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Anthropogenic pressures within the breeding range of the Hen Harrier *Circus cyaneus* in Ireland

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ABSTRACT

Capsule: Patterns in the frequency and co-occurrence of anthropogenic pressures associated with suitable breeding habitat for Hen Harriers *Circus cyaneus* demonstrates the need for specific, focussed management and policy options aimed at mitigating impacts on this threatened population.

Aims: To describe anthropogenic pressures and threats in the upland breeding range of Hen Harriers and to explore their potential impacts on the declining Hen Harrier population.

Methods: We used text mining, mixed-effects models, principal component analysis and clustering methods to explore anthropogenic pressures on suitable breeding and foraging habitats for Hen Harriers in Ireland, based on the 2015 national breeding Hen Harrier survey data.

Results: Mixed-effects models described a strong influence of agriculture, forestry, predator activity, and recreational activities on survey areas that contained Hen Harrier territories. Cluster analyses described three discrete pressure clusters and showed consistent co-occurrence of independent pressures.

Conclusions: Areas of suitable habitat for Hen Harriers in the uplands overlap with areas that experience anthropogenic pressures known to negatively impact on this vulnerable bird species. Combined with clear evidence for the co-occurrence of multiple pressures at a regional scale, this demonstrates a clear need for statutory agencies to consider the potential cumulative impacts of individual pressures when developing conservation strategies for Hen Harriers.

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Many species, worldwide, are threatened by anthropogenic pressures that require intervention to mitigate or eliminate their negative impacts (Wilcove *et al.*1998, Carroll *et al.* 2015, Di Minin *et al.* 2016). Such pressures can result in stress responses or reduced fitness in wildlife that, in some cases, have severe impacts on individuals or populations (Wilcove *et al.*1998, Taylor & Knight 2003, Johnson *et al.* 2005, Ciuti *et al.* 2012, Coetzee & Chown 2016). Conservation processes typically aim to prevent species population declines and extinctions (Soule 1985). However, conservation policy must also be cognizant of the sustainable management of environmental resources and other activities of economic and social importance including commercial forestry, agriculture, and recreation (Young *et al.* 2005, Kareiva & Marvier 2012, Kennedy *et al.* 2016, Vangansbeke *et al.* 2017).

Human activities in the vicinity of breeding birds can lead to increased rates of nest desertion (White & Thurow 1985), and reduced rates of site occupancy (Webber *et al.* 2013), territory establishment (Bötsch *et al.* 2017), breeding success (Balotari-Chiebao *et al.* 2016), and survival (Ruhlen *et al.* 2003, including illegal killing, e.g. Smart *et al.* 2010). Quantifying the extent and ecological relevance of each of these impacts informs our understanding of human–wildlife interactions and underpins conservation and resource management processes. It is essential, therefore, that human activities that have the potential to affect wildlife, particularly vulnerable species of conservation concern, are properly assessed and understood, so that appropriate measures can be developed to facilitate conservation and sustainable land and resource use.

Hen Harriers *Circus cyaneus* are medium-sized raptors that nest largely in upland areas, preferentially in heather moorland (Redpath *et al.*1998, Barton *et al.* 2006, Amar *et al.* 2008, Ruddock *et al.* 2012, 2016,

