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Unleashed: walking dogs off the lead greatly increases habitat disturbance in UK lowland heathlands

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Abstract
Human population growth is associated with increased disturbance to wildlife. This effect is particularly acute in urban and periurban areas, where the area of effective disturbance extends beyond that of human presence by the roaming behaviour of pet dogs. Dogs are globally the dominant companion animal, with a population of ~12 million in the UK. As urban areas extend, dogs are exercised in green space close to housing. In southeast and southern England these areas include lowland heath, a habitat of high conservation value. To quantify disturbance caused by dog walkers and their dogs, we used GPS units to track the movement of people and their dogs across four lowland heath sites, used a questionnaire to ask about dog walking habits, and mapped potential areas of disturbance caused by dog walkers. Questionnaires were completed by 798 dog walkers and the walks of 162 owners and their 185 dogs were recorded. Mean (±SE) walk time was 56 ± 23 min, walk distance 3.75 ± 1.68 km and dogs were a median distance of 20 m from the owner during walks. Dogs were walked once (44%) or twice (56%) a day. Most (always: 85%; always or occasionally: 95%) dogs were walked off the lead even when signs were present requesting that dogs were kept on a lead. This resulted in up to a 21% increase in reserve area disturbed. In one reserve (Snelsmore Common), > 90% of the area was disturbed by dogs, greatly eroding its conservation value. This work highlights the importance of considering how dog ownership can exacerbate levels of disturbance in sensitive periurban habitats when housing developments are planned.

Keywords *Canis familiaris* · Disturbance · Pet dog · Flight initiation distance · GPS tracking · Lowland heathlands

Introduction

We are undergoing a biodiversity crisis, and one driver in the decline of species globally is human disturbance (Beale and Monaghan 2004; Pirotta et al. 2018). The presence of humans causes a range of behaviours in wild animals that may increase susceptibility to predation (Chan et al. 2010) and detract from other activities such a feeding and breeding (Wilson et al., 2020). Many bird species perceive humans as predators and respond by fleeing (Bötsch et al. 2018), with longer flight initiation distances assumed to be associated with contexts which individuals consider more threatening (Frid and Dill 2002). Flight initiation distances vary with the number of humans encountered, their speed and angle of approach, and notably, whether they are accompanied by a dog (Weston et al. 2012).

Domestic dogs (*Canis familiaris*) are the most popular companion animal in the world, with an estimated global population of one billion (Gompper 2014), which is likely an underestimate. Dogs predate wild animals (Gompper 2021), including species like rabbits and deer, and can also have indirect effects on the environment. Dog urine and faeces add high levels of nitrogen and phosphorus which is especially an issue in habitats with nutrient poor soils like heathlands (De Frenne 2022). Dogs also have the potential to significantly increase the exposure pathway of veterinary medicines into the environment, especially aquatic environments when dogs enter the water following flea treatments (Diepens et al. 2023). However, the most frequent cause of disturbance will be directly through the presence of dogs as they receive exercise outside of the home. Although

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evidence suggests that dog walking can disturb birds (Banks and Bryant 2007; Steven et al. 2011; Weston and Stankowich, 2015), and the presence of dogs has been associated with lower chick survival (Dowling and Weston 1999), the scale of potential disturbance caused during dog walking has received little attention in the literature, including in a recent review of dog-wildlife interactions (Gompper 2021). Where walking takes place in breeding bird habitat, this disturbance has the potential to reduce available breeding habitat for many species as well as negatively affecting fecundity through sub-lethal fear effects (Beckerman et al. 2007).

In the UK, 30% of people own one or more dogs, resulting in a population of over 11 million owned dogs (Murray et al. 2015). Dogs are commonly exercised by their owners, on or off a lead or leash, and dog walking is commonly found to have a negative effect on birds [e.g. in all 11 papers reviewed by Steven et al. (2011)]. Even the presence of dog walkers and their dogs, despite being walked on a lead, reduces bird abundance and diversity, with ground nesting birds the most affected (Banks and Bryant 2007). A study of European nightjars (*Caprimulgus europaeus*), using nest observation cameras documented incidences of birds being flushed from eggs and chicks by dog presence (Langston et al. 2007). This disturbance is also magnified in areas with high human density, with a surrogate for human density and settlement measures being shown to negatively affect European nightjar abundance (Liley and Clarke 2003). Most research on the disturbance caused by dogs has focused on the behavioural and physiological effects on wildlife, with less focus on the behaviours of dogs or their owners. Minimising these impacts would depend on management interventions which changed the behaviour of dogs, which are controlled by the dog owner. Popular interventions are dog-free zones and keeping dogs on leads, and although existing evidence suggests that compliance may be an issue (Dowling and Weston 1999; Schneider et al., 2019).

Nearly half of all bird species (49%, 5412 species) have declining populations (BirdLife International 2022), particularly for species that have specialist habitat requirements (BirdLife International 2020). In the UK some bird species are specialists of lowland heathlands, habitats characterised by the presence of grasses and dwarf shrubs such as gorse (*Ulex europaeus*) and heather (*Calluna vulgaris*), in areas less than 300 m above sea level. These habitats have declined considerably because of lack of management and land use change, with only one sixth of the heathland present in 1800 remaining (Price 2003). These habitats often contain rare and declining species such as the Dartford warbler (*Sylvia undata*) a ground nesting bird which is a specialist of lowland heaths (Newton et al. 2009; Moore 1962).

