GAME & WILDLIFE CONSERVATION TRUST

Changes in upland bird numbers and distribution in the Berwyn Special Protection Area, North Wales between 1983 and 2012

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Summary

The Berwyn Special Protection Area (SPA) supports the most extensive tract of blanket bog and upland heath in Wales. The site was designated in 1998 as an SPA for its internationally significant numbers of hen harrier *Circus cyaneus*, merlin *Falco columbarius*, peregrine *Falco peregrinus* and red kite *Milvus milvus*, whilst also supporting significant proportions of Welsh populations of upland breeding waders. Following the Second World War there has been a decline in grouse moor management in the Berwyn and by the late 1990s driven grouse shooting had ceased. In this report, we assess changes in the numbers of red grouse and the abundance of other upland birds in the Berwyn using shooting bag records, grouse count data collected on four moors between 1995 and 2012; and repeat upland bird surveys in 1983-5 and 2002.

Main findings

- **Between 1983-5 and 2002, lapwing were lost from the Berwyn survey areas, golden plover declined from 10 birds to one and curlew declined by 79% despite its conservation designations.**
- **Carrion crow numbers increased six-fold and raven four-fold, with the number of occupied 1-km^2 grid squares doubling and trebling respectively.**
- **Buzzard numbers increased two-fold in abundance and the number of occupied grid squares increased four-fold. Peregrines also increased seven-fold in abundance, whilst hen harriers declined by half. There were no significant changes detected in the abundance of the other SPA designated raptors, merlin and red kite.**
- **Meadow pipits and whinchat doubled and stonechat increased ten-fold between surveys. Ring ouzel declined by 78% and tree pipit by 50%.**
- **The numbers of red grouse shot in the Berwyn peaked in the early 1900s and then declined, with driven grouse moor management having ceased by the late 1990s.**
- **Between the upland breeding bird surveys, red grouse numbers declined by 54% and the occupied range of 1-km^2 grid squares fell by 38%.**
- **Grouse count data on four moors collected since 1995 showed that grouse numbers have remained at low levels on three of the moors, with adult summer densities at Llanarmon declining from 15 grouse km^{-2} in 1995 to 3 grouse km^{-2} in 2009. Summer densities ranging from 21 grouse km^{-2} at Llanarmon to 6 grouse km^{-2} at Vyrnwy.**
- **For black grouse, numbers declined by 78% between the upland breeding bird surveys and occupied 1-km^2 grid squares fell by 28%.**
- **To restore breeding wader populations within the Berwyn, we recommend that predator control is incorporated as a general tool within agri-environment schemes, particularly where habitat enhancements through heather burning and appropriate grazing are being practised.**

Acknowledgements

We would like to thank the Moorland Association for funding this study. We would also like to thank the Countryside Council for Wales (CCW) for providing data from the upland bird surveys undertaken in the Berwyn in 1983-5 and 2002 and to the numerous fieldworkers from CCW and RSPB who completed the survey work. We would also like to thank all the landowners for allowing us access to their land to undertake grouse counts in spring and summer and to the RSPB for providing grouse count data from Vyrnwy. Thanks also to Julie Ewald, Neville Kingdom and Christopher Wheatley who gave valuable assistance with GIS related issues and to Nicholas Aebischer for providing National Gamebag Census data for moors within the Berwyn.

Introduction

Heather *Calluna vulgaris* dominated moorland in the uplands of the United Kingdom is of high international conservation importance for a range of birds species (Thompson *et al.* 1995). In Wales, the Berwyn is the most important upland area for breeding birds and was designated as a Special Protection Area (SPA) in accordance with the European Union Birds Directive (EEC 1979) in 1998 to protect the internationally significant populations of hen harrier *Circus cyaneus*, merlin *Falco columbarius*, peregrine *Falco peregrinus* and red kite *Milvus milvus* (Table 1). The Berwyn also supports significant proportions of the Welsh populations of other upland birds and is designated as a Site of Special Scientific Interest (SSSI) for its upland breeding bird assemblage, which includes black grouse *Tetrao tetrix*, red grouse *Lagopus lagopus scoticus*, golden plover *Pluvialis apricaria,* dunlin *Calidris alpina*, snipe *Gallinago gallinago*, curlew *Numenius arquata*, short-eared owl *Asio flammeus*, whinchat *Saxicola rubetra*, stonechat *Saxicola torquata*, wheatear *Oenanthe oenanthe*, ring ouzel *Turdus torquatus*, raven *Corvus corax* and chough *Pyrrhocorax pyrrhocorax*.

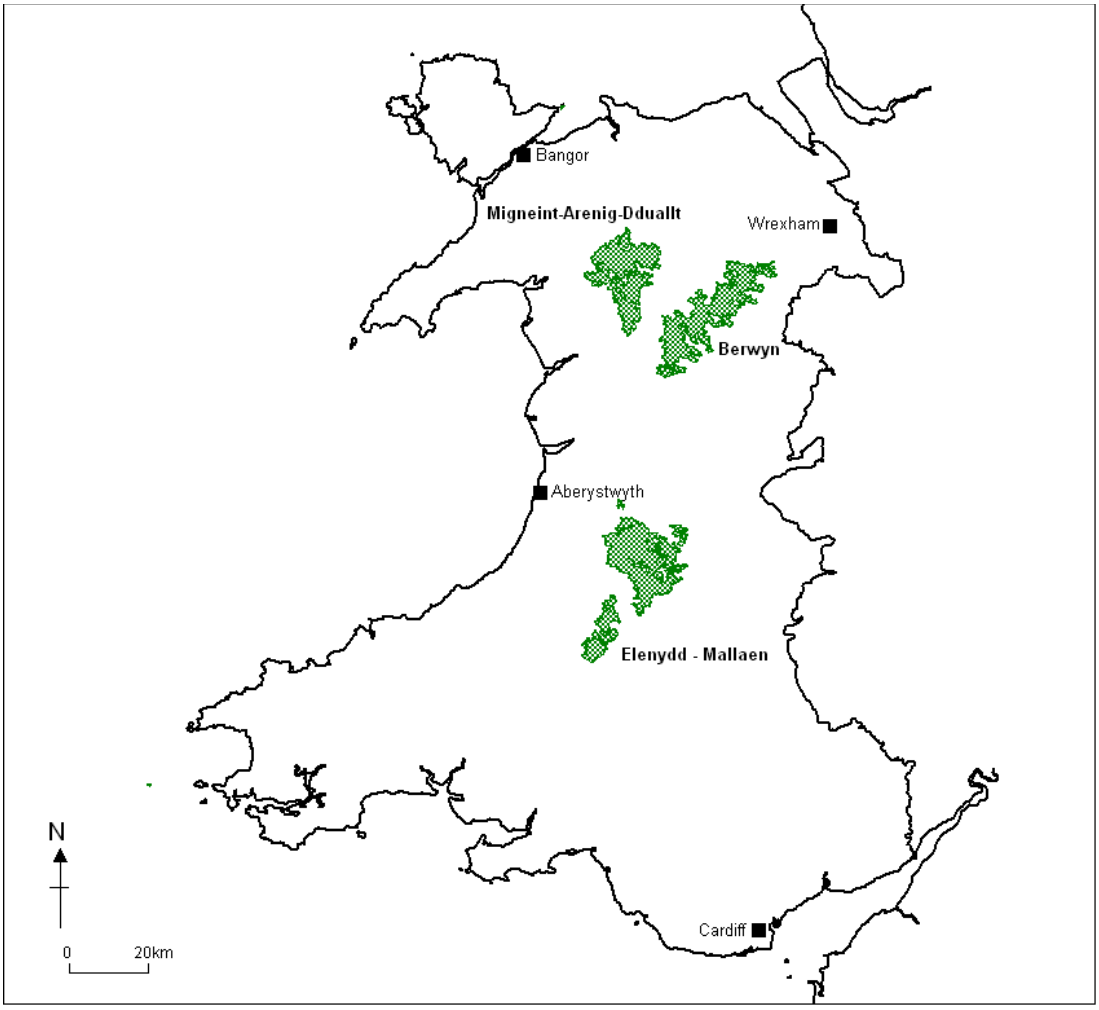
Table 1. Performance indicators for breeding population size for the four raptor species, hen harrier, merlin, peregrine and red kite which the Berwyn is designated (Source: Berwyn SPA core management plan, 2008).

Species	Targets
Hen Harrier	14 pairs representing at least 2.8% of the breeding population in Great Britain (5 year mean, 1991-1995)
Merlin	14 pairs representing at least 1.1% of the breeding population in Great Britain (5 year mean, 1991-1995)
Peregrine	18 pairs representing at least 1.5% of the breeding population in Great Britain (5 year mean, 1991-1995)
Red Kite	2 pairs representing at least 1.2% of the breeding population in Great Britain (5 year mean, 1991-1995)

The Berwyn Special Protection Area (SPA) is an extensive area of heather moorland running south west from Llangollen in the north east to Mallwyd in the south west covering 241.8 km^2 (Figure 1). Habitats in the Berwyn grade from the ffridd (upland fringes) on the lower slopes (300m) through acid grassland, dry heath up to blanket bog on the higher areas (830m). The area supports the most extensive tract of blanket bog in Wales, which is dominated by National

Vegetation Classification (NVC) type M19 *Calluna vulgaris*- cotton grass *Eriophorum vaginatum* blanket mire. It also contains the largest stand of upland European dry heath, which consists principally of NVC type H12 *Calluna vulgaris*- bilberry *Vaccinium myrtillus* heath (Berwyn SPA core management plan, 2008).