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Watson 2017), during the breeding season. Upland habitats in Ireland have been subjected to degradation and land-use change. As a result of a large-scale afforestation programme in the Republic of Ireland from the 1950s and the conversion of 'traditional' open habitats to forest, Hen Harriers in Ireland are also frequently associated with young (i.e. pre-thicket) conifer plantations that provide them with areas for nesting and foraging (Wilson *et al.* 2009, Irwin *et al.* 2012, Wilson *et al.* 2012, Ruddock *et al.* 2016). Anthropogenic impacts such as afforestation and forest management (NPWS 2015), landscape degradation and land-use change (Wilson *et al.* 2009, 2012), livestock grazing (O'Rourke & Kramm 2009), illegal burning (Renou-Wilson *et al.* 2011), peat extraction (O'Riordan *et al.* 2015), recreation (Hynes & Buckley 2007), and wind energy development (Wilson *et al.* 2017) could have important implications for breeding Hen Harriers in Ireland. While some mortality (via poisoning/shooting) has been recorded, the level of persecution observed in Britain (Redpath *et al.* 2010, Murgatroyd *et al.* 2019) has not been frequently observed in Ireland, perhaps as there are no areas that are managed solely for driven grouse shooting. Moreover, red grouse (*Lagopus lagopus scotica*) are red-listed species of conservation concern in Ireland (National Red Grouse Steering Committee 2013) and there is a widespread, self-imposed moratorium on grouse shooting by shooting fraternity. However, raptors are known to migrate within the British Isles (Mead, 1973) and persecution of Hen Harriers in Britain could have hitherto undescribed impacts on the Irish population. The Hen Harrier population in Ireland is of national conservation concern (Colhoun & Cummins 2013), with a population of between 108 and 157 breeding pairs recorded in the most recent national survey (Ruddock *et al.* 2016). The species is listed under Annex I of the European Commission Birds Directive (2009/147/EC) that requires Member States to designate Special Protection Areas (SPAs) for their survival and reproduction. Six Hen Harrier SPAs containing important breeding areas for the species were designated in Ireland in 2007.

Hen Harrier monitoring and conservation research in Ireland to date has focussed on national population estimates (Barton *et al.* 2005, Ruddock *et al.* 2012, 2016), the impacts of afforestation (Irwin *et al.* 2012, Wilson *et al.* 2009, 2012) and wind farm development (Fernández-Bellon *et al.* 2015, Wilson *et al.* 2017) on their populations, as required to inform conservation management. Due to the targeted nature of previous research, very little information is available in the published literature regarding the broader range of anthropogenic pressures that might impact breeding Hen Harriers and associated foraging and breeding habitat. Furthermore, previous research has considered how individual pressures impact separately and in specific contexts while consideration of the synergies between pressures is lacking. To address these gaps, we explored data on anthropogenic pressures affecting Hen Harriers within their breeding range in Ireland, with the aim of deriving information that would inform conservation and management processes for this threatened species.

Methods

The 2015 National Survey of Breeding Hen Harriers in Ireland was conducted between March and September 2015 in suitable Hen Harrier habitat in upland areas, largely, but not exclusively, between 200 and 600 m above sea level and within the Hen Harrier breeding range (Ruddock *et al.* 2016). Survey squares of 10 km^2 ($n = 268$) were defined using the Irish National Grid (Figure 1(a)). Anthropogenic activities that could potentially impact on breeding Hen Harriers ('pressures' from hereon) were recorded from vantage points within each survey square during each of 4–6 dedicated watches per square, during the breeding season. Where sites were occupied, vantage points were a minimum of 500 m from nests sites. Vantage points were identified *a-priori* based on habitat suitability, topographical constraints, and the potential for observers to cause disturbance to breeding birds (Ruddock & Whitfield 2007, Whitfield *et al.* 2008). Hen Harrier territories ($n = 100$, across 54 survey squares) were recorded where identified; occupancy was based on observations of Hen Harrier breeding behaviour and the repeated presence of birds (Ruddock *et al.* 2016). Data were collected by staff, members, and volunteers from the National Parks & Wildlife Service (NPWS), BirdWatch Ireland (BWI), Irish Raptor Study Group (IRSG), Golden Eagle Trust (GET), university researchers, and independent commercial and voluntary ornithological surveyors.

