by county and by decade from 1960 to 1999.

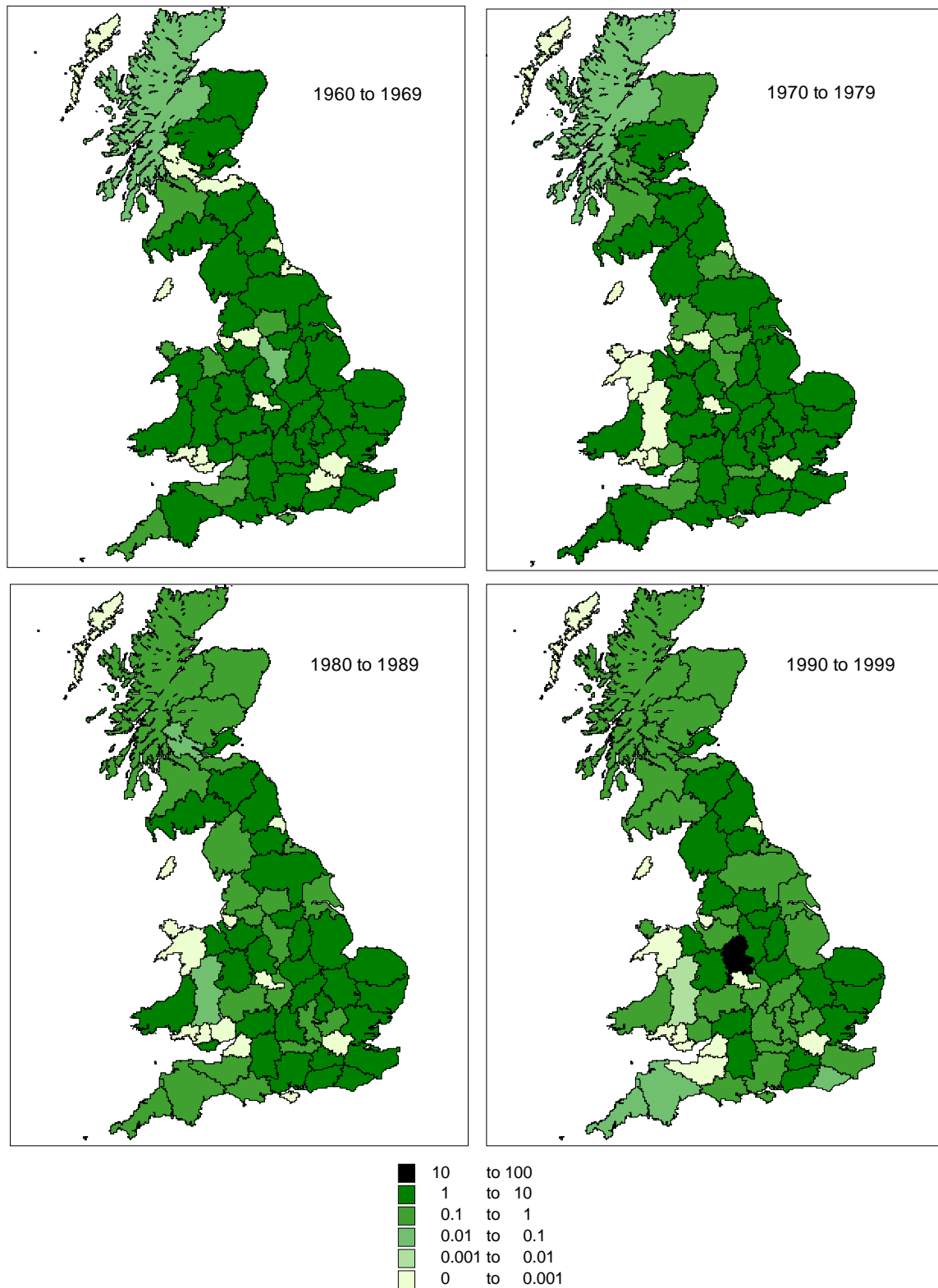


Figure 6.2. Weasel bag density (number shot per 100 ha) synoptically by county and by decade from 1960 to 1999.