Figure 1. Location of the Berwyn Special Protection Area (SPA) in Wales



Following the Second World War, 46% of heather moorland in Wales (Lovegrove *et al*. 1995) and 39% of heather moorland in the Berwyn has been lost due to overgrazing by sheep and commercial afforestation (Berwyn SPA core management plan, 2008). Similarly, there has been a decline in moorland management for red grouse shooting, where moorland gamekeepers are employed to burn heather and control predators to produce harvestable surpluses for driven shooting (Hudson 1992), with none of the moorland in the Berwyn now managed as driven grouse moor. In the Berwyn SPA, some two thirds of the moorland is managed as a nature

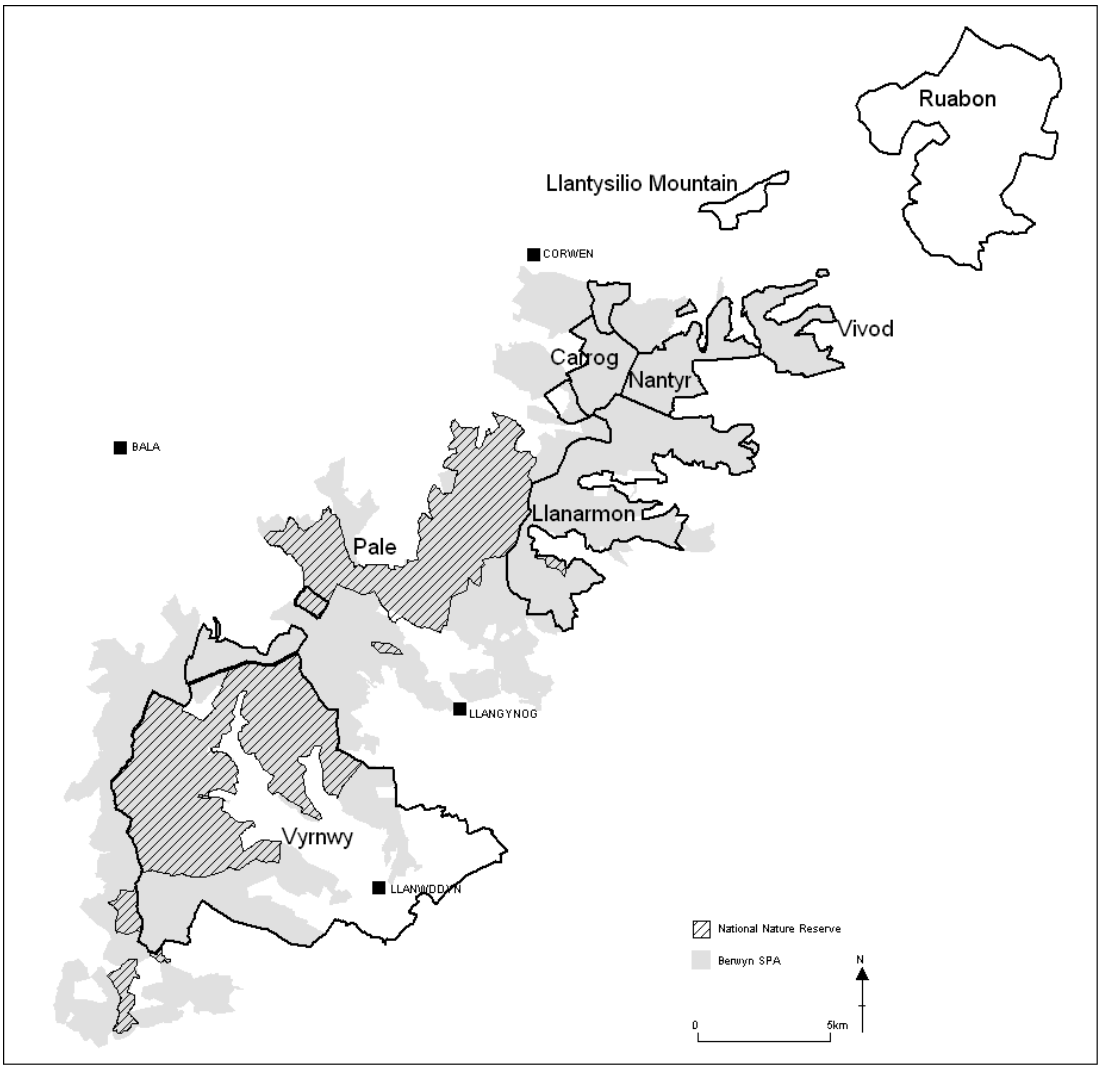
reserve by Severn Trent Water/ Royal Society for the Protection of Birds at Vyrnwy and by the Countryside Council for Wales (CCW) at Pale. On the remaining moors, the less intensive walked-up grouse shooting is now only practised (Sotherton *et al*. 2009). In this study we assess the changes in the abundance of red grouse and a suite of other upland breeding birds in the Berwyn SPA from red grouse shooting bag records, grouse counts conducted on 16, 1-km^2 blocks on four moors between 1995 and 2012 and from a repeat upland bird survey across 107, 1-km^2 grid squares in 1983-5 and 2002 (Sim *et al.* 2005).

Methods

Study area

The Berwyn covers 241.8 km^2 of upland North Wales, designated as a SPA, SSSI and a Special Area of Conservation (SAC). The largest landholding here is the 100.8 km^2 Severn Trent Water/ RSPB Vyrnwy Estate, which includes 42 km^2 of the Berwyn National Nature Reserve (NNR) (Figure 2). The second largest holding is the 38 km^2 Pale Moor NNR managed by CCW. The remainder of the Berwyn SPA is managed privately, with the main landholdings being the Llanarmon Estate covering 31.4 km^2 and the Carrog (5.8 km^2), Nantyr (9.4 km^2) and Vivod (7.0 km^2) estates. Grouse count data were also available from Ruabon, which although not within the Berwyn SPA were included in the analyses as the moor lies adjacent to the north east (Figure 2) and is within the same SAC.

Figure 2. Distribution of the main landholdings within the Berwyn SPA



Data sources

Upland bird survey data from the Berwyn SPA in 1983-5 and 2002 were sourced under licence from Countryside Council for Wales (CCW). Red grouse bag data were extracted from the GWCT's National Gamebag Census (NGC) which collects shooting bag returns annually from over 600 estates in the UK (Tapper 1992) for moors with returns from the Berwyn. Red grouse count data between 1995 and 2000 were collected as part of The Welsh Grouse Project, a partnership project between GWCT, CCW and RSPB. Subsequent grouse counts were undertaken on Llanarmon, Pale and Ruabon periodically by GWCT and by the RSPB at Vyrnwy.

Red grouse surveys

Red grouse were surveyed using pointing dogs pre-breeding in spring (March and April) and post-breeding in summer (July and August) within 1-km^2 blocks on four moors; Vyrnwy, Ruabon, Pale and Llanarmon (Figure 2). Surveys commenced in 1995 with red grouse surveyed within two 1-km^2 count areas at Ruabon; six at Pale; six at Vyrnwy and two at Llanarmon. All four moors were surveyed in summer up until 2000 (Table 2). Then, surveys have been undertaken less frequently, with Vyrnwy surveyed the most regularly (in seven of the 11 years).

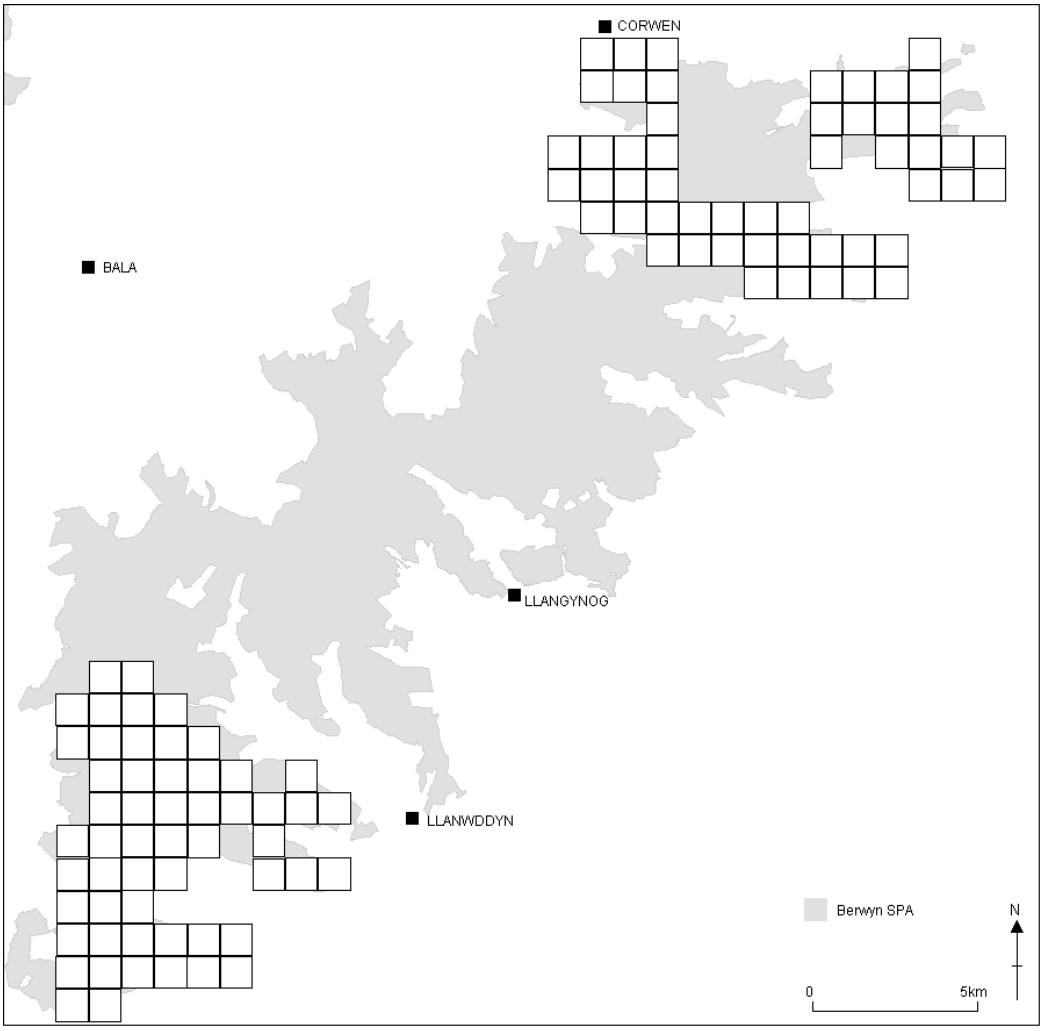
Table 2. Red grouse surveys undertaken in spring and summer on four moors, Vyrnwy, Ruabon, Pale and Llanarmon in the Berwyn 1985-2012

	Moor							
	Pale		Llanarmon		Ruabon		Vyrnwy	
Year	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer
1995	√	√	√	√	√	√	√	√
1996	√	√	√	√	√	√		√
1997	√	√	√	√	√	√	√	√
1998	√	√	√	√	√	√	√	√
1999	√	√		√		√	√	√
2000	√	√		√		√		√
2001							√	
2002	√	√					√	√
2003	√	√					√	√
2004	√	√					√	√
2005								
2006		√						√
2007			√	√	√	√		
2008							√	√
2009		√		√		√	√	√
2010							√	√
2011								
2012	√				√			

Upland bird surveys

We assessed upland bird survey data collected in the Berwyn SPA within 107, 1-km^2 grid squares (Figure 3) grouped by CCW/RSPB into 14 plots for reporting purposes which were surveyed in 1983-5 and then again in 2002. In 1983, 22, 1-km^2 squares were surveyed, with a further 52 in 1984 and 33 in 1985, with all repeated in 2002. Parallel line transects were walked across the study plots with two observers spaced at 200m apart. Surveys were undertaken between 08.30 and 18.00 hours BST to avoid the main periods of rapidly changing bird activity (Reed *et al*. 1985). All bird sightings were mapped on to 1:10000 or 1:25000 maps using standard behaviour codes. Surveys were not carried out in high winds greater than 35 km/hour, heavy rain or poor visibility. Repeat surveys in 2002 were undertaken within seven days of the original survey dates with all surveyors received training in the survey technique used to allow comparability between surveys (Sim *et al*. 2005).