Pressures were divided into 47 discrete categories (online Table S1) aligned with the European Commission Birds Directive (2009/147/EC) reporting matrix. The frequency of occurrence of each pressure within 2 km of vantage point locations was recorded within each survey square. Initial exploration of the data revealed extreme outliers, therefore we adopted a precautionary approach and applied consistent thresholds throughout. Values for individual pressures that occurred beyond two standard deviations (SD) from the mean were replaced with the maximum value

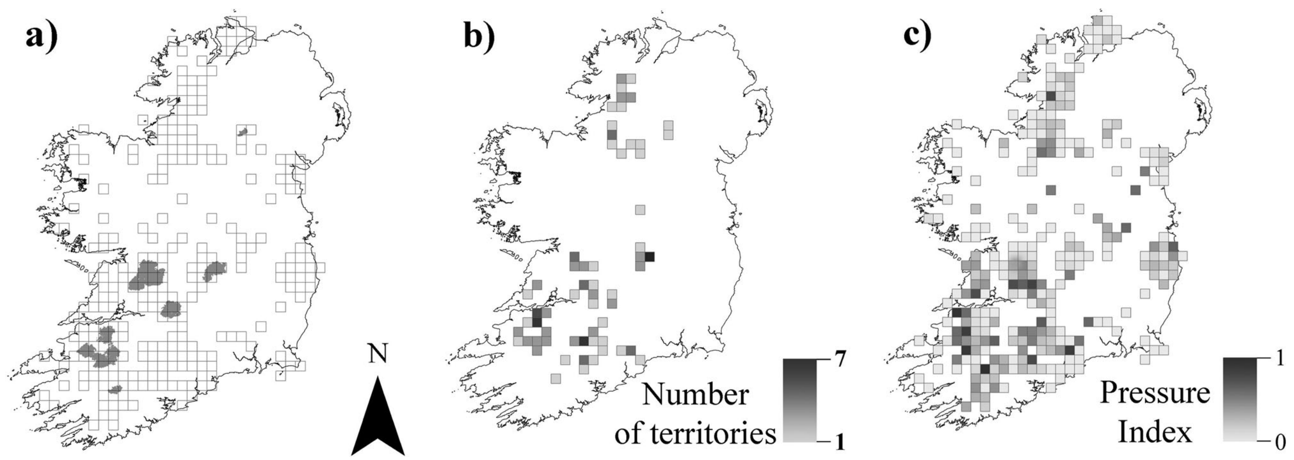

Figure 1. Maps of Ireland showing: (a) survey squares and SPAs (as indicated by grey polygons), (b) the total number of confirmed Hen Harrier territories per square, and (c) pressure indices derived from cumulative observations of pressures within each survey square. See online Table S2 for square-specific data.

as defined by the aforementioned threshold, rounded to the nearest whole integer. This allowed us to capture the prevalence of each pressure at each location while mitigating over-inflation. The sum frequency of each pressure was calculated: (i) across all survey squares where the total number of recorded pressures was greater than zero ($n = 146$; online Table S2); (ii) across squares located within SPA boundaries only ($n = 24$); and (iii) across squares where confirmed Hen Harrier territories were present ($n = 54$). It was necessary to account for variation in survey effort as the number of visits made to vantage points varied between observers. Therefore, a Pressure Index (PI) was created, where the total number of pressures was divided by the total number of visits (Ruddock *et al.* 2016). PI scores were normalized between 0 and 1 to facilitate comparisons between sites. General linear models were used to investigate differences between PI scores – with zero counts removed and remaining data log transformed to meet model assumptions – where PI was the dependent variable and the location of vantage points relative to SPA boundaries (inside/outside) and confirmed Hen Harrier territories (present/absent) were explanatory variables. Models explored each category (SPA boundaries and Hen Harrier territories) independently as well as part of a fully-factorial model that included an interaction term.

Principal component analysis (Jolliffe & Cadima 2016) and linear mixed-effects models were used to investigate relationships between the presence/absence of Hen Harrier territories and pressure categories. Data were Box Cox transformed to remove skewness, centred, and standardized to have mean = 0 and standard deviation = 1 prior to analysis. Principal components (PCs) that cumulatively accounted for over 50% of the variance were retained for inclusion in models. The presence/absence of Hen Harrier territories (Figure 1(b)) was entered as a binary dependent variable, retained PCs were included as explanatory variables and surveyor identity was included as a random variable. Model permutations were ranked using the Akaike Information Criterion (AIC); the top subset of models was found within ΔAIC $\leq$ 2 units (Burnham & Anderson 2002).