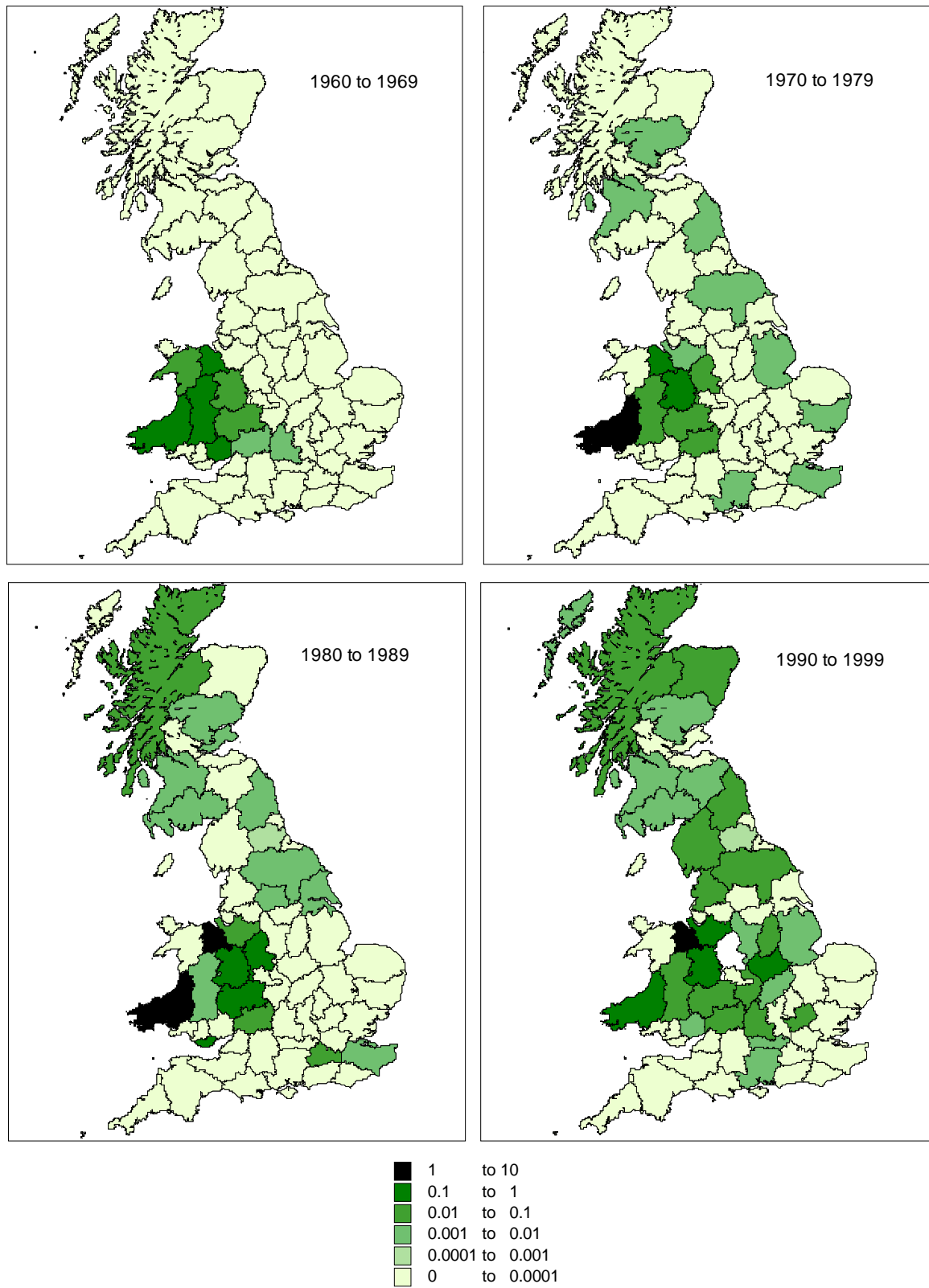


Figure 6.3. Polecat bag density (number shot per 100 ha) synoptically by county and by decade from 1960 to 1999.