Figure 3. Location of the upland bird survey 1-km^2 squares in the Berwyn SPA surveyed in 1983-5 and repeated in 2002



Analyses

Differences in red grouse spring and summer densities and breeding productivity between moors and years were tested using ANOVA. Changes in red grouse abundance in spring and summer between 1995 and 2012 were assessed using linear regression. Data were not available from counts in spring and summer on all moors in all years (Table 2) therefore to assess whether red grouse populations were in decline or were just at different stages within a natural cycle (Hudson 1992) we increased the sample size by calculating adult summer densities for those years with only spring count data available. Adult summer densities were estimated through calculating a mean breeding season loss rate (change in numbers of adults between spring and summer counts) calculated from all moors where spring and summer data were available.

The analyses of breeding bird abundance were based on the maximum count from one of the two visits. Counts of flocks of waders (five or more) were excluded. We tested for significant differences only where the measure abundance was 30 or more in either the original or repeat survey. We assessed changes in the numbers of breeding birds between surveys in 1983-85 and 2002 using Generalised Linear Models (GLM) with a Poisson error distribution and a logarithm link function in Genstat 11 (VSN international Ltd). All birds were counted in both survey years, with the exception of skylark and meadow pipit which were only counted across both periods in six of the 14 study plots.

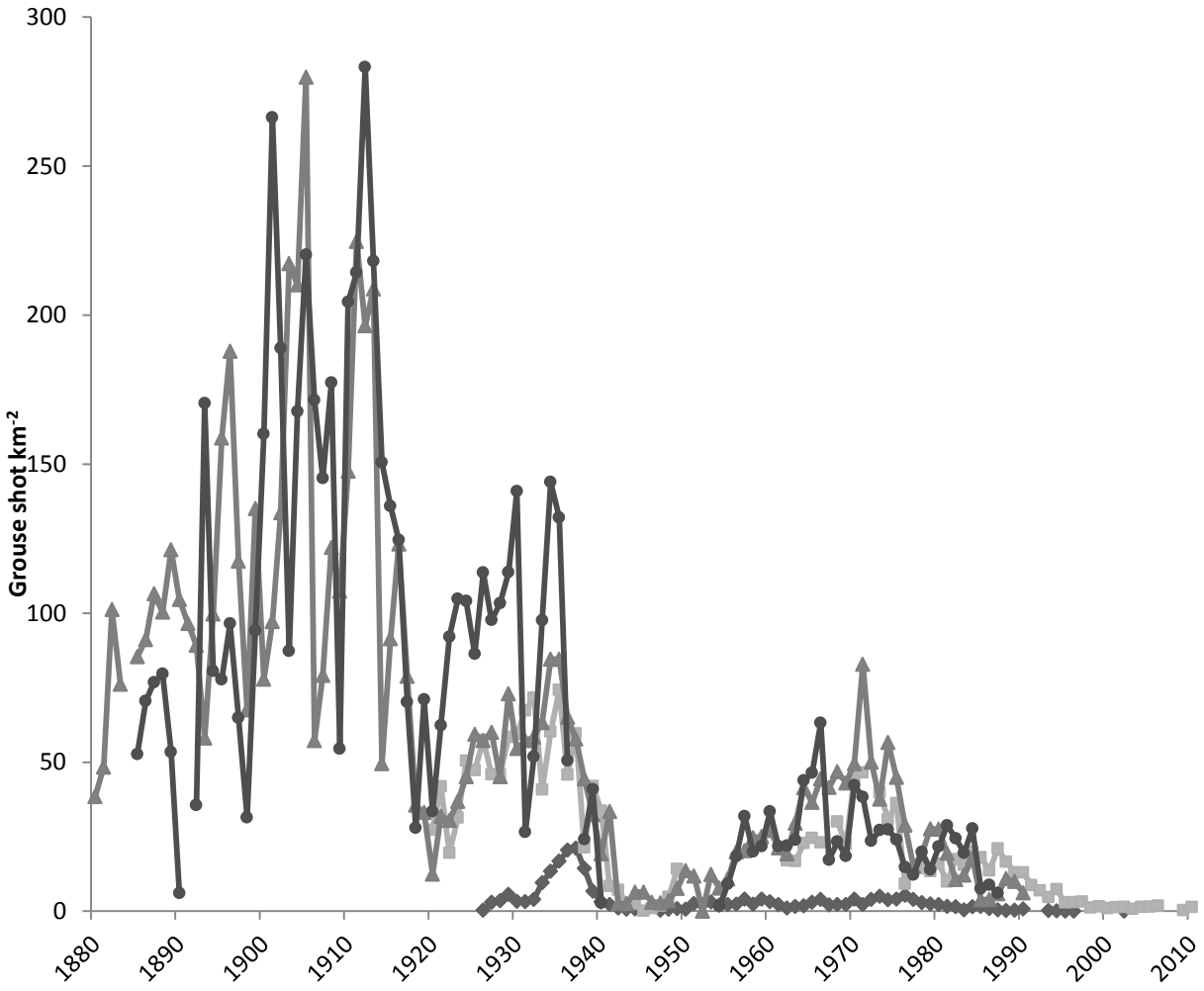
Results

Red grouse

National Gamebag Census

Long term red grouse bag data were available from four moors in the Berwyn 1880-2010. In the early 1900s the numbers of red grouse shot peaked on one moor at 282 grouse shot km^{-2} but then subsequently declined (Figure 4), with little shooting during the Second World War. Following the Second World War the numbers shot increased on three of the moors, peaking in the 1970s at 82 grouse km^{-2} but by the early 1990s grouse were infrequently shot on all four moors.

Figure 4. Numbers of red grouse shot km^{-2} on four moors in the Berwyn 1880-2010



In 1994, a survey to establish the extent and management of grouse moors in Wales (CCW unpublished report) identified ten grouse moors in the Berwyn, with data available for nine. Gamekeepers were employed on five moors (four part-time and one full-time), with the other four unkeepered. Two moors shot driven grouse, five shot grouse walked up, whilst grouse were no longer shot on the remaining two moors. By the late 1990s, driven grouse moor management in the Berwyn had effectively ceased (Offord 2002, Whitfield & Fielding 2009).

Pre-breeding densities

Between 1995 and 2012, spring densities of red grouse differed between the four moors Llanarmon, Pale, Ruabon and Vyrnwy ($F_{3,14}$= 13.2, P<0.001) but not between years ($F_{14,14}$=2.34, P=0.06) (Table 3). Average spring densities at Llanarmon (15.8 grouse km^{-2}) and Ruabon (16.1 grouse km^{-2}) were four-fold higher than at Vyrnwy (4.2 grouse km^{-2}) and just over double that at Pale (6.7 grouse km^{-2}).

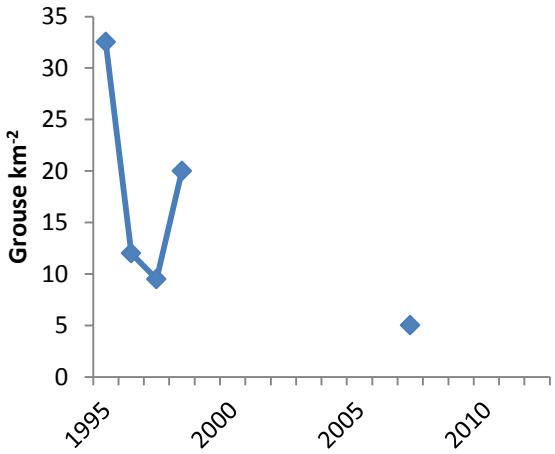
Table 3. Average spring and summer densities and breeding productivity recorded on the four moors, Llanarmon, Pale, Ruabon and Vyrnwy in the Berwyn SPA between 1995 and 2012

Moor	Mean spring density (grouse km^{-2} ±1SE)	Mean summer density (grouse km^{-2} ±1SE)	Breeding productivity (chicks per hen ±1SE)
Llanarmon	15.8 (4.8)	20.6 (3.2)	2.7 (0.5)
Pale	6.7 (0.9)	9.4 (2.6)	2.5 (0.4)
Ruabon	16.1 (2.4)	15.5 (3.2)	3.0 (0.6)
Vyrnwy	4.2 (0.4)	5.9 (2.3)	2.5 (0.4)

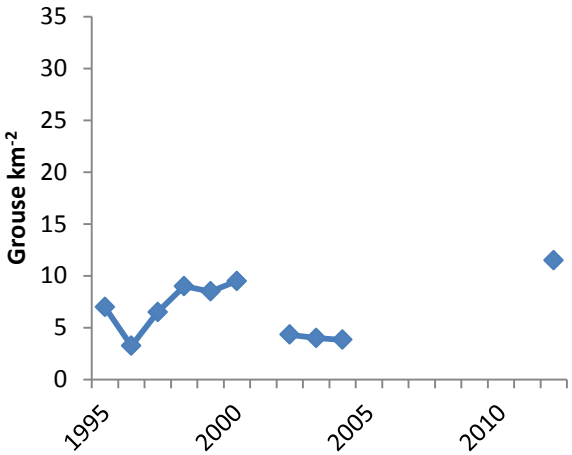
Between 1995 and 2012, red grouse densities in spring on three of the four moors, Ruabon (slope= -0.32, r^2=0.14, P=0.46), Pale (slope= 0.18, r^2=0.10, P=0.38) and Vyrnwy (slope= -0.15, r^2=0.29, P=0.09) remained at low levels, with no evidence of any trend (Figure 5). At Llanarmon, spring densities declined from 32.5 grouse km^{-2} in 1995 to 5 in 2007 but the decline was not statistically significant (slope= -1.43, r^2=0.41, P=0.24) (Figure 5a).

Figure 5. Red grouse spring densities (grouse km^{-2}) on the four moors, Llanarmon, Pale, Ruabon and Vyrnwy in the Berwyn SPA between 1995 and 2012