Cluster analysis was used to quantify associations between individual pressure categories across all survey squares. The various methods that comprise cluster analyses provide a means of classifying multivariate data into subgroups according to the similarity of their attributes, thus revealing the underlying structure (Everitt *et al.* 2009). We calculated the distance of each recorded pressure from the cluster's mean using a Euclidean distance index and applied the Ward error sum of squares hierarchical clustering method (Ward 1963) to the resultant data. The optimal number of clusters (k_t) was identified using average silhouettes (Kaufman & Rousseeuw 1990) and Approximately Unbiased (AU) P-values with multiscale bootstrap resampling ($B = 10\,000$) where clusters with $P \geq 0.95$ were strongly supported (Suzuki & Shimodaira 2006). All data analyses and plotting were carried out using the statistical programme R (R Core Team 2017), specifically the packages *cluster* (Maechler *et al.* 2018) and *pvclust* (Suzuki & Shimodaira 2015), *dendextend* (Galili 2015), *nlme* (Pinheiro *et al.* 2017), and *caret* (Kuhn 2017). Data are subject to data-sharing agreements and, therefore, cannot be redistributed. However, R code used for data exploration and analyses are available at http://doi.org/10.5281/zenodo.3549584.

Results

A total of 2873 individual pressure occurrences were recorded during this study. There were no anthropogenic pressures recorded in 45% of survey squares. The most frequently recorded pressures across all survey squares were *forest management and use* (13% of occurrences), *paths, tracks, forest roads* (11%), *uncontrolled burning* (6%), and *wind energy production* (6%). Similar pressures were recorded inside and outside of SPA boundaries: *forest management and use* (14% and 11% of occurrences, respectively), *paths, tracks, forest roads* (10%, 0%), forest planting on open ground (0%, 8%), *uncontrolled burning* (6.6%, 7%), and *wind energy production* (9.5%, 7%). The most frequently recorded pressures associated with confirmed Hen Harrier territories were *loss of habitat features* (13.7%), *dispersed habitation* (10.5%), *paths, tracks, forest roads* (9.2%), and *forest management* (8.1%). In contrast, pressures at vantage points where there were no Hen Harrier territories were *forest management and use* (16%), *off-road motorized driving* (12%), *forest planting on open ground* (11%), and *mechanical removal of peat* (11%).

Pressure indices varied between survey squares (Figure 1(c)) and only one survey square had a PI > 0.5. Survey squares where vantage points occurred within SPAs had a maximum PI of 0.22 (mean ± SD = 0.08 ± 0.07), which was significantly higher than those outside SPAs ($t = 0.028$; $\beta \pm SD = -0.44 \pm 0.20$; $P = 0.03$). Survey squares where vantage points were associated with Hen Harrier territories had a maximum PI of 0.42 (mean ± SD = 0.10 ± 0.09; online Table S1), which was significantly higher than those that were not associated with territories ($t = 0.038$; $\beta \pm SD = -0.39 \pm 0.19$; $P = 0.04$; Table 1).

Both silhouette and AU clustering methods supported three discrete clusters ($P \geq 0.05$). The largest cluster (*ii*) consisted of 25 pressure categories while the smallest (*iii*) was the most distinct and consisted of 5 pressure categories. One sub-cluster was statistically supported (*iv*) and was comprised of 17 pressure categories (Figure 2).

Table 1. General linear model results for regional differences in pressures on Hen Harrier breeding habitat – expressed as a Pressure Index (PI; log transformed). s = Special Protection Areas (SPA; inside/outside); r = confirmed territories (present/absent). Regression coefficients ($\beta \pm$ SE) and significance of contributory variables are given, where $^*P < 0.05$.