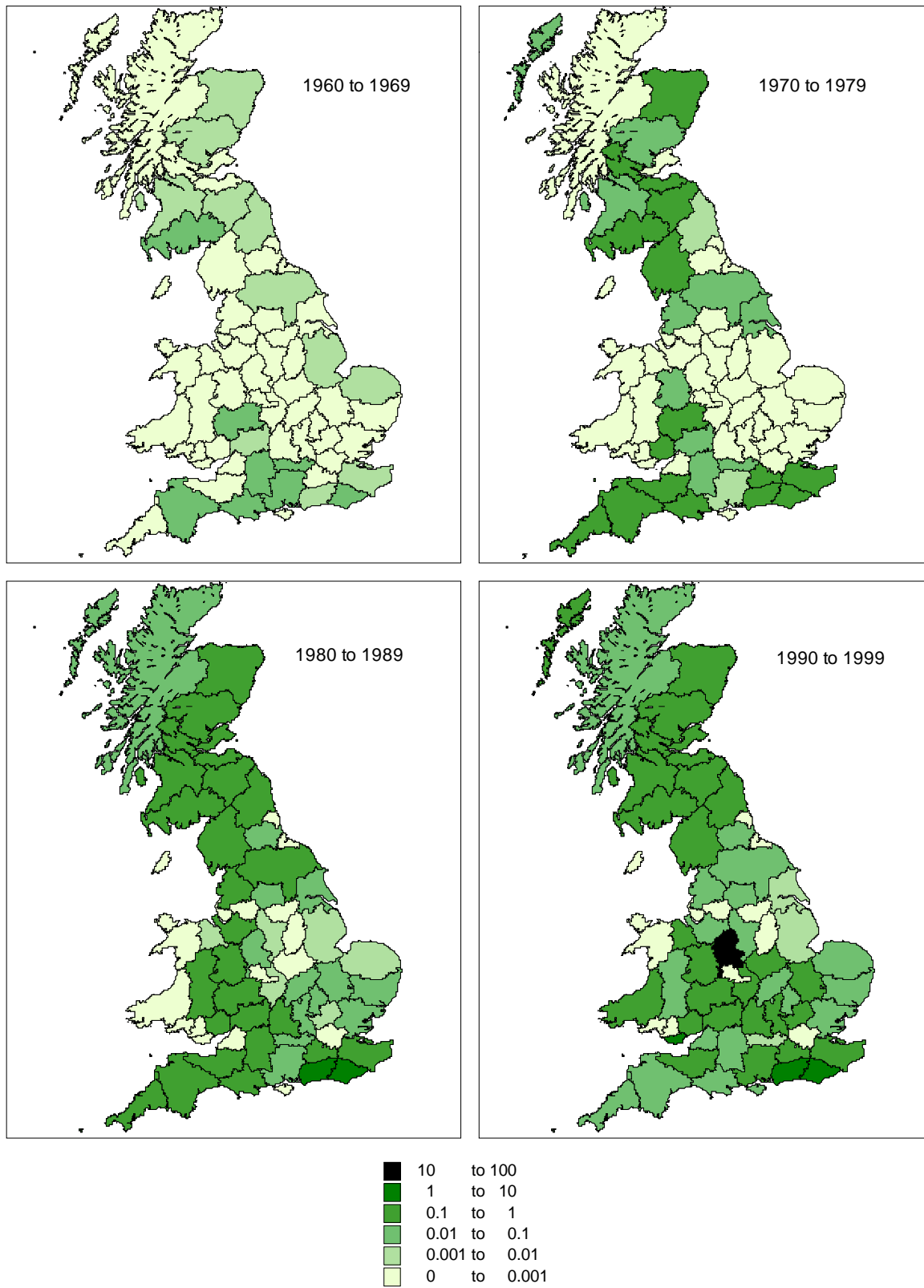


Figure 6.4. Mink bag density (number shot per 100 ha) synoptically by county and by decade from 1960 to 1999.