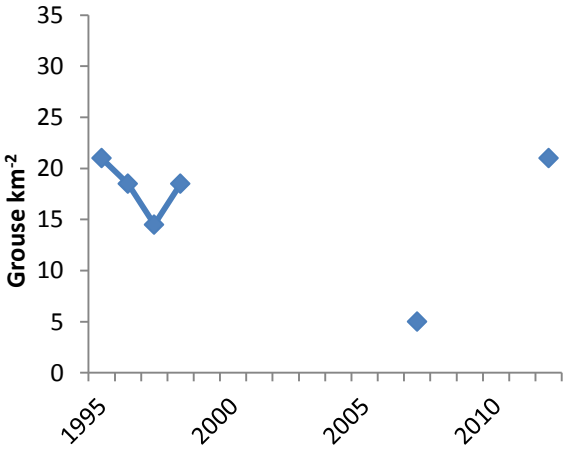
(a) Llanarmon



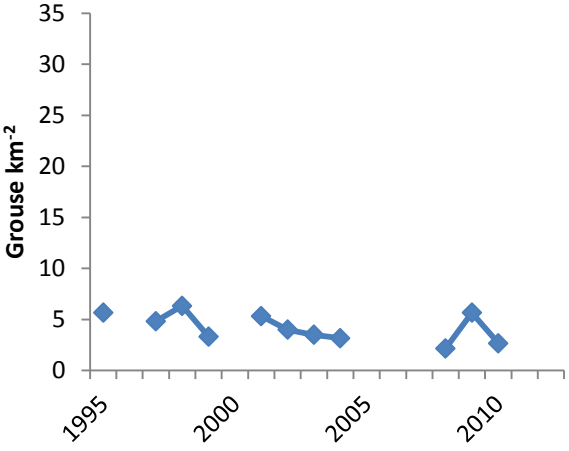
(b) Pale



(c) Ruabon



(d) Vyrnwy

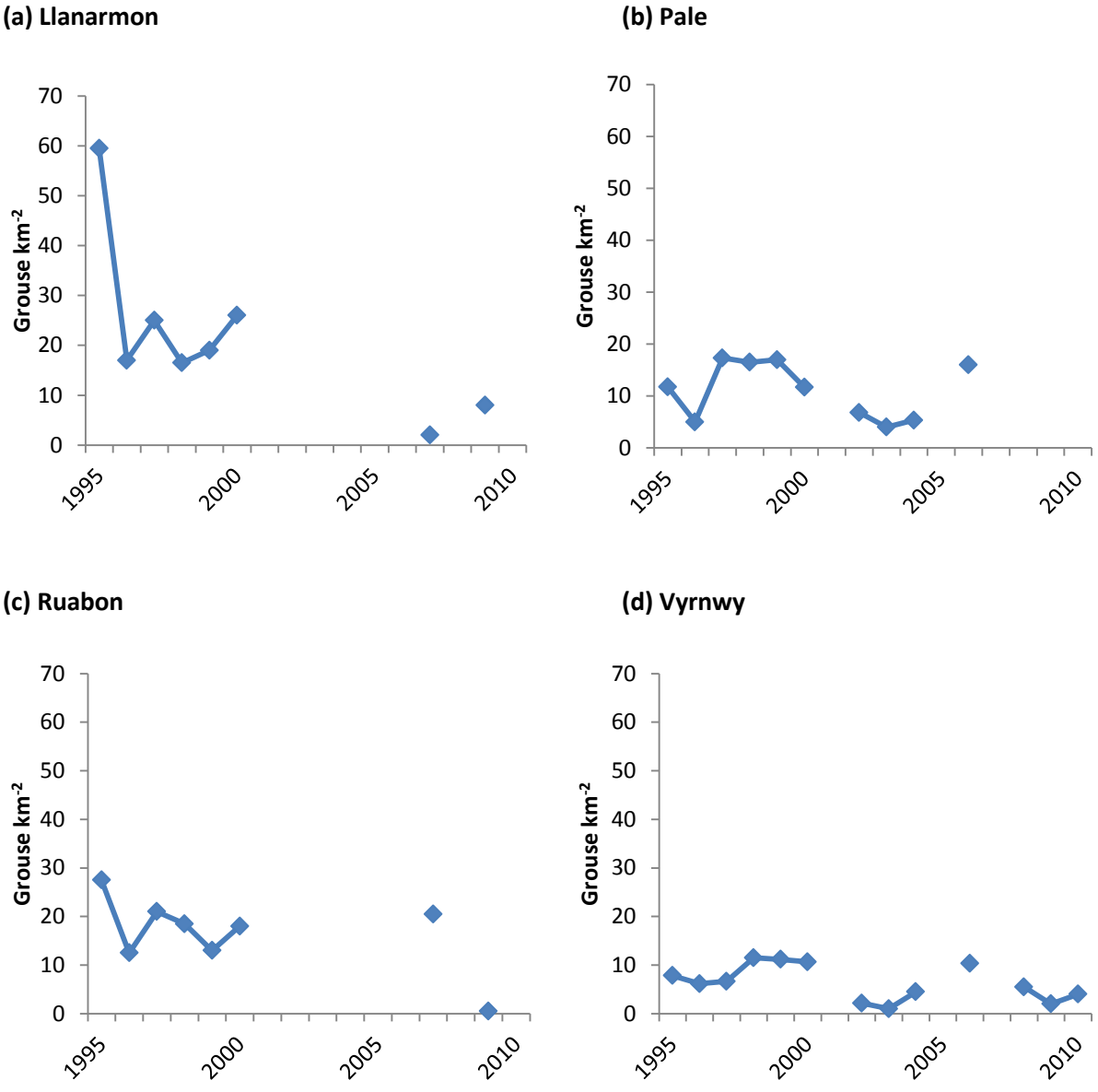


Post-breeding densities

Summer densities of red grouse differed between moors ($F_{3,14}$= 4.9, P=0.009) but not between years ($F_{13,23}$=1.9, P=0.08). Average summer densities ranged from 20.6 grouse km^{-2} at Llanarmon to 5.9 (±.2.3SE) grouse km^{-2} at Vyrnwy (Table 3). There were no trends in summer densities between 1995 and 2011 at Ruabon (slope= -0.91, r^2=0.24, P=0.13), Pale (slope= -0.32, r^2=0.00, P=0.56) or Vyrnwy (slope= -0.33, r^2=0.14, P=0.12) (Figure 6). At Llanarmon, summer

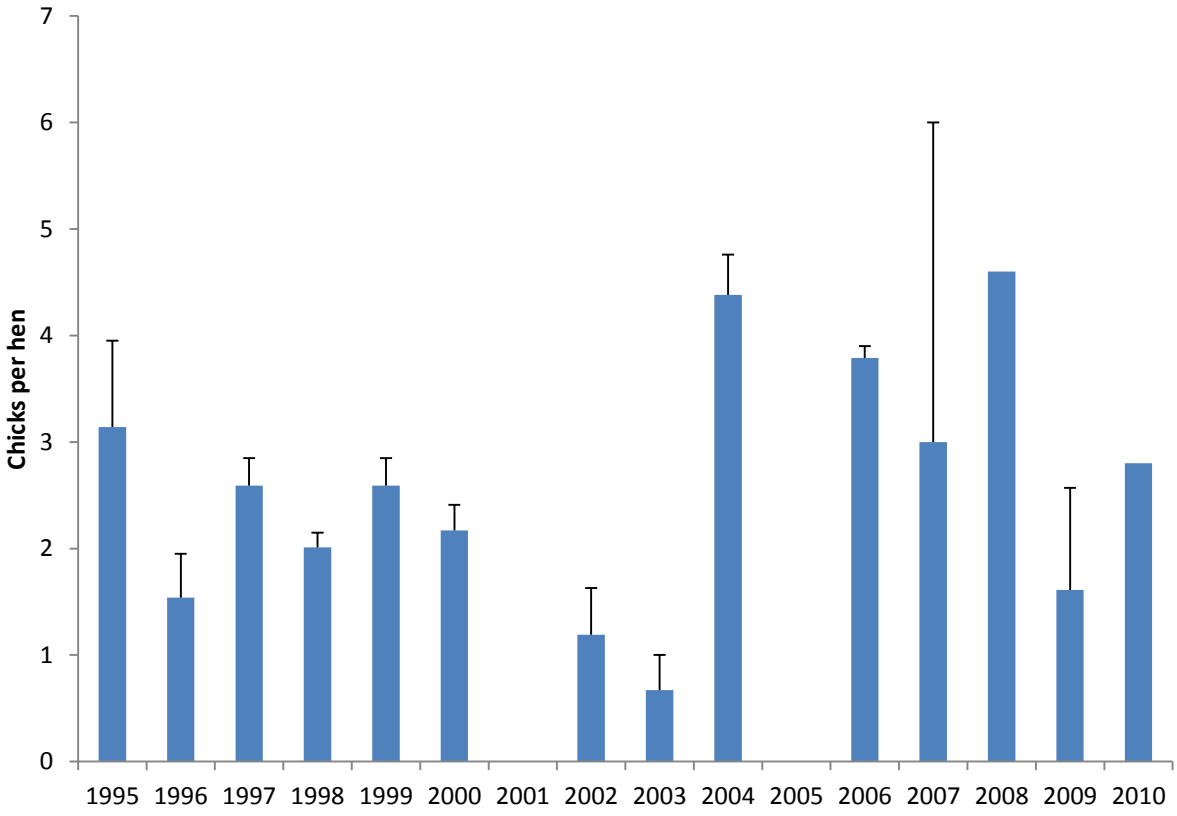
densities declined from 59.5 grouse km^{-2} in 1995 to 8 in 2009, but the decline was not statistically significant (slope= -2.32, r^2=0.47, P=0.06) (Figure 6a).

Figure 6. Red grouse summer densities (grouse km^{-2}) on the four moors Llanarmon, Pale, Ruabon and Vyrnwy in the Berwyn SPA between 1995 and 2011



Breeding productivity did not differ between moors ($F_{3,22}$=0.23, P=0.87) or years ($F_{13,23}$=1.6, P=0.15). Breeding productivity ranged from 0.7 chicks per hen in 2003 to 4.6 in 2008 (Figure 7).

Figure 7. Red grouse breeding productivity (mean chicks per hen (±1SE)) from four moors Llanarmon, Vyrnwy, Pale and Ruabon in the Berwyn SPA between 1995 and 2010 (No data were collected in 2001 due to a Foot and Mouth Disease outbreak)

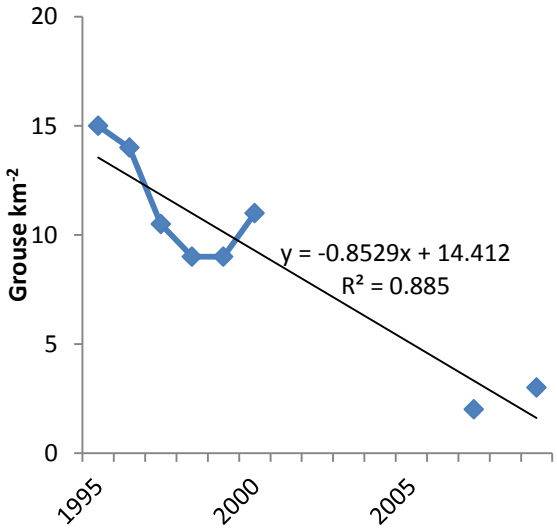


Adult summer density

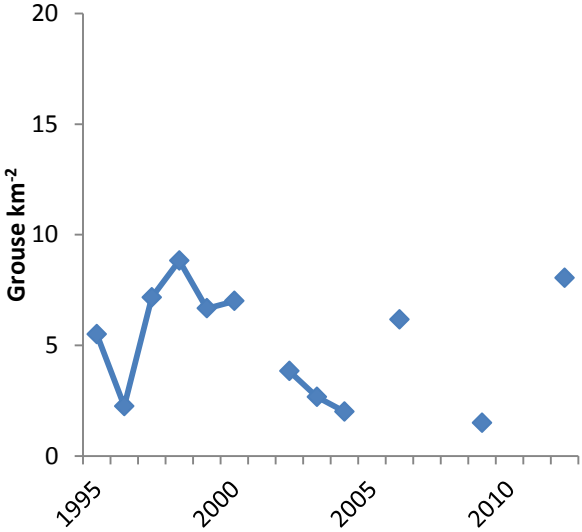
Adult summer densities differed between moors ($F_{3,24}$=10.62, P<0.001) and years ($F_{15,24}$=3.13, P=0.006). No trends were evident at Pale (slope=-0.06, r^2=0.02, P=0.69), Ruabon (slope=-0.31, r^2=0.23, P=0.19) or Vyrnwy (slope=-0.85, r^2=0.88, P=0.07) (Figure 8). Cycling was evident at Pale (Figure 8b) and Vyrnwy (Figure 8d). At Llanarmon, adult summer densities declined from 15 birds km^{-2} in 1995 to 3 in 2009 (slope=-0.85, r^2=0.88, P<0.001) (Figure 8a).