Model	Variable	T	β (±SE)		
PI ~ r	r	0.038	−0.39	±	0.19*
PI ~ s	s	0.028	−0.44	±	0.20*
PI ~ $r + s + r^*s$	s	−0.515	−0.14	±	0.28
	r	−0.683	−0.16	±	0.23
	s^*r	−1.128	−0.46	±	0.40

A total of seven principal component axes, accounting for >50% of the total variance, were retained for inclusion in mixed-effects models investigating the relationship between the presence/absence of Hen Harrier territories and associated pressures. The top subset of models (ΔAIC ≤ 2) included PC1, PC2, and PC3. PC1 accounted for the greatest proportion of total variance (20%); loadings were most strongly weighted towards aspects of agricultural and forestry activity and predators; PC2 (8%) was weighted towards forest management and site access; and PC3 was weighted towards forest clearance and recreational activities (Table 2). The best approximating model was positively influenced by PC1 and PC3, and negatively influenced by PC2 (Table 2). It should be noted that PC1 includes *nest destruction*, *predation by birds*, and *predation by mammals*. These pressures can only occur where Hen Harriers nest, hence the observed positive association is to be expected.

Discussion

The results show that suitable Hen Harrier breeding habitats in Ireland are subjected to a wide range of anthropogenic pressures that could have significant implications for this vulnerable species. The number and variety of pressures recorded demonstrates the potential for direct disturbance of Hen Harriers throughout the breeding season. The issue is potentially exacerbated by the fact that and Hen Harriers are frequently recorded to over-winter in these same upland areas (O'Donoghue, 2010). Furthermore, the co-occurrence of pressures as described by cluster analyses demonstrates the considerable potential for cumulative effects. Anthropogenic impacts are not homogenous in their severity or extent. This is certainly true in the current study, where some pressures will have more severe consequences for Hen Harriers or will act at different spatial scales. However, there is a dearth of quantitative data on the impacts of described pressures on Hen Harriers. Our results highlight the importance of managing pressures in an integrated manner rather than on an individual basis. This provides support for the effective management of suitable breeding areas to minimize the potential impact of anthropogenic pressures on vulnerable Hen Harrier populations.

Planted forests and the presence of tracks or roads were recorded at high frequencies in all survey squares across Ireland. Large areas of Irish upland habitat have been afforested in recent decades and total forest cover is expected to continue to increase from the current 11% to as much as 18% in the next 30 years (NPWS

