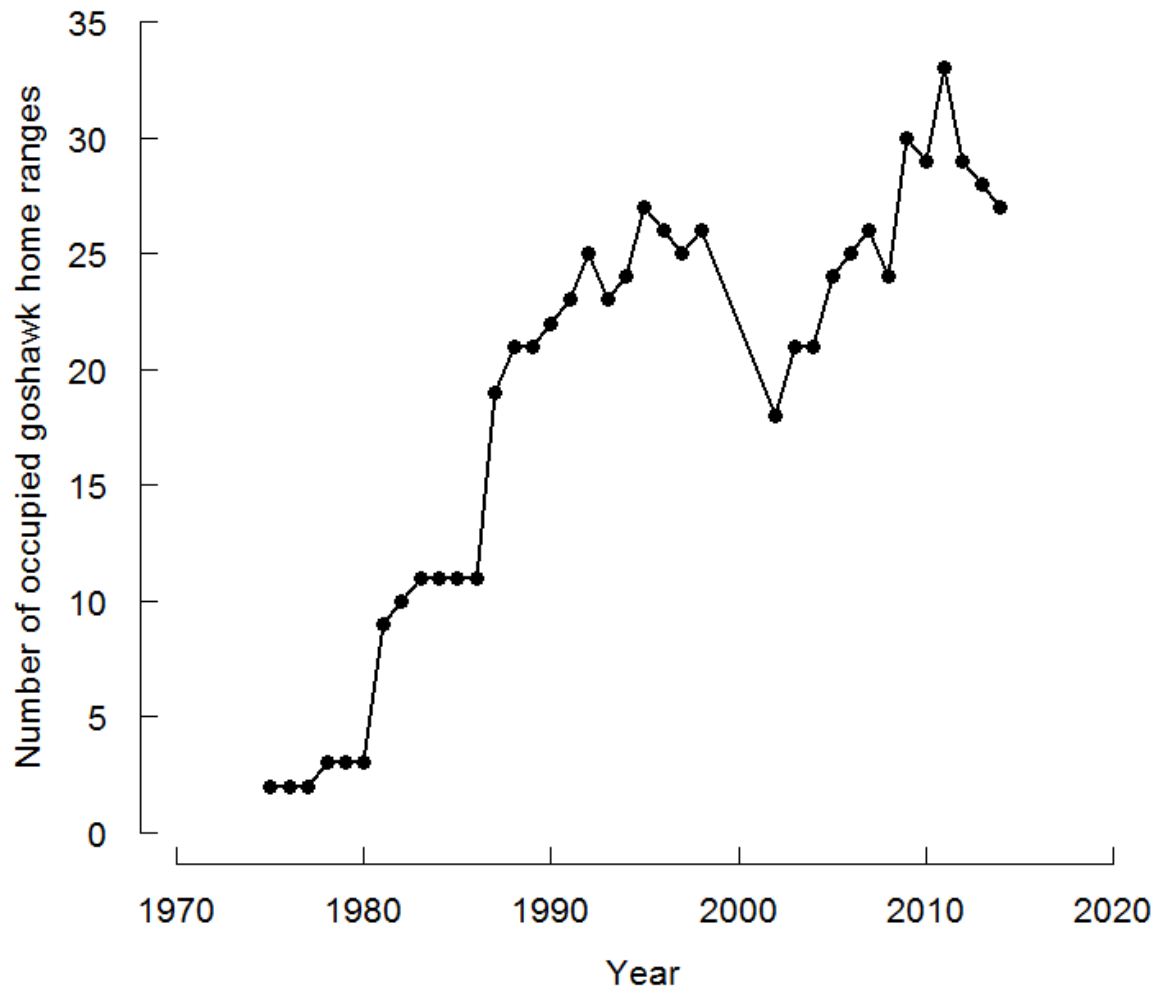


**Supplementary material**

**Appendix 1:** The number of occupied northern goshawk home-ranges in Kielder Forest, UK



**Appendix 2:** The average number of kestrels, tawny owls and sparrowhawks killed by the goshawk population each year

To estimate the average number of each species killed by the goshawk population each year, we first calculated the average number of each species killed per pair of goshawks, each year when 1-14, 15-24 and 25+ goshawk home-ranges were occupied, using the following equation taken from Petty *et al.* (2003).