## 7 Historical sample sizes of game and predator species over the period 1801 to 1960 at UK and country level

The tables below list historical sample sizes by species for the four quarter centuries between 1801 and 1900 and for the six decades between 1901 and 1960 at the UK and country levels. The sample sizes are the number of individual estates contributing bag data for a given species over the associated period.

### 7.1a Number of shoots providing bag data on game species (UK)

	Rabbit	Brown Hare	Blue Hare	Roe Deer	Red Deer	Sika Deer	Fallow Deer	Muntjac	Water Deer	Wild Boar
1801 to 1825	4	5	0	0	0	0	0	0	0	0
1826 to 1850	10	13	3	2	0	0	0	0	0	0
1851 to 1875	47	46	18	2	10	0	2	0	0	0
1876 to 1900	175	136	56	10	17	0	0	0	0	0
1901 to 1910	198	153	60	10	18	0	0	0	0	0
1911 to 1920	246	191	77	12	20	0	0	0	0	0
1921 to 1930	351	288	87	15	19	0	0	0	0	0
1931 to 1940	372	317	94	21	19	0	1	0	0	0
1941 to 1950	170	132	68	14	21	1	0	1	0	0
1951 to 1960	191	162	83	16	23	0	0	0	0	0

### 7.1b Number of shoots providing bag data on predator species (UK)

	Hedgehog	Weasel	Stoat	Polecat	Mink	Fox	Feral Cat	Wild Cat	Brown Rat	Grey Squirrel
1801 to 1825	0	0	0	0	0	0	0	0	0	0
1826 to 1850	0	0	0	0	0	0	0	0	0	0
1851 to 1875	0	0	0	0	0	0	0	0	0	0
1876 to 1900	0	2	0	0	0	0	1	0	0	0
1901 to 1910	1	6	4	0	0	2	0	0	1	1
1911 to 1920	3	15	6	0	0	13	2	0	3	1
1921 to 1930	6	20	10	0	0	15	5	0	4	1
1931 to 1940	7	19	12	0	0	17	4	0	4	0
1941 to 1950	4	19	13	0	0	22	3	0	3	3
1951 to 1960	6	21	13	0	0	26	5	0	5	4

### 7.2a Number of shoots providing bag data on game species (England)

	Rabbit	Brown Hare	Blue Hare	Roe Deer	Red Deer	Sika Deer	Fallow Deer	Muntjac	Water Deer	Wild Boar
1801 to 1825	3	3	0	0	0	0	0	0	0	0
1826 to 1850	6	9	0	0	0	0	0	0	0	0
1851 to 1875	13	19	0	0	0	0	0	0	0	0
1876 to 1900	61	72	1	0	0	0	0	0	0	0
1901 to 1910	74	80	1	0	0	0	0	0	0	0
1911 to 1920	95	101	2	0	0	0	0	0	0	0
1921 to 1930	172	180	3	1	0	0	0	0	0	0
1931 to 1940	192	200	2	3	0	0	0	0	0	0
1941 to 1950	56	65	0	1	0	0	0	1	0	0
1951 to 1960	77	90	0	1	0	0	0	0	0	0

### 7.2b Number of shoots providing bag data on predator species (England)

	Hedgehog	Weasel	Stoat	Polecat	Mink	Fox	Feral Cat	Wild Cat	Brown Rat	Grey Squirrel
1801 to 1825	0	0	0	0	0	0	0	0	0	0
1826 to 1850	0	0	0	0	0	0	0	0	0	0
1851 to 1875	0	0	0	0	0	0	0	0	0	0
1876 to 1900	0	0	0	0	0	0	0	0	0	0
1901 to 1910	1	1	1	0	0	1	0	0	1	1
1911 to 1920	1	1	1	0	0	1	0	0	1	1
1921 to 1930	3	4	4	0	0	1	2	0	3	0
1931 to 1940	3	3	3	0	0	1	1	0	3	0
1941 to 1950	2	2	2	0	0	1	1	0	2	1
1951 to 1960	3	3	3	0	0	2	2	0	3	2