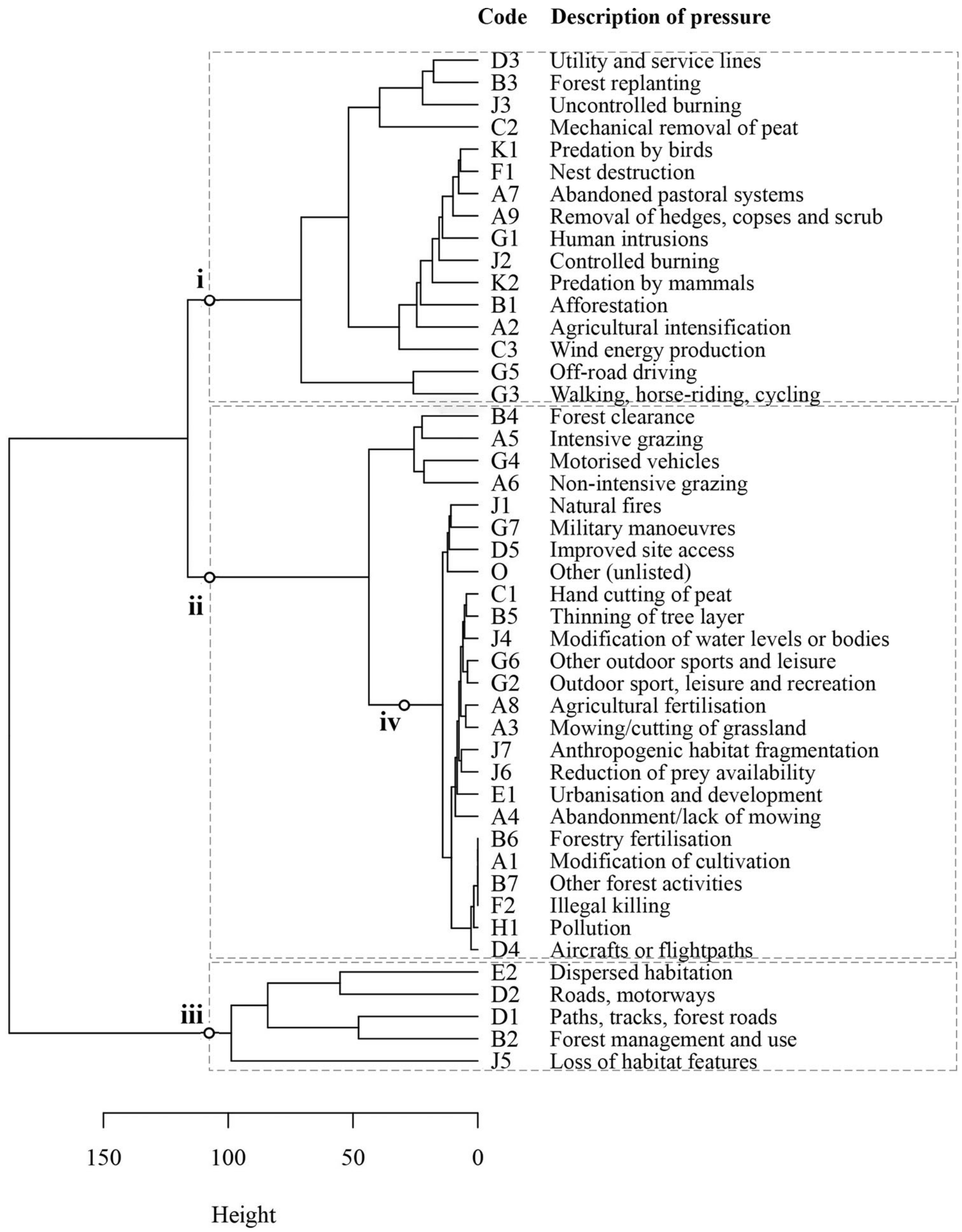

Figure 2. Relationships between pressures associated with potentially suitable breeding habitat for Hen Harriers. Pressure codes are taken and descriptions abbreviated from those given in Ruddock *et al.* (2016). Dashed grey rectangles indicate outermost clusters identified via the silhouette method and multiscale bootstrapping (10 000 iterations; Approximately Unbiased $P \leq 0.05$). ○ = clusters supported at AU $P \leq 0.05$. For detailed pressure definitions, see online Table S1.

2015). In the absence of their traditional open heath and blanket bog habitat, Hen Harriers in Ireland are frequently associated with young (i.e. pre-thicket) conifer plantations that provide areas that Hen Harriers use for nesting and foraging (Wilson *et al.* 2009, Irwin *et al.* 2012, Wilson *et al.* 2012, Ruddock *et al.* 2016). Hen Harriers cannot use closed-canopy forests for breeding or foraging, therefore the maturation of the existing forest estate threatens to deprive Hen Harriers of already scarce breeding habitat, while further increases in forest cover could also lead to increased habitat fragmentation and subsequently reduce the capacity of the landscape to support breeding pairs. Recreational activities were also strongly associated with survey squares containing Hen Harrier territories. Systematic reviews have demonstrated that recreational activities can negatively impact breeding birds (Steven *et al.* 2011, Larson *et al.* 2016) including above-ground foragers (Bötsch *et al.* 2017). Thus, there exists the potential for the direct disturbance of Hen Harriers throughout the breeding season.

Table 2. Linear mixed-effects model results for pressures – expressed as PC – associated with confirmed Hen Harrier territories (present/absent). Models were evaluated according to their AIC value. Factors retained in the top subset of n models (<Δ2 AIC) are highlighted. Constituent pressures along with pressure codes and associated loadings (coefficients in parentheses) are given. Pressure codes are taken and descriptions are abbreviated from those given in Ruddock *et al.* (2016; see online Table S1). Regression coefficients ($\beta \pm$ SE) and significance of contributory PCs are given, where $^{*}P < 0.05$, $^{**}P < 0.01$, and $^{***}P < 0.001$. For constituent pressures in PC4-7, see online Table S3.