Figure 8. Red grouse adult summer densities (grouse km^{-2}) on the four moors Llanarmon, Pale, Ruabon and Vyrnwy in the Berwyn SPA between 1995 and 2012

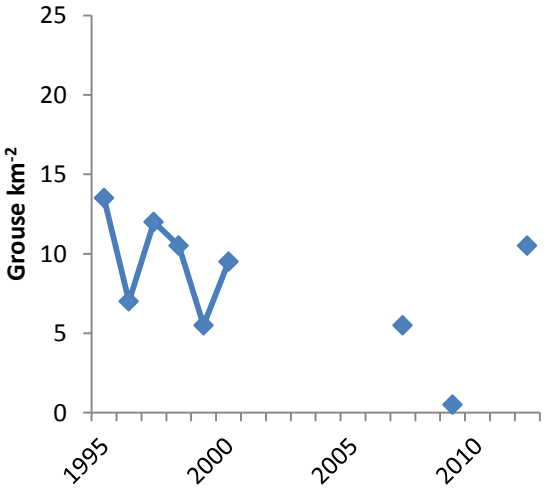
(a) Llanarmon



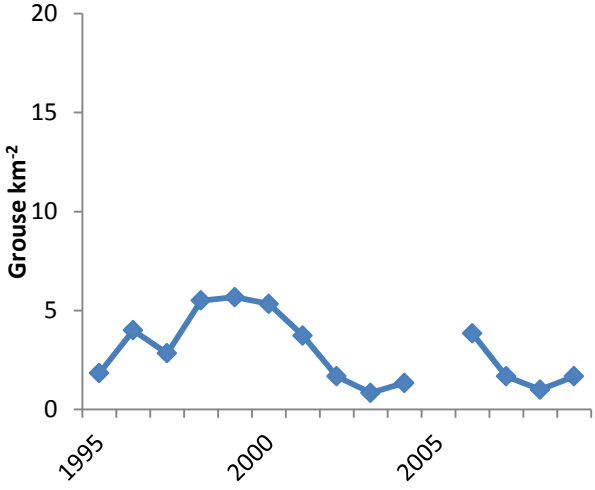
(b) Pale



(c) Ruabon



(d) Vyrnwy



Upland bird surveys

Breeding waders

In 1983-85, lapwing were present, albeit in low numbers (14 birds) (Table 4) found within 10, 1-km^2 grid squares (Table 5, Figure 9a) but in the repeat survey in 2002 lapwing were absent. Similarly, in 1983-85 a maximum of 10 golden plover were recorded over the two counts observed within 11, 1-km^2 grid squares, but in 2002 only one bird was observed (Figure 9b). Curlew declined by 79% between survey years from 148 (1.38 birds km^{-2}) to 31 (0.29 birds km^{-2}) with occupied range contracting by 75% (Table 5) (Figure 9c). Snipe were present in both surveys albeit at low density. The abundance of all breeding waders combined declined by 80% between survey years.

Table 4. The total numbers and density of breeding waders (birds km^{-2}) in the Berwyn SPA survey areas in 1983-5 and 2002 and the changes in abundance between survey years

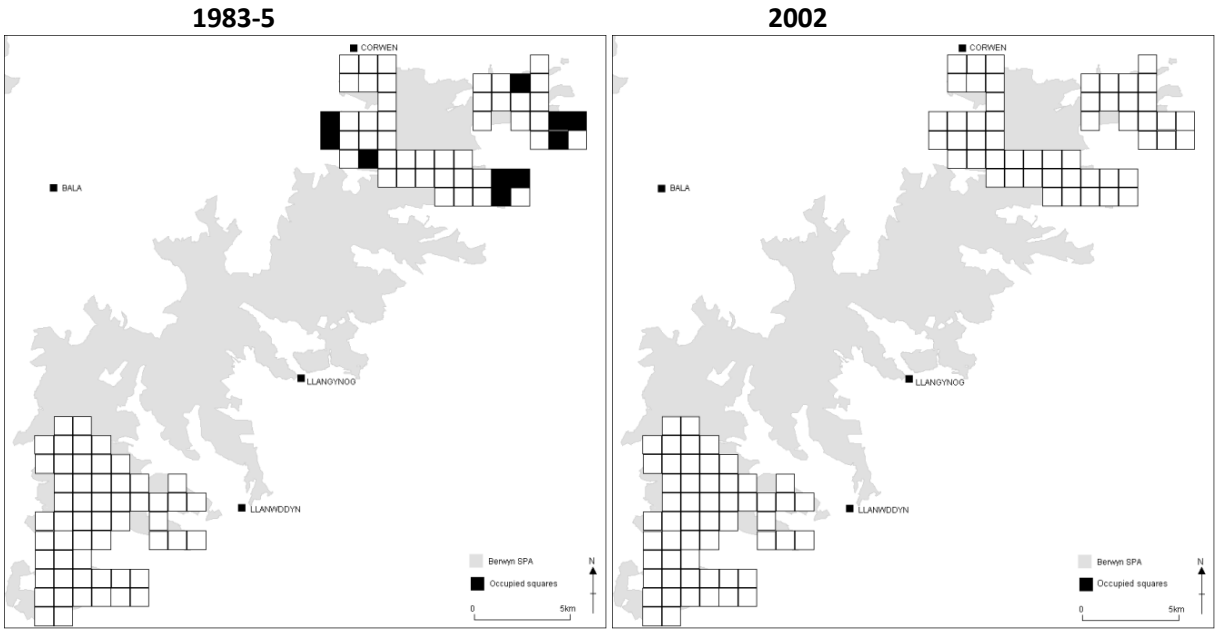
Species	Total number (density - birds km^{-2})		Change (%)	$F_{1,27}$	P
	1983-5	2002			
Lapwing	14 (0.13)	0 (0)	-100		
Curlew	148 (1.38)	31 (0.29)	-79	83.14	<0.001
Golden plover	10 (0.09)	1 (0.01)	-90		
Snipe	9 (0.08)	4 (0.05)	-44		
All waders	181 (1.69)	36 (0.35)	-80	105.82	<0.001

Table 5. Changes in the distribution (presence within 1-km^2 squares) of breeding waders in the Berwyn SPA between 1983-5 and 2002

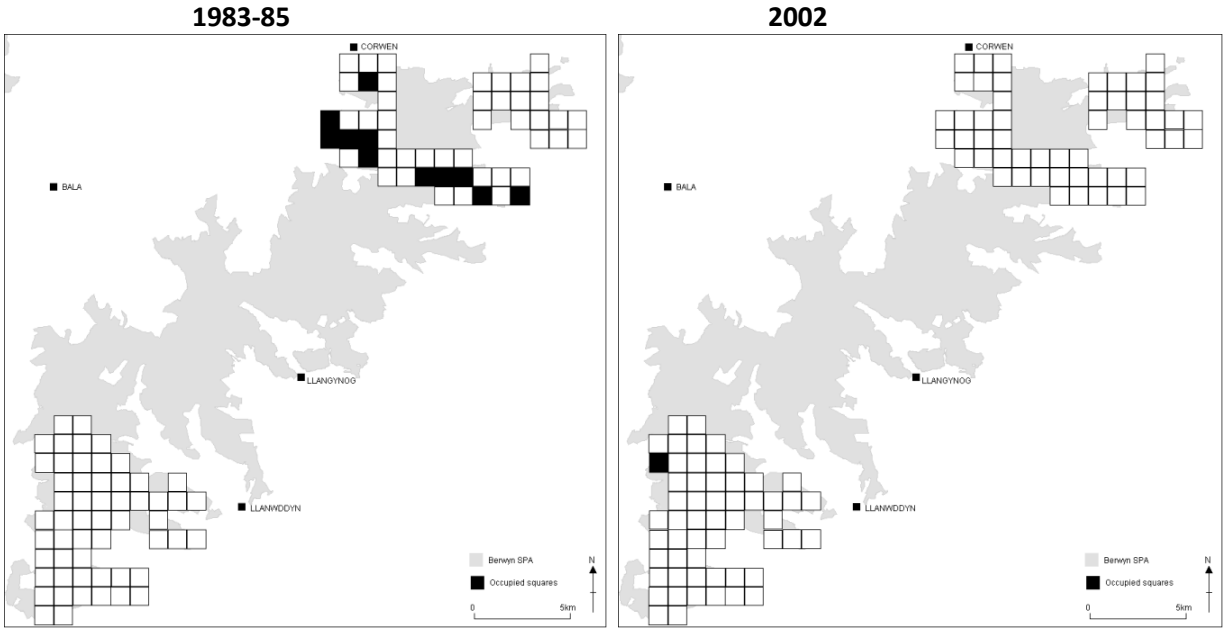
	1-km^2 grid squares observed		
	1983-5	2002	% change
Lapwing	10	0	-100
Curlew	68	17	-75
Golden Plover	11	1	-91
Snipe	8	5	-38

Figure 9. Distribution of breeding waders in 1983-5 and in 2002 in the Berwyn SPA (filled 1-km^2 squares denotes presence, open squares absence).