$$IK = (CF + CM + CY) * (PT) / M$$

IK is the estimated number of individuals killed by a pair of goshawks between March and August (184 days). CF = estimated total food consumption of a female goshawk during the breeding season (189g of food per day \* 184 days). CM = total food consumption of a male goshawk during the breeding season (133g of food per day \* 184 days). The daily food consumption values used for male and female goshawk are the same as those used by Petty *et al.* (2003), originally calculated by Kenward *et al.* (1981). CY = total food consumption of young goshawks (i.e. offspring) during the breeding season (161g of food per day (CF+CM/2) \* 108 days \* mean fledged brood size of breeding pairs). The mean fledged brood size of goshawks was 2.19 in years when fewer than 15 home-ranges were occupied, 1.93 when 15-24 home-ranges were occupied and 1.31 when 25 or more home-ranges were occupied. The CY estimate assumes that young goshawks: 1) hatch around mid-May; 2) do not leave their natal territory until August; and 3) that juveniles have the same overall food intake as adults. Although young nestlings require less food than adults, older nestlings require more, such that when averaged over the entire period nestling food intake can be assumed to be equivalent to that of adults. M = average mass of the prey species. We used an average mass of 208g for kestrel (Ratcliffe 1993); 470g for tawny owl and 205g for sparrowhawk (Robinson 2005). PT = proportion biomass of the prey species in the diet. We used the dietary data to estimate of the proportion biomass of each of the three mesopredator species in goshawk diet for each of the three goshawk abundance categories (i.e. using pooled annual diet data collected when the number of occupied goshawk home-ranges was 1-14, 15-24 and 25+). This average proportion was then used in the above equation to calculate the number of individuals of each species killed during the breeding season by a goshawk pair. To get an estimate of the total number of each species killed each year by the entire goshawk population and how that has changed as the goshawk population increased in abundance, we multiplied our estimate of the number of individuals killed by a pair of goshawks (IK) by the average number of home-ranges occupied by goshawks for each of the goshawk abundance categories. The average number of home-ranges occupied in each goshawk abundance category was estimated to be 6.5, 21.75 and 27.38 when respectively 1-14, 15-24 and 25+ goshawk home-ranges were occupied.

**Appendix 3:** List of the species killed by northern goshawks in Kielder Forest, and the taxonomic prey group they were assigned to, along with the body mass used for each species to estimate their percentage biomass contribution to goshawk diet. We were not always able to differentiate between male and female prey remains, consequently we used the midpoint between the average mass for males and females in our biomass estimates. Body mass estimates for birds were obtained from the British Trust for Ornithology ([www.bto.org/birdfacts](http://www.bto.org/birdfacts)) and mass estimates for mammals were obtained from the British Mammal Society (<http://www.mammal.org.uk>).