Principal Component (% variance explained)	Pressure	β	± SE	t	
PC1	Abandoned pastoral systems (A7; 0.29)	0.025	0.007	3.52	**
(21%)	Removal of hedges, copse and scrub (A9; 0.29)				
	Forest replanting (B3; 0.27)				
	Nest destruction (F1; 0.29)				
	Controlled burning (J2; 0.27)				
	Predation by birds (K1; 0.31)				
	Predation by mammals (K2; 0.26)				
PC2	Forest management and use (B2; −0.28)	−0.046	0.009	−5.05	***
(10%)	Forest clearance (B4; −0.30)				
	Thinning of tree layer (B5; −0.26)				
	Paths, tracks, forest roads (D1; −0.35)				
	Roads, motorways (D2; −0.33)				
	Natural Fires (J1; −0.30)				
PC3	Dispersed habitation (E2; −0.32)	0.044	0.011	−3.91	**
(7%)	Outdoor sport, leisure and recreation (G2; −0.35)				
	Walking, horse-riding, cycling (G3; −0.42)				
	Motorized vehicles (G4; −0.29)				
	Off-road driving (G5; −0.32)				
	Other outdoor sports and leisure (G6; −0.30)				
PC4		0.010	0.013	0.78	
PC5		−0.004	0.014	−0.27	
PC6		−0.005	0.014	−0.38	
PC7		0.006	0.015	0.41	

Mammalian and avian predators were among the factors strongly associated with Hen Harrier territories. O'Donoghue (2010) attributed 55% of all nest failures in south and west Ireland in 2007 and 2008 to predation events and Red Foxes (*Vulpes vulpes*) have been observed depredating Hen Harrier chicks via remote-sensing camera traps (Irwin *et al.* 2012, Fernández-Bellon *et al.* 2018a). Other potential predators of Hen Harrier nests in Ireland include Pine Marten *Martes martes*, American Mink *Neovison vison*, Stoat *Mustela erminea*, Raven *Corvus corax*, and Hooded Crow *Corvus cornix* (Picozzi 1984, Fernández-Bellon *et al.* 2018a). These predators can have substantial negative impacts on ground-nesting birds (Paton 1994) as eggs and young chicks are particularly vulnerable to predation when parents are absent. Populations of generalist predators may be bolstered by changes in land-use and management, including afforestation and other forms of habitat fragmentation (Prestt 1965, Hayden & Harrington 2000, Chalfoun *et al.* 2002, Twining *et al.* 2019). However, data on the abundance and activity of upland predators in Ireland are scarce; efforts to investigate such may be of considerable benefit to the conservation of Hen Harriers.

It is notable that wind energy production was recorded more frequently within SPA boundaries than outside but was rarely recorded in survey squares that contained breeding Hen Harriers (3.3%) in this study, perhaps indicating avoidance of wind farms for breeding purposes (see also Wilson *et al.* 2017). Indeed, windfarm construction activity has been implicated in the desertion of traditional breeding sites in Ireland (O'Donoghue *et al.* 2011). The construction and operation of wind turbines can have both lethal and sub-lethal impacts on birds (Drewitt & Langston 2006, Marques *et al.* 2014, Balotari-Chiebao *et al.* 2016, Smith & Dwyer 2016, Fernández-Bellon *et al.* 2018b, Thaker *et al.* 2018). The Republic of Ireland is committed to European Union targets on renewable energy including a national target of 40% electricity from renewables by 2020, which is likely to involve the construction of additional wind farms (DCCAE 2010). Wind energy developments tend to be upland-focussed and future, large-scale expansion may pose a threat to breeding Hen Harriers. A bird sensitivity mapping tool has been developed to guide the siting of future wind energy developments in Ireland in relation to the distribution of species of conservation concern, including Hen Harrier (McGuinness *et al.* 2015). However, there is as yet no mandatory obligation on developers to use this tool.