(a) Lapwing

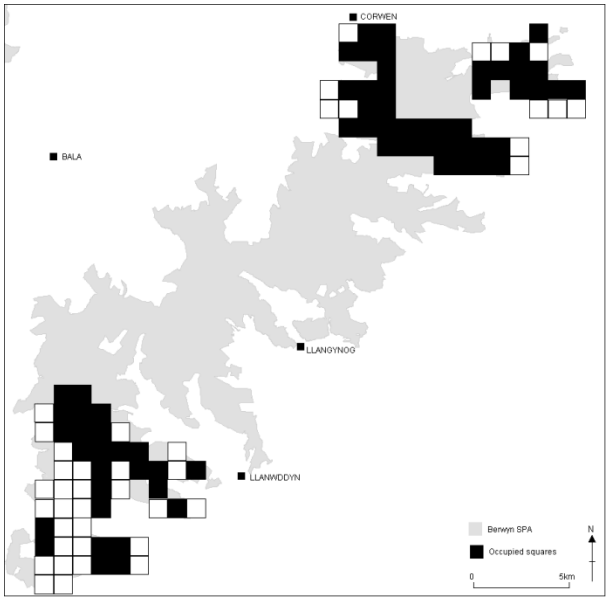


(b) Golden plover

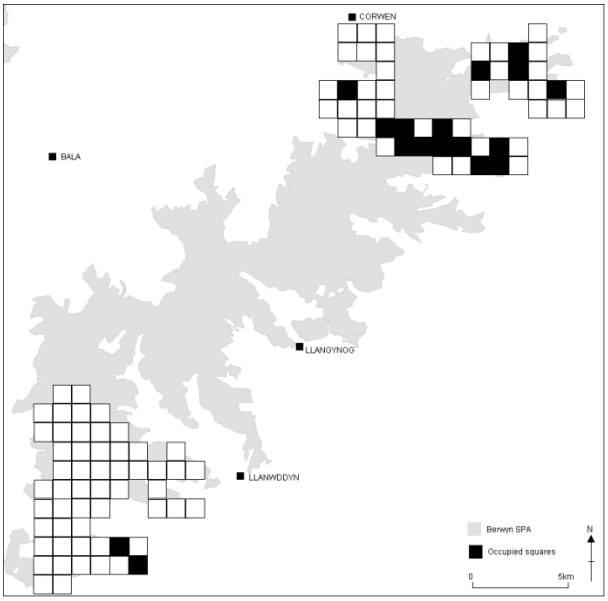


(c) Curlew

1983-85

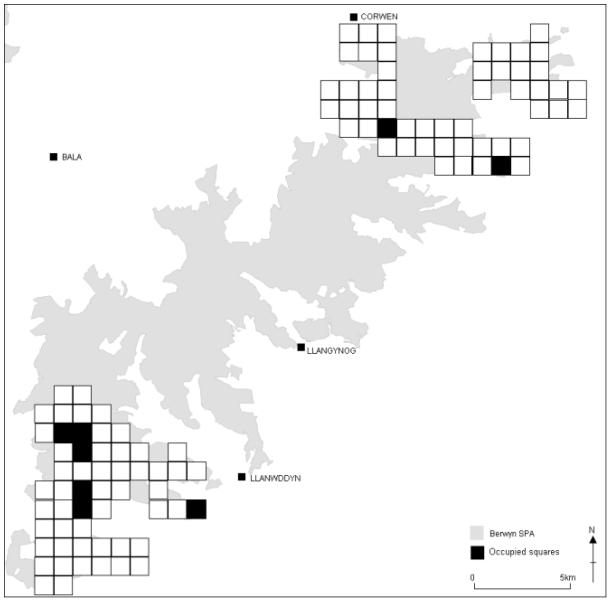


2002

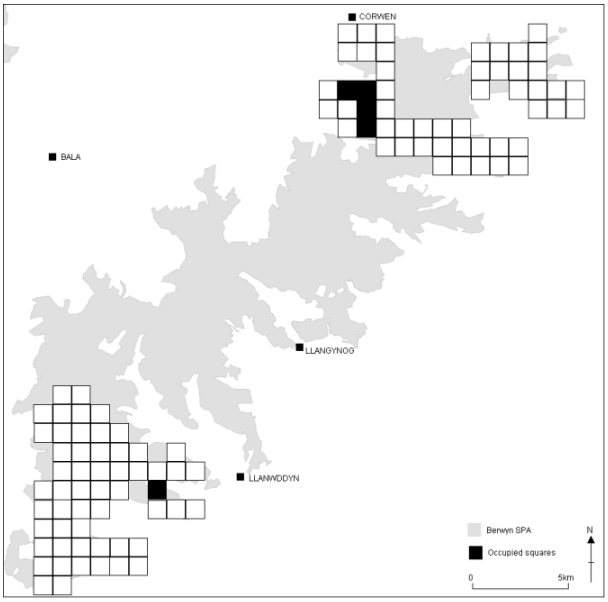


(d) Snipe

1983-5



2002



Passerines

Moorland specialists

Between the surveys in 1983-5 and 2002 the numbers of meadow pipits *Anthus pratensis* and whinchat doubled and stonechat increased ten-fold (Table 6). The occupied range of meadow pipits remained unchanged, whilst whinchat increased by 50% from 42 to 63 occupied 1-km^2 grid squares and stonechat by 700% from six to 48 grid squares (Table 7). There were no significant changes in the numbers or distribution of skylark *Alauda arvensis* or wheatear between survey years. Ring ouzel declined by 78% and tree pipit *Anthus trivialis* by 50% between surveys.

Other passerines

Between survey years wren *Troglodytes troglodytes* increased eightfold and there were increases in the numbers of summer visiting willow warbler *Phylloscopus trochilus* (+145%), whitethroat *Sylvia communis* (+900%), grasshopper warbler *Locustella naevia* (+100%) and chiffchaff *Phylloscopus collybita* (+471%) (Table 6). Woodpigeon *Columba palumbus* increased from two (0.02 birds km^{-2}) in 1983-5 to 45 (0.42 birds km^{-2}) in 2002. Overall the densities of all passerines combined doubled between survey years.

Table 6. The total numbers and density of passerines in the Berwyn SPA survey areas in 1983-5 and 2002 and the changes in abundance between survey years (*skylark and meadow pipit were only surveyed in six plots across both survey years)

Species	Total numbers (density- birds km^{-2})		Change (%)	$F_{1,27}$	P
	1983-5	2002			
Skylark*	53 (1.02)	63 (1.21)	+19	0.86	0.35
Meadow pipit*	602 (11.58)	1220 (23.46)	+103	213.83	<0.001
Whinchat	84 (0.79)	187 (1.75)	+122	40.15	<0.001
Stonechat	7 (0.07)	76 (0.71)	+914	67.05	<0.001
Wheatear	25 (0.23)	24 (0.22)	-4		
Ring ouzel	10 (0.09)	2 (0.02)	-78		
Tree pipit	107 (0.40)	21 (0.20)	-50	7.72	0.005
Wren	16 (0.15)	133 (1.24)	+727	104.94	<0.001
Willow warbler	31 (0.29)	76 (0.71)	+145	19.53	<0.001
Whitethroat	2 (0.02)	22 (0.20)	+900		
Grasshopper warbler	0 (0)	10 (0.09)	+100		
Woodpigeon	2 (0.02)	45 (0.42)	+2000	48.52	<0.001
Cuckoo	11 (0.10)	5 (0.05)	-50		
Chiffchaff	8 (0.07)	43 (0.40)	+471	26.39	<0.001
Linnet	29 (0.27)	38 (0.36)	+33	1.21	0.27
All passerines	(15.1)	(31.04)	+120	384.57	<0.001

Table 7. Changes in the distribution (presence within 1-km^2 squares) of passerines in the Berwyn SPA between 1983-5 and 2002

Species	1-km^2 grid squares observed		
	1983-5	2002	% change
Skylark*	49 (52)	51 (52)	+4
Meadow pipit*	49 (52)	50 (52)	+2
Whinchat	42	63	+50
Stonechat	6	48	+700
Wheatear	20	12	-40
Ring ouzel	7	2	-71
Tree pipit	24	16	-33
Wren	15	55	+267
Willow warbler	16	26	+63
Whitethroat	2	13	+550
Grasshopper warbler	0	6	+100
Woodpigeon	1	10	+900
Cuckoo	10	6	-40
Chiffchaff	7	21	+200
Linnet	4	14	+250

Corvids

Carrion crow *Corvus corone* increased six-fold from 49 (0.46 birds km^{-2}) to 308 (2.88 birds km^{-2}) between 1983-5 and 2002 (Table 8) with their occupied range doubling from 26 to 61, occupied 1- km^2 grid squares (Table 9, Figure 10a). Raven *Corvus corax* also increased four-fold from 12 (0.11 birds km^{-2}) to 49 (0.46 birds km^{-2}) with their occupied range trebling from 11 to 32 occupied 1-km^2 squares (Table 9, Figure 10b). Jackdaw *Corvus monedula* also increased in density from one (0.01 birds km^{-2}) in 1983-5 to 21 (0.21 birds km^{-2}) in 2002. All corvids combined increased six-fold between survey years.

Table 8. The total numbers and density of corvids in the Berwyn SPA survey areas in 1983-5 and 2002 and the changes in abundance between survey years

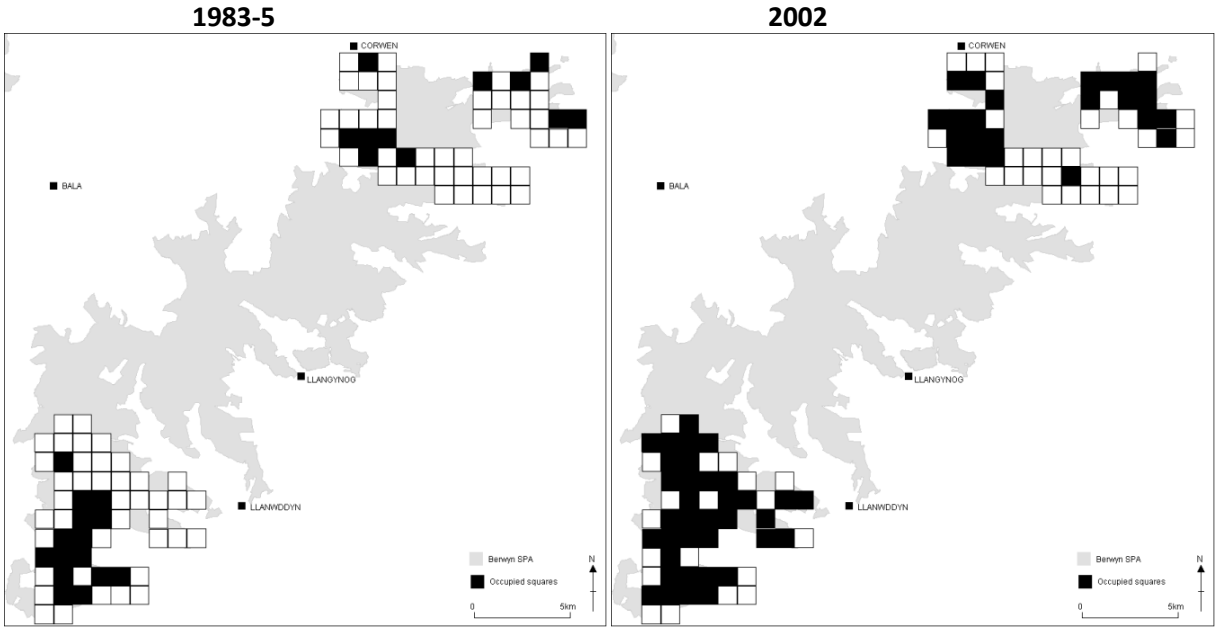
Species	**Total numbers (density - birds km^{-2})**		**Change (%)**	**$F_{1,27}$**	**P**
	1983-5	**2002**			
Raven	12 (0.11)	49 (0.46)	+318	24.07	<0.001
Carrion crow	49 (0.46)	308 (2.88)	+526	209.35	<0.001
Jackdaw	1 (0.01)	23 (0.21)	+2000		
All corvids	62 (0.58)	380 (3.55)	+512	254.33	<0.001

Table 9. Changes in the distribution (presence within 1-km^2 squares) of corvids in the Berwyn SPA between 1983-5 and 2002