### 7.3a Number of shoots providing bag data on game species (Wales)

	Rabbit	Brown Hare	Blue Hare	Roe Deer	Red Deer	Sika Deer	Fallow Deer	Muntjac	Water Deer	Wild Boar
1801 to 1825	1	2	0	0	0	0	0	0	0	0
1826 to 1850	3	4	1	1	0	0	0	0	0	0
1851 to 1875	16	18	1	0	0	0	0	0	0	0
1876 to 1900	31	31	1	0	0	0	0	0	0	0
1901 to 1910	28	29	0	0	0	0	0	0	0	0
1911 to 1920	28	30	0	0	0	0	0	0	0	0
1921 to 1930	35	32	0	0	0	0	0	0	0	0
1931 to 1940	30	31	0	0	0	0	0	0	0	0
1941 to 1950	17	16	0	0	0	0	0	0	0	0
1951 to 1960	9	8	0	0	0	0	0	0	0	0

### 7.3b Number of shoots providing bag data on predator species (Wales)

	Hedgehog	Weasel	Stoat	Polecat	Mink	Fox	Feral Cat	Wild Cat	Brown Rat	Grey Squirrel
1801 to 1825	0	0	0	0	0	0	0	0	0	0
1826 to 1850	0	0	0	0	0	0	0	0	0	0
1851 to 1875	0	0	0	0	0	0	0	0	0	0
1876 to 1900	0	0	0	0	0	0	0	0	0	0
1901 to 1910	0	1	0	0	0	0	0	0	0	0
1911 to 1920	1	1	1	0	0	0	1	0	1	0
1921 to 1930	2	2	2	0	0	2	2	0	1	1
1931 to 1940	2	2	2	0	0	2	2	0	1	0
1941 to 1950	2	2	2	0	0	2	2	0	1	2
1951 to 1960	2	2	2	0	0	2	2	0	1	2

#### 7.4a Number of shoots providing bag data on game species (Scotland)

	Rabbit	Brown Hare	Blue Hare	Roe Deer	Red Deer	Sika Deer	Fallow Deer	Muntjac	Water Deer	Wild Boar
1801 to 1825	0	0	0	0	0	0	0	0	0	0
1826 to 1850	1	0	2	1	0	0	0	0	0	0
1851 to 1875	18	9	17	2	10	0	2	0	0	0
1876 to 1900	82	33	54	10	17	0	0	0	0	0
1901 to 1910	95	44	59	10	18	0	0	0	0	0
1911 to 1920	122	60	75	12	20	0	0	0	0	0
1921 to 1930	143	76	84	14	19	0	0	0	0	0
1931 to 1940	149	86	92	18	19	0	1	0	0	0
1941 to 1950	96	51	68	13	21	1	0	0	0	0
1951 to 1960	104	64	83	15	23	0	0	0	0	0

#### 7.4b Number of shoots providing bag data on predator species (Scotland)

	Hedgehog	Weasel	Stoat	Polecat	Mink	Fox	Feral Cat	Wild Cat	Brown Rat	Grey Squirrel
1801 to 1825	0	0	0	0	0	0	0	0	0	0
1826 to 1850	0	0	0	0	0	0	0	0	0	0
1851 to 1875	0	0	0	0	0	0	0	0	0	0
1876 to 1900	0	2	0	0	0	0	1	0	0	0
1901 to 1910	0	4	3	0	0	1	0	0	0	0
1911 to 1920	1	13	4	0	0	12	1	0	1	0
1921 to 1930	1	14	4	0	0	12	1	0	0	0
1931 to 1940	2	14	7	0	0	14	1	0	0	0
1941 to 1950	0	15	9	0	0	19	0	0	0	0
1951 to 1960	1	16	8	0	0	22	1	0	1	0