The timing of disturbance events may be a key consideration and many sources of disturbance may already be present at the onset of breeding, when pairs are establishing territories, potentially resulting in nest abandonment. Other pressures such as peat extraction or illegal burning may not occur until after laying and, hence, can impact on parental care and, ultimately, breeding success. Such activities also effectively sterilise breeding habitat in the longer-term. Current mitigation measures for Hen Harriers in Ireland adopt a reactive approach where circular 'High Likelihood Nesting Areas' (HNLA, formerly Red Areas) of high sensitivity to Hen Harriers, that contain nesting pairs and with a radius of 1.2 km, are added to the HNLA network when new breeding pairs are identified (NPWS 2015). Some forestry operations that may cause disturbance are regulated within these HNLAs during the breeding season (Forest Service 2012). However, the protection afforded by HNLAs only applies to known pairs within the SPA network. Therefore, all other pairs that are outside of the SPA network (>50% of the breeding population; Ruddock *et al.* 2016) remain vulnerable to direct disturbance from forest management activities during the nesting season. Moreover, breeding Hen Harriers have been recorded travelling as far as 11 km from active nests (Irwin *et al.* 2012, Arroyo *et al.* 2014) and human activities and impacts in the wider landscape can have impacts on the physiology (Abbasi *et al.* 2017) and mortality (Ferrer & Hiraldo 1993) of birds. Human activities within the foraging range of breeding Hen Harriers could result in patch avoidance and/or stress-related responses in foraging birds, potentially keeping them away from the nest for longer periods of time and subsequently increasing chick vulnerability. It is possible that Hen Harriers in Ireland have the capacity to develop a tolerance for human activities during the breeding season, though this may be highly dependent on temporal and spatial variation of disturbance sources (Ruddock & Whitfield 2007, Whitfield *et al.* 2008). However, given their small population size and conservation status, the precautionary principle suggests that human activities should be strictly regulated in areas of suitable Hen Harrier breeding and foraging habitat, particularly during key breeding months. Furthermore, pressures and their potential impacts on breeding Hen Harriers must be placed in a broader context that includes the timing of pressure occurrence, the composition of the wider landscape, and the conservation of suitable habitat.

The pressures described herein represent potential disturbances to Hen Harriers throughout their breeding cycle and therefore may have important consequences for long-term population persistence or recovery. Recent research suggests that the same pressures impact another upland bird of prey, the Short-eared Owl *Asio flammeus*, across their European range (Fernández-Bellon, unpubl. data). Thus, we recommend the following actions to enhance conservation benefits for Hen Harriers and other sensitive upland species and habitats: (i) restrict forestry activities within the known Hen Harrier range during the Hen Harrier breeding season (March–August) by using targeted surveys to detect Hen Harrier presence, thereby ensuring that forest management activities can be undertaken in areas that do not hold Hen Harriers during the summer months; (ii) review and identify risks during the wintering season for Hen Harriers, particularly as many of the upland breeding sites can be used by roosting birds during winter; (iii) quantify the abundance and activity of upland predators and explore options for predator control, where appropriate; (iv) avoid recreation and non-licensed forestry-related activities in areas known to hold Hen Harriers, throughout the breeding season, supported by a programme of community engagement, awareness-raising and upland signage; and (v) improve lines of communication between stakeholders so that potentially disturbing or damaging activities can be identified at the earliest stages.

Failure to mitigate anthropogenic disturbances in upland areas of potentially suitable Hen Harrier breeding habitat, whether inside or outside of SPAs, could have negative consequences for this already vulnerable population. To date, none of the SPAs in the Hen Harrier Natura 2000 network possess management plans, one of the key requirements of such sites, over a decade on from designation in 2007, and a Hen Harrier Threat Response Plan, initiated by the National Parks & Wildlife Service in the Republic of Ireland in 2016 with wide stakeholder consultation, has yet to be published. Furthermore, connecting multiple pressures is a key issue for conservation management, and Hen Harrier conservation policies must comprehensively account for cumulative anthropogenic impacts at regional level. Successful mitigation and management would represent a significant step towards the conservation of Hen Harriers in Ireland and serve as an example for upland conservation initiatives in Europe.

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