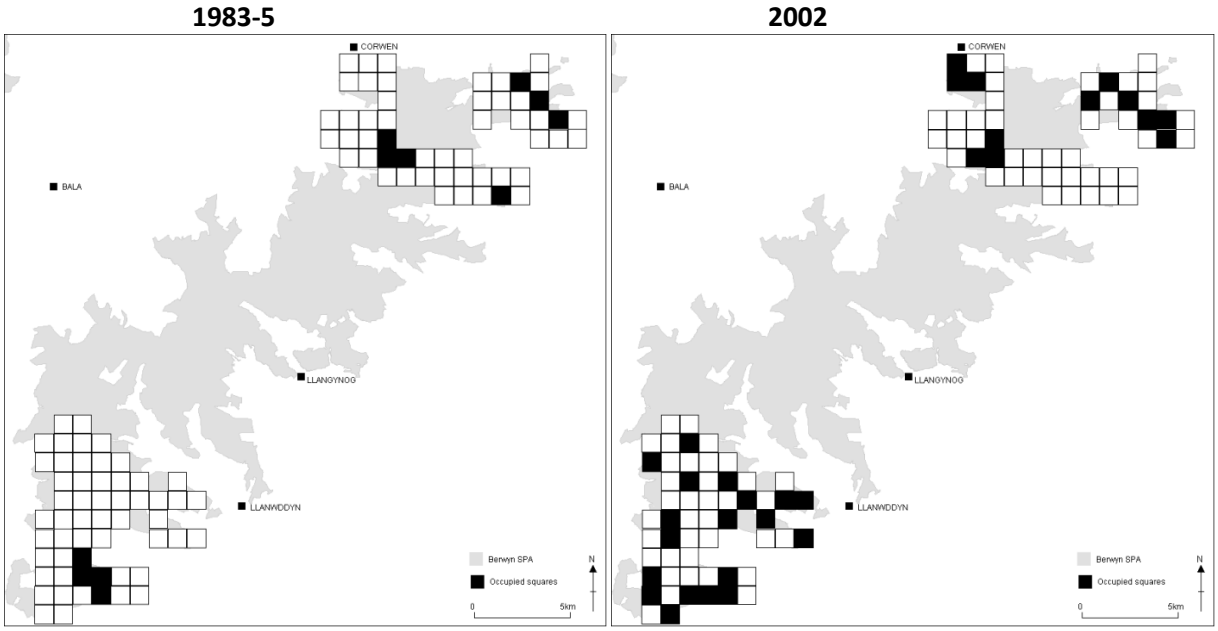
	1-km^2 grid squares observed		
	1983-5	2002	% change
Carrion crow	26	61	+135
Raven	11	32	+191
Jackdaw	1	1	0

Figure 10. Distribution of the corvids, carrion crow and raven in 1983-5 and in 2002 in the Berwyn SPA (filled 1-km^2 squares denotes presence, open squares absence).

(a) Carrion crow



(b) Raven



Raptors

Buzzard *Buteo buteo* increased two-fold from 14 (0.13 birds km^{-2}) to 27 (0.33 birds km^{-2}) between 1983-5 and 2002 (Table 10), with their occupied range increasing four-fold from nine to 37, 1-km^2 grid squares (Table 11, Figure 11). Peregrines also increased seven-fold from one (0.01 birds km^{-2}) to seven birds (0.07 birds km^{-2}) and range increased from one to eight occupied 1-km^2 grid squares (Table 11). Hen harrier declined by 48% from 35 to 18 birds. There were no significant changes detected in the abundance of the other raptors, merlin, red kite, short eared owl, goshawk *Accipter gentilis* or kestrel *Falco tinnunculus*. There were no significant changes in the abundance of all raptors combined between surveys.

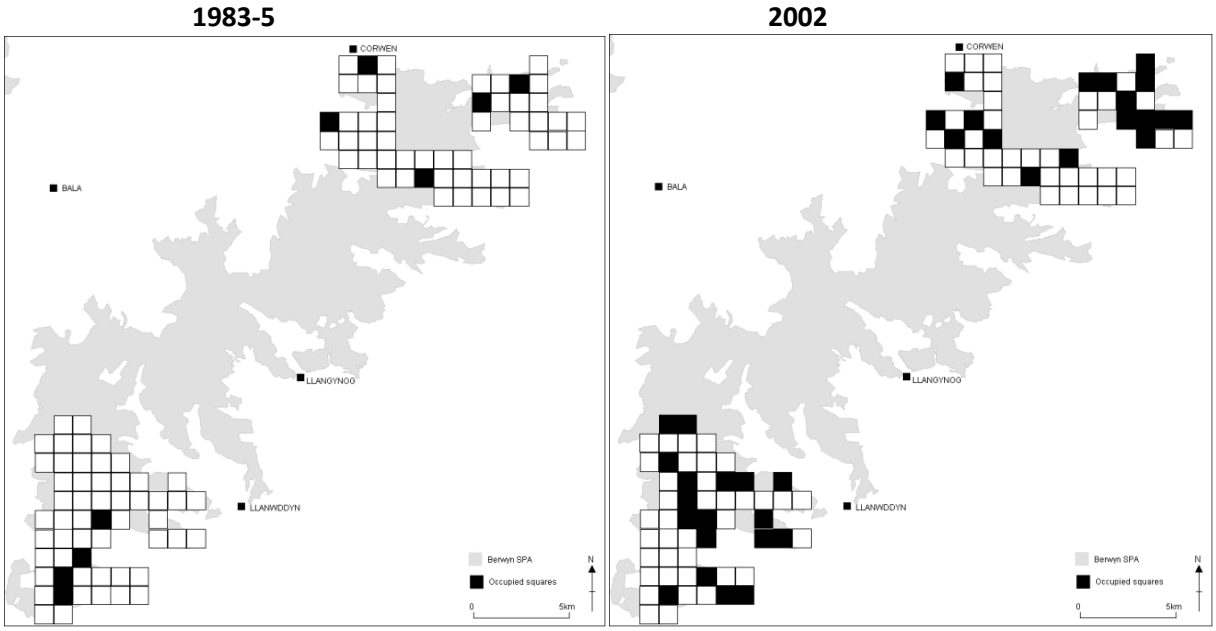
Table 10. The total numbers and density of raptors in the Berwyn SPA survey areas in 1983-5 and 2002 and the changes in abundance between survey years

Species	Total numbers (density- birds km^{-2})		Change (%)	$F_{1,27}$	P
	1983-5	2002			
Hen harrier	35 (0.33)	18 (0.17)	-48	-1.18	0.24
Merlin	10 (0.09)	14 (0.13)	+44		
Red Kite	2 (0.02)	4 (0.04)	+100		
Peregrine	1 (0.01)	8 (0.07)	+600		
Buzzard	14 (0.13)	35 (0.33)	+154	9.30	0.002
Short-eared owl	3 (0.03)	2 (0.02)	-33		
Kestrel	18 (0.17)	15(0.14)	-18		
Goshawk	0 (0)	2 (0.02)	+100		
All raptors	83 (0.78)	98 (0.92)	+18	1.24	0.27

Table 11. Changes in the distribution (presence within 1-km^2 squares) of upland birds between 1983-5 and 2002 in the Berwyn SPA

	1-km^2 grid squares observed		
	1983-5	2002	% change
Hen Harrier	21	19	-10
Merlin	10	11	+10
Red Kite	2	4	+100
Peregrine	1	8	+700
Buzzard	9	37	+311
Short-eared owl	3	1	-67
Kestrel	19	15	-21
Goshawk	0	3	+100

Figure 11. Distribution of buzzards in 1983-5 and in 2002 in the Berwyn SPA (filled 1-km^2 squares denotes presence, open squares absence).



Gamebirds

The numbers of red grouse and black grouse encountered on the upland breeding bird surveys declined by 54% and 78% respectively between survey years (Table 12). Occupied range of red grouse declined by 38% from 52 to 32 occupied 1-km^2 grid squares and black grouse by 28% from 25 to 18 occupied squares (Table 13, Figure 12a). The abundance of all game birds combined declined by 63% between survey years.

Table 12. The total numbers and density of gamebirds in the Berwyn SPA survey areas in 1983-5 and 2002 and the changes in abundance between survey years

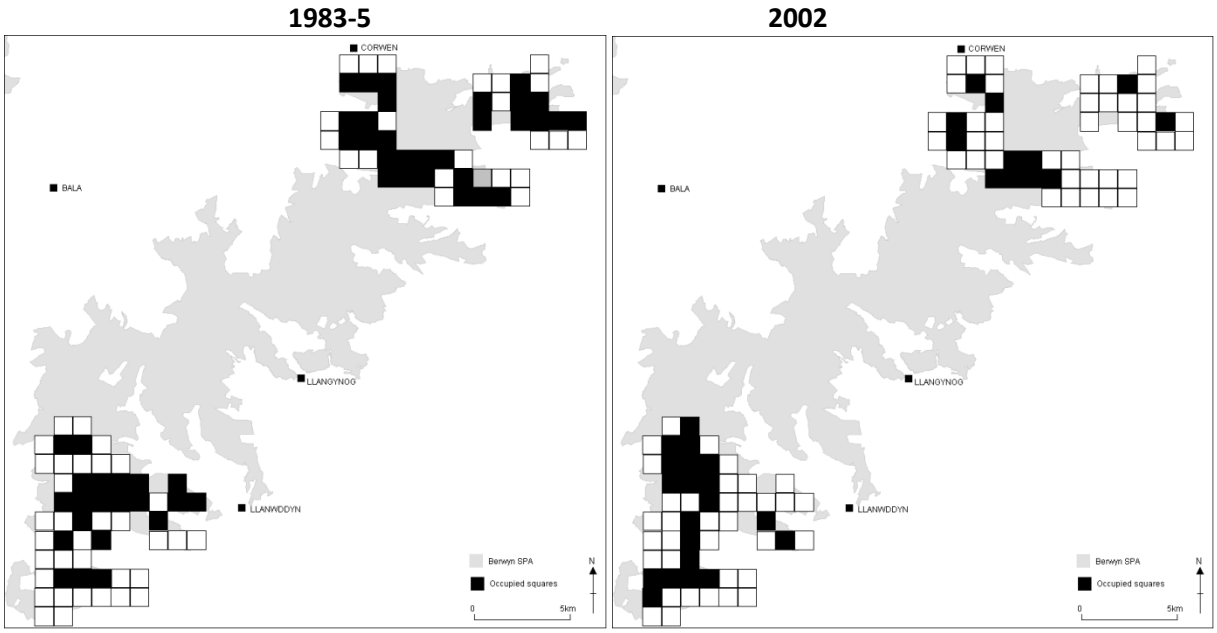
Species	Total number (density - birds km^{-2})		Change (%)	$F_{1,27}$	P
	1983-5	2002			
Red grouse	117 (1.09)	54 (0.50)	-54	23.77	<0.001
Black grouse	111 (1.04)	25 (0.23)	-78	58.76	<0.001
Pheasant	7 (0.07)	10 (0.09)	+29		
All gamebirds	235 (2.20)	89 (0.82)	-63	68.22	<0.001

Table 13. Changes in the distribution (presence within 1-km^2 squares) of gamebirds in the Berwyn SPA between 1983-5 and 2002