### 7.5a Number of shoots providing bag data on game species (Northern Ireland)

	Rabbit	Brown Hare	Blue Hare	Roe Deer	Red Deer	Sika Deer	Fallow Deer	Muntjac	Water Deer	Wild Boar
1801 to 1825	0	0	0	0	0	0	0	0	0	0
1826 to 1850	0	0	0	0	0	0	0	0	0	0
1851 to 1875	0	0	0	0	0	0	0	0	0	0
1876 to 1900	1	0	0	0	0	0	0	0	0	0
1901 to 1910	1	0	0	0	0	0	0	0	0	0
1911 to 1920	1	0	0	0	0	0	0	0	0	0
1921 to 1930	1	0	0	0	0	0	0	0	0	0
1931 to 1940	1	0	0	0	0	0	0	0	0	0
1941 to 1950	1	0	0	0	0	0	0	0	0	0
1951 to 1960	1	0	0	0	0	0	0	0	0	0

### 7.5b Number of shoots providing bag data on predator species (Northern Ireland)

	Hedgehog	Weasel	Stoat	Polecat	Mink	Fox	Feral Cat	Wild Cat	Brown Rat	Grey Squirrel
1801 to 1825	0	0	0	0	0	0	0	0	0	0
1826 to 1850	0	0	0	0	0	0	0	0	0	0
1851 to 1875	0	0	0	0	0	0	0	0	0	0
1876 to 1900	0	0	0	0	0	0	0	0	0	0
1901 to 1910	0	0	0	0	0	0	0	0	0	0
1911 to 1920	0	0	0	0	0	0	0	0	0	0
1921 to 1930	0	0	0	0	0	0	0	0	0	0
1931 to 1940	0	0	0	0	0	0	0	0	0	0
1941 to 1950	0	0	0	0	0	0	0	0	0	0
1951 to 1960	0	0	0	0	0	0	0	0	0	0

## 8 Interpretation of results from the National Gamebag Census

The question of whether species are increasing or declining in abundance is of central importance in species conservation and management. Surveillance or monitoring programmes should be capable of identifying long-term trends, and of distinguishing between long-term trends and short-term fluctuations that are the result of natural between-year variation in breeding success and mortality. In the case of bag data, use of a GLM framework incorporating the estimation of a set of site-specific factors in addition to year-specific factors allows average bags to vary between sites (shoots); annual variation is then modelled in a parallel fashion across locations on a logarithmic scale. In practice it is likely that annual trends differ between estates, and this variation is captured within the 95% confidence limits of the annual indices through the bootstrapping procedure.

Trends derived from bags are, however, unusual because the data analysed represent numbers of animals killed rather counts of live animals. It is important to understand this distinction, because there are potential biases associated with bag data that do not occur with count data, and that could obscure an underlying trend or create the appearance of a change in abundance where none has occurred. We review below the main potential sources of bias that need to be borne in mind when interpreting the trends presented in this report.

The most important one is the fact that the number of animals killed is a function both of the abundance of animals on the ground and of the amount of effort invested in culling them. These two factors are therefore confounded in bag data, so it is not necessarily true that the number of animals killed is a reliable index of population density. For game animals, there will be changes on an annual basis in the number of shooting days per site and number of shooters per day that will cause effort to vary over time. For predatory species, the number of gamekeepers per site, number of traps set, type of trap and duration of trapping will all influence effort and contribute to variation in numbers of animals killed. In practice, it appears that much of this variation adds noise to an underlying trend that reflects population density (Whitlock et al. 2003). The comparisons with trends obtained from other surveys such as the BBS, for species in common, are one way in which it is possible to be alerted to the possible onset of bias caused by changes in effort.