Prey group	Common name	Mass (g)
Corvid	Carrion crow/rook ( <i>Corvus corone/C. frugilegus</i> )	510
Corvid	Eurasian jay ( <i>Garrulus glandarius</i> )	170
Corvid	Jackdaw ( <i>Corvus monedula</i> )	220
Corvid	Magpie ( <i>Pica pica</i> )	220
Corvid	Raven ( <i>Corvus corax</i> )	1200
Game	Black grouse ( <i>Tetrao tetrix</i> )	1065
Game	Pheasant ( <i>Phasianus colchicus</i> )	1190
Game	Red grouse ( <i>Lagopus lagopus scotica</i> )	600
Game	Red-legged partridge ( <i>Alectoris rufa</i> )	490
Mammal	Common shrew ( <i>Sorex araneus</i> )	9.5
Mammal	European hare ( <i>Lepus europaeus</i> )	3500
Mammal	European rabbit ( <i>Oryctolagus cuniculus</i> )	1600
Mammal	Field vole ( <i>Microtus agrestis</i> )	30
Mammal	Grey squirrel ( <i>Sciurus carolinensis</i> )	552.5
Mammal	Mole ( <i>Talpa europaea</i> )	100
Mammal	Pygmy shrew ( <i>Sorex minutus</i> )	4
Mammal	Rat ( <i>Rattus norvegicus</i> )	360
Mammal	Red squirrel ( <i>Sciurus vulgaris</i> )	200
Mammal	Stoat ( <i>Mustela erminea</i> )	266.25
Mammal	Weasel ( <i>Mustela nivalis</i> )	90.25
Other	Blackbird ( <i>Turdus merula</i> )	100
Other	Black-headed gull ( <i>Chroicocephalus ridibundus</i> )	290
Other	Blue tit ( <i>Cyanistes caeruleus</i> )	10.5
Other	Budgerigar ( <i>Melopsittacus undulatus</i> )	35
Other	Chaffinch ( <i>Fringilla coelebs</i> )	24
Other	Coal tit ( <i>Periparus ater</i> )	9
Other	Common frog ( <i>Rana temporaria</i> )	22.7
Other	Common gull ( <i>Larus canus</i> )	400
Other	Common lizard ( <i>Zootoca vivipara</i> )	4
Other	Common toad ( <i>Bufo bufo</i> )	55
Other	Crossbill ( <i>Loxia curvirostra</i> )	43
Other	Cuckoo ( <i>Cuculus canorus</i> )	120
Other	Curlew ( <i>Numenius arquata</i> )	985
Other	Domestic chicken ( <i>Gallus gallus domesticus</i> )	1900
Other	Eurasian bullfinch ( <i>Pyrrhula pyrrhula</i> )	21
Other	Fieldfare ( <i>Turdus pilaris</i> )	100

Prey group	Common name	Mass (g)
Other	Goldcrest ( <i>Regulus regulus</i> )	6
Other	Great spotted woodpecker ( <i>Dendrocopos major</i> )	85
Other	Great tit ( <i>Parus major</i> )	18.5
Other	Green woodpecker ( <i>Picus viridis</i> )	190
Other	Kittiwake ( <i>Rissa tridactyla</i> )	410
Other	Lapwing ( <i>Vanellus vanellus</i> )	230
Other	Lesser black-backed gull ( <i>Larus fuscus</i> )	830
Other	Lesser redpoll ( <i>Acanthis cabaret</i> )	11
Other	Mallard ( <i>Anas platyrhynchos</i> )	1090
Other	Meadow pipit/tree pipit ( <i>Anthus pratensis/A. trivialis</i> )	19
Other	Mistle thrush ( <i>Turdus viscivorus</i> )	130
Other	Moorhen ( <i>Gallinula chloropus</i> )	320
Other	Newt ( <i>Triturus vulgaris</i> )	30
Other	Oyster catcher ( <i>Haematopus ostralegus</i> )	540
Other	Pied wagtail ( <i>Motacilla alba</i> )	21
Other	Redshank ( <i>Tringa totanus</i> )	120
Other	Robin ( <i>Erithacus rubecula</i> )	18
Other	Siskin ( <i>Spinus spinus</i> )	15
Other	Skylark ( <i>Alauda arvensis</i> )	38.5
Other	Snipe ( <i>Gallinago gallinago</i> )	110
Other	Song thrush ( <i>Turdus philomelos</i> )	83
Other	Starling ( <i>Sturnus vulgaris</i> )	78
Other	Swallow ( <i>Hirundo rustica</i> )	18.5
Other	Teal ( <i>Anas crecca</i> )	330
Other	Tree creeper ( <i>Certhia familiaris</i> )	10
Other	Whinchat ( <i>Saxicola rubetra</i> )	17
Other	Willow warbler ( <i>Phylloscopus trochilus</i> )	10
Other	Woodcock ( <i>Scolopax rusticola</i> )	280
Pigeon	Collared dove ( <i>Streptopelia decaocto</i> )	200
Pigeon	Feral pigeon ( <i>Columba livia</i> )	300
Pigeon	Wood pigeon ( <i>Columba palumbus</i> )	450
Raptor	Barn owl ( <i>Tyto alba</i> )	300
Raptor	Common buzzard ( <i>Buteo buteo</i> )	890
Raptor	Common kestrel ( <i>Falco tinnunculus</i> )	208
Raptor	Long-eared owl ( <i>Asio otus</i> )	290
Raptor	Merlin ( <i>Falco columbarius</i> )	205
Raptor	Northern goshawk ( <i>Accipiter gentilis</i> )†	1000
Raptor	Short-eared owl ( <i>Asio flammeus</i> )	330
Raptor	Sparrowhawk ( <i>Accipiter nisus</i> )	205
Raptor	Tawny owl ( <i>Strix aluco</i> )	470

† Goshawk chicks were only included in the diet if there was evidence to suggest that it was a case of cannibalism rather than fledglings dying in the nest.