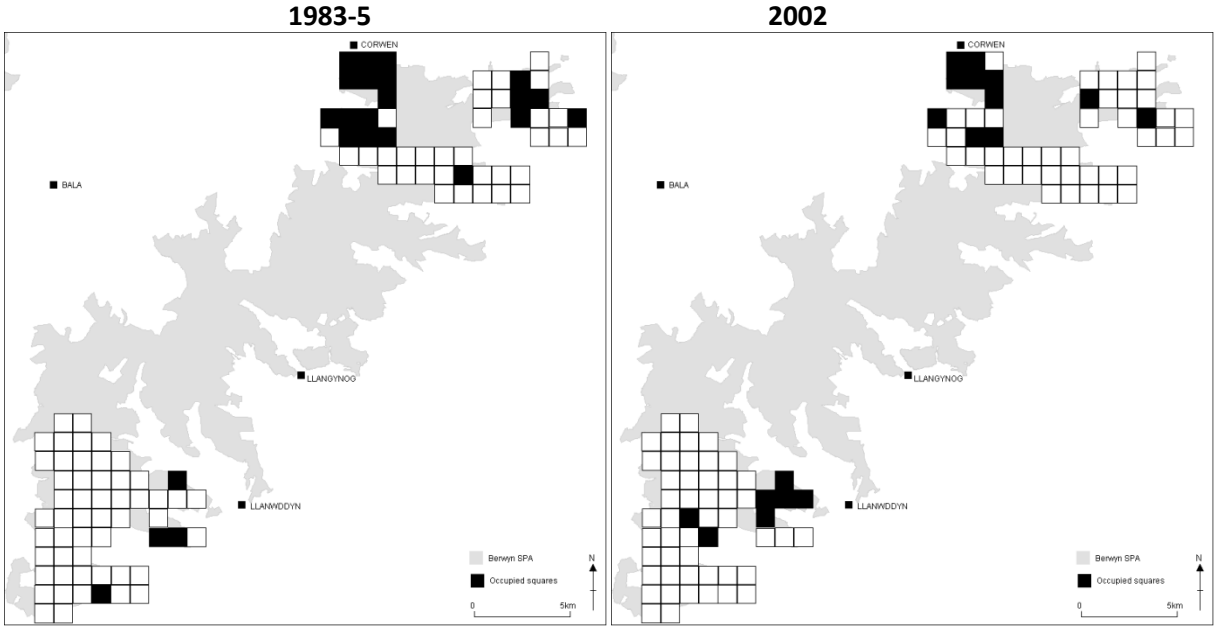
	1-km^2 grid squares observed		
	1983-5	2002	% change
Red grouse	52	32	-38
Black grouse	25	18	-28
Pheasant	6	8	

Figure 12. Distribution of red grouse and black grouse in 1983-5 and in 2002 in the Berwyn SPA (filled 1-km^2 squares denotes presence, open squares absence).

(a) Red grouse



(b) Black grouse



Changes in the ranked abundance of birds in the Berwyn

Between survey years meadow pipit remained the most abundant bird within the Berwyn (Table 14). In 1983-5 curlew were the second most abundant bird species but by 2002 they had dropped down to fourteenth, red grouse dropped from third to eighth, and black grouse, tree pipit and hen harrier all dropped out of the top ten. In 2002, carrion crow moved up to third from seventh, with stonechat, raven and woodpigeon all moving up.

Table 14. The ranked abundance of birds in the Berwyn SPA recorded on upland bird surveys in 1983-5 in relation to 2002

Rank	1983-5	2002
1	Meadow pipit	Meadow pipit
2	Curlew	Skylark
3	Red grouse	Carrion crow
4	Skylark	Whinchat
5	Black grouse	Wren
6	Whinchat	Stonechat
7	Carrion crow	Willow warbler
8	Tree pipit	Red grouse
9	Hen harrier	Raven
10	Willow warbler	Woodpigeon

Trends in relation to conservation status

Between 1983-5 and 2002 two thirds of Red-listed species (those which are globally threatened according to International Union for Conservation of Nature and Natural Resources (IUCN) criteria) declined in abundance in the Berwyn SPA (Table 15). Short-eared owl and kestrel remained stable whilst there were increases in the numbers of willow warbler and grasshopper warbler.

Table 15. Trends in numbers of birds within the Berwyn SPA in relation to their conservation status in Wales (Johnstone *et al.* 2011)

Trend	Conservation status in Wales		
	RED	**AMBER**	**GREEN**
Decreasing	Lapwing	Tree pipit	
	Curlew		
	Golden plover		
	Ring ouzel		
	Black grouse		
	Red grouse		
	Cuckoo		
Stable	Short-eared owl	Red kite	
	Hen harrier	Merlin	
	Kestrel	Snipe	
		Skylark	
		Wheatear	
Increasing	Willow warbler	Meadow pipit	Whinchat
	Grasshopper warbler	Whitethroat	Stonechat
			Wren
			Raven
			Carrion crow
			Jackdaw
			Peregrine
			Woodpigeon
			Buzzard

Discussion

Grouse moor management effectively ceased within the Berwyn SPA in the 1990s. Red grouse remain at low densities, with shooting now restricted to walked-up shooting in good breeding years (Sotherton *et al.* 2009). In comparison to other areas of the UK where red grouse management persists, numbers of red grouse in Wales are now low and are considered critically endangered following a rapid decline in range and abundance (Johnstone *et al*. 2011). For purposes of comparison, from a sample of 43 moors in northern England between 1990 and 2011 red grouse summer densities were on average 177 grouse km^{-2} and in 2011 summer densities were the highest recorded in the past thirty years with 318 grouse km^{-2} reported (Baines *et al*. 2011).

With the cessation of grouse moor management in the Berwyn the assemblage of breeding waders declined, lapwing were absent in the surveyed areas in 2002, golden plover declined to one individual and curlew declined by 79% despite the high levels of conservation designation given to the area. Whilst the breeding waders declined in the Berwyn SPA, the corvids; carrion crow and raven flourished, with increases also in the raptors; buzzard and peregrine. The increasing trend in numbers of raptors in the Berwyn reflects a wider UK trend, with buzzards increasing by 435% between 1970 and 2010 and peregrine by 194% between 1970 and 2002 (Eaton *et al*. 2011) recovering from the legacy of organochlorine pesticides and historical persecution (Banks *et al.* 2002). Similar changes in bird assemblages were observed following the cessation of driven grouse moor management on a Scottish moor within a Scottish SPA (Baines *et al*. 2008). On this moor, in the absence of gamekeepering, carrion crow and red fox *Vulpes vulpes* abundance increased, whilst, when managed previously for driven shooting, red grouse, curlew, lapwing, golden plover, skylark and hen harrier were all more abundant.

Breeding waders are declining throughout the British uplands (Sim *et al*. 2005) attributed to commercial afforestation, drainage, increases in generalist predators, changes in grazing patterns and a decline in grouse moor management. Grouse moors form an important refuge for breeding waders. A survey of upland breeding birds in parts of England and Scotland found that the densities of golden plover, curlew, redshank and lapwing were up to five-fold greater on managed grouse moors compared to unmanaged moorland (Tharme *et al*. 2001). The rates of decline observed in breeding waders in the Berwyn are of conservation concern, and it is likely that in the coming decades, lapwing, golden plover and curlew will be lost from the Welsh uplands unless urgent conservation management is implemented. Measures to prevent their loss from these areas are required now as these birds demonstrate philopatry to breeding grounds and have high site fidelity in breeding adults (Thompson *et al*. 1995, Pearce Higgins & Yalden 2003, Grant *et al.* 1999). Therefore, if lost as a breeding species it is unknown if even if conditions were improved whether birds would re-colonise because the nearest breeding populations are 100 km to the east in the Peak District.

To restore breeding waders in the Berwyn SPA, control of the generalist predators, carrion crow and red fox is recommended (Fletcher *et al.* 2010). In Northumberland, predator control increased the breeding success and subsequent abundance of lapwing, curlew, golden plover and red grouse, which in the absence of predator control failed to rear sufficient chicks to sustain numbers which subsequently declined (Fletcher *et al*. 2010). Implementing predator control alone in the Berwyn is likely to be ineffective, as habitats have also subtly changed. Sheep grazing reductions to restore blanket bog habitats and the cessation of burning have made the Berwyn less attractive to breeding waders. Similarly, the maturation of commercial forest stands has also reduced the availability of habitats for moorland birds whilst providing habitat for generalist predators. Evidence of these subtle changes in the vegetation from managed heathland to unmanaged scrub can be deduced from the changes in the top ten common birds encountered on upland bird surveys between 1983-5 and 2002. In 1983-5, six species in the top ten were moorland and moorland fringe species; red grouse, curlew, meadow pipit, hen harrier, skylark and black grouse, but in 2002, only three of these remained with more scrub specialists, willow warbler and wren now occupying the top ten. Similarly there were increases between survey years in whitethroat, grasshopper warbler and chiffchaff all considered to be more scrub specialists than moorland birds. It is evident that to restore the suite of upland waders to the Berwyn, both habitat management through burning and grazing in conjunction with predator control would be required.

The Berwyn was designated as an SPA for hen harrier, merlin, peregrine and red kite. From the repeat upland bird survey, peregrine increased whilst hen harrier declined. Over a similar timeframe, more robust hen harrier monitoring within the Berwyn reported that numbers of hen harrier increased from 5 pairs in 1983 to a peak of 18 territorial pairs in 1988, falling to 5 pairs in 2000 (Offord 2002). Since then numbers have recovered to 13 pairs in 2004, with a wider recovery throughout Wales (Whitfield & Fielding 2009). Despite these increases, a report on the status on the designated raptors concluded that the Berwyn SPA was considered to be in unfavourable condition for these species as it had failed to meet targets for the numbers of breeding pairs (Pathfinder Report 2008). Hen harriers prefer tall mature heather for nesting (Redpath *et al.* 1998) and following a cessation in heather burning and reduced grazing this is not deemed limiting in the Berwyn. Similarly, persecution stopped (Whitfield & Fielding 2009) and a key prey species, meadow pipit (Amar *et al*. 2003) doubled in abundance between surveys in 1983-5 and 2002. Therefore an increase in numbers may have been expected here. Ground nesting raptors such as hen harrier and merlin are vulnerable to nest predation by foxes (Baines *et al.* 2008). Therefore it is likely that predator control to increase breeding waders, in the absence of illegal persecution would also be beneficial to these breeding raptors.

In the UK, breeding golden plover, dunlin, lapwing and curlew are disappearing from upland areas (Sim *et al*. 2005), and grouse moors have been shown to support higher densities than

unmanaged moorland (Tharme *et al.* 2001, Tapper *et al*. 2005). In the Berwyn and wider Welsh uplands no driven grouse shooting is now practised. The Berwyn has a history of producing good grouse bags, but despite significant investment in heather moorland in northern England and Scotland, this has not occurred in Wales. Restoring grouse moor management in Wales would be difficult and very expensive due to a number and combination of factors which include the fragmentation of heather habitats due to commercial afforestation, the presence of the disease Louping ill, high densities of breeding raptors and heather burning restricted on blanket bog. To restore breeding wader populations within the Berwyn, we suggest that predator control is incorporated as a general tool within agri-environment schemes, particularly where habitat enhancements through heather burning and appropriate grazing are being practised.

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