Legislation, which can vary in its implementation on country basis, often initiates changes in shooting and culling practices. For instance, changes in legislation have progressively outlawed a number of fox control methods over the last 100 years, primarily because they have been judged inhumane. Variability in pest control methods over time resulting from either changing legislation or improvements in efficiency influences effort, and hence bags, over varying timescales. Developments in predator control practice can also effect a change in the seasonality of culling. In recent decades, there has been a shift away from culling of foxes in the spring and summer using snares and terriers to autumn and winter culling by lamping with a rifle. This is likely to affect fox bags because the culling period now coincides with an annual peak in fox density and dispersal before high natural mortality occurs over the winter (Reynolds 2000). Legislation may also affect the reliability of NGC data for species afforded statutory protection, for example protection of the wildcat and partial protection of the hedgehog under the 1981 Wildlife and Countryside Act, by causing a systematic decrease in the numbers recorded on predator sheets.

Even if the direction and magnitude of changes in effort were known, another factor that may lead to exaggeration of trends is the possibility that the relationship between yield and effort may not be linear but density-dependent, i.e. effort may be related to abundance. This would occur if less effort is invested in culling in years of low density. This would lead to proportionally fewer individuals of a species being killed as numbers on the ground decline, and consequently a steeper decline in bags than in actual density. Hudson (1992) noted that bags of Red Grouse *Lagopus Lagopus* tended to under-emphasize the extent of any decline in grouse numbers, because estates where grouse stocks fell to a level where grouse shooting ceased in any one year may not provide bag records. For predators on shooting estates, less effort may also be invested in control if abundance is perceived to be lower in a particular year. However, predator control tends to be prophylactic, i.e. independent of predator density in a particular year. At high predator density, trap saturation may also be possible, especially for single-catch traps, although it is unlikely given the legislative requirement for daily checking of traps by keepers and typically low trapping rates.

Culling can itself be the cause of changes in the abundance of a species, which poses a problem because the method of data collection then has a direct impact on the quantity it intends to measure. It is impossible to assess the implications of this for population dynamics without some *a priori* knowledge of population size and demography. The proportion of a population removed by hunting may be considerable: Hutchings & Harris (1996) estimated that around 60% of a local Brown Hare population may be removed by February culls. Hunting can also alter the age and sex structure of a population: this is particularly well documented in the fisheries literature, where gear selectivity has resulted in lower mean size and mean age of sexual maturity (Cook et al. 1997, O'Brien 1999). It is, however, unlikely that such extreme effects would be observed in mammalian species in the UK, as harvesting pressure is generally lower than that of commercial fisheries. It is possible that hunting could affect the sex structure of mammal populations. For example, the catchability of mustelids using tunnel traps is dependent on their mass, which varies according to gender: females are the lighter sex and may not spring a trap unless it is lightly set (Anon. 1994).

More generally, there are two other issues that need to be taken into consideration when interpreting the trends arising from analysis of NGC bag data. The first is that for some pest species, it is impossible to record the numbers killed over a year accurately because mortality is unobserved and hence unquantifiable. In such cases numbers recorded on NGC forms are either best guesses or observed (i.e. minimum) numbers. This applies especially to Brown Rat and Grey Squirrel, for which poisoning is legal.

The second issue is representativeness. The sites contributing records to the NGC do so on a voluntary basis, and cannot be assumed to represent a random sample of shoots across the UK. Even if they were, shoots would also need to be typical of the British countryside in general. Landowners participating in field sports such as fox hunting and gamebird shooting were found to maintain more established woodland and plant more new woodland and hedgerows than non-participants (Oldfield et al. 2003), and in the uplands, moors managed for grouse shooting retained considerably more heather than non-managed moors (Robertson et al. 2001). Owing to these management practices, estates are likely to be atypical with respect to the densities of game and non-game species they support, as they offer good-quality habitat in terms of food resources, shelter and breeding requirements, but also carry out predator control. Nevertheless, any bias induced by non-randomness is probably reduced by the fact that the same sites contribute records over many years, and results from the same site are directly

comparable between years. Toms et al. (1999) considered that using the same sites in consecutive surveys may avoid bias if there is a subjective element in the choice of sampling sites and this subjective element does not remain constant over time. They also emphasized the powerful advantage of historical continuity in improving the precision of estimates of change as it removes the component of error variance associated with site. The NGC thus benefits greatly from its historical continuity, which is reinforced by constant attempts to obtain historical records from new participants.

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