**Appendix 5:** Occurrence of raptor species in the breeding season diet of a northern goshawk population in Kielder Forest, UK when the number of goshawk home-ranges occupied each year was estimated to be 1-14, 15-24 and 25 or more.

Species	<i>n</i>				% Biomass				% Frequency				% of raptors			
	Total	1-14	15-24	25+	Total	1-14	15-24	25+	Total	1-14	15-24	25+	Total	1-14	15-24	>25
Common kestrel *	228	24	128	76	1.46	0.68	1.83	1.48	2.94	1.35	3.73	2.99	49.03	54.55	56.89	38.78
Tawny owl *	106	7	30	69	1.53	0.45	0.97	3.04	1.37	0.39	0.87	2.71	22.80	15.91	13.33	35.20
Sparrowhawk	48	2	22	24	0.30	0.06	0.31	0.46	0.62	0.11	0.64	0.94	10.32	4.55	9.78	12.24
Short-eared owl *	23	7	14	2	0.23	0.32	0.32	0.06	0.30	0.39	0.41	0.08	4.95	15.91	6.22	1.02
Barn owl *	14	0	3	11	0.13	0	0.06	0.31	0.18	0	0.09	0.43	3.01	0	1.33	5.61
Long-eared owl *	17	0	12	5	0.15	0	0.24	0.14	0.22	0	0.35	0.20	3.66	0	5.33	2.55
Merlin	14	0	12	2	0.09	0	0.17	0.04	0.18	0	0.35	0.08	3.01	0	5.33	1.02
Northern goshawk	13	4	3	6	0.40	0.55	0.21	0.56	0.17	0.22	0.09	0.24	2.80	9.09	1.33	3.06
Common buzzard	2	0	1	1	0.05	0	0.06	0.08	0.03	0	0.03	0.04	0.43	0	0.44	0.51

\* Denotes raptor species which are dependent on field voles

**Appendix 6:** The proportion of goshawk breeding attempts which were successful (i.e. fledged at least one chick) shown in relation to goshawk abundance (number of occupied goshawk territories) and according to when the goshawk home-range first became established. Numbers in parentheses are the total number of breeding attempts for each category.

Home-ranges established	Number of occupied goshawk home ranges		
	$\leq 14$	15-24	$\geq 25$
Early (1973-1986)	0.73 (60)	0.76 (114)	0.51 (112)
Middle (1987-2001)	-	0.77 (96)	0.61 (125)
Late (2002-2014)	-	0.75 (20)	0.25 (44)



Data file for analysis of goshawk reproductive success.

Year	# failed breeding attempts	Total # breeding attempts	total # chicks fledged	# of goshawk home-ranges
1	1	2	3	2
2	0	1	3	3
3	0	2	6	3
4	0	2	5	3
5	1	3	6	9
6	2	7	16	10
7	2	8	16	11
8	1	9	25	11
9	1	11	29	11
10	4	11	18	11
11	3	13	27	19
12	3	18	38	21
13	4	20	43	21
14	3	19	55	22
15	1	20	49	23
16	5	18	35	25
17	2	19	43	23
18	5	19	34	24
19	7	23	41	27
20	4	22	49	26
21	11	25	36	25
22	18	26	22	26
23	12	24	31	24
24	7	20	32	20
26	4	15	24	18
27	8	21	29	21
28	5	20	35	21
29	9	23	31	24
30	11	23	27	25
31	8	24	32	26
32	7	23	35	24
33	13	28	33	30
34	11	26	30	29
35	13	33	39	33
36	16	29	23	29
37	14	25	20	28
38	6	20	35	27