Countries, including the UK, are under pressure from increasing demand for housing and development (Hashemi 2013). This pressure is leading to increasing development in areas which border sites with significant value for wildlife. It has been suggested that housing development should be at least 400 m from nature reserves and other protected areas because of the effects of domestic cat (*Felis catus*) roaming and predation (Thomas et al. 2014; Pirie et al. 2022). There are also potential consequences from the increased numbers of walkers and dog walkers on these nature reserves and other protected areas when development is in close proximity. Housing developments close to natural areas lead to an increase in visitor numbers and so cause additional pressure on the wildlife found there (Weitowitz et al. 2019). Although it is common to walk a dog on a lead, people often remove this when they enter larger green spaces. Dogs off the lead and roaming off the trail could pose a greater risk to wildlife, as they roam further from their owners (Schneider et al., 2019). In the UK, SANGs (Suitable Alternative Natural Greenspaces) are being promoted as dog friendly walking spaces, situated in areas with less sensitive wildlife as a way to reduce visits to heaths (Thames Basin Heaths Partnership 2023). We currently know very little about the number of people who walk their dogs in lowland heath areas, what proportion of dogs are kept on a lead in lowland heath habitats and how this activity could reduce potential breeding habitat for birds of conservation importance.

The aims of the study were to: (1) use GPS trackers to understand the habitat use of dog owners and their dogs in lowland heaths; (2) to determine the proportion of potential bird nesting habitat reduced due to the disturbance caused by the walkers; dogs had they been on a 3 m long lead; dogs off the lead.

Materials and methods

Study sites

The study took place between 19th June 2017 and 23rd September 2017. All four sites sampled (Fig. 1; Table 1) were lowland heath habitats located in South-East England and are managed for both nature and human recreation by Surrey Wildlife Trust (Chobham Common; National Nature Reserve and Special Protection Area) and Berkshire, Buckinghamshire and Oxfordshire Wildlife Trust (Snelsmore Common; Greenham and Crookham Common; Wildmore Heath). Each site had clear signs asking dog walkers to keep their dogs on leads during the bird breeding season (March-September). There are no legal penalties for dog walkers who do not comply with these requests. The study was approved by the University of Reading School of Biological

Fig. 1 The four lowland heaths in South East England sampled between 19th June 2017 and 23rd September 2017. The basemap shows the Ordnance Survey GB Miniscale with urban areas in lilac, and larger settlements labelled by name. Inset maps show Snelsmore Common (A), Chobham Common (B), Greenham and Crookham Commons (C) and Wildmoor Heath (D). Each map shows the extent of the study site, Ordnance Survey Open Roads and a scale bar indicating 1000 m

Sciences ethical review committee (reference: SBS 16–17 24).

Dog owner questionnaire

All dog owners were approached by a surveyor as they entered the site. They were asked whether they would consent to be part of a study about local dog walking. If they consented the surveyor asked them a series of questions (supplementary materials) about their dog(s) and their walking habits before asking if they would consent to the tracking part of the research project. Questionnaire data were collected using the website/app Crowd Signal. Participants were provided with contact details and told that they could remove consent for their data to be used at any time.

GPS tracking

The GPS trackers (i-got U GT120 USB GPS receiver tracking devices, MobileAction, Taiwan), weighed 20 g and were 44.5×28.5×13 mm in size. The trackers have an error of 10.03 m (+/- 0.48) in open habitats (which forms the habitat type of each study area) (Coughlin and van Heezik 2015). The devices were encased in a blue gel case and were attached to the dog's collar by the owner and hung around the owner's neck using a lanyard.

A total of 572 dog owners expressed an interest during the dog owner questionnaire in GPS tracking their own walk and that of their dog(s). Due to GPS tracker availability at the time and GPS tracker failure, tracking data from 162 owner/dog pairs were used in subsequent analyses.

Flight initiation distance

Mean flight initiation distances were estimated using data from Livezey et al. (2016), which were collected between 2009 and 2015. Data for nesting birds were excluded due to low sample sizes. Data for non-Passeriformes were excluded due to low sample sizes and because the species of significant conservation concern in UK lowland heaths are all Passeriformes. Then, only data for pedestrian disturbances were used, due to low samples sizes of other means of disturbance. Mean flight initiation distance across the 553 data points ranged between 2.0 and 79.6 m. The 1st, 2nd and 3rd quartiles were 6.1, 8.5 and 12 m respectively.

Table 1 Area disturbed at least once during the sample period by owners, owners and dogs, or owners if dogs are kept on a 3 m lead, for birds with flight initiation distances of 6.1 m (1st quartile), 8.5 m (median) and 12 m (3rd quartile)

Area name and coordinates	No. walks sampled (number of dogs, number of sampling days)	Total size of reserve area (km^2)	Area disturbed by owners (km^2)			Area disturbed by owners with dogs on 3 m lead (km^2)			Area disturbed by owners and dogs without lead (km^2)			Increased area of disturbance from lack of lead (%)		
			1st Quartile	Median	3rd Quartile	1st Quartile	Median	3rd Quartile	1st Quartile	Median	3rd Quartile	1st Quartile	Median	3rd Quartile
Chobham Common 51.37545, -0.61507	39 (47, 16)	6.557	0.764	0.926	1.128	0.963	1.100	1.279	1.121	1.313	1.544	16	19	21
Greenham and Crookham Common 51.37776, -1.24911	48 (52, 13)	2.805	1.214	1.466	1.754	1.521	1.717	1.955	1.602	1.842	2.105	5	7	8
Snelsmore Common Country Park 51.43622, -1.33445	43 (52, 14)	1.040	0.657	0.759	0.873	0.781	0.859	0.952	0.814	0.911	1.018	4	6	7
Wildmore Heath 51.36044, -0.79712	32 (35, 12)	0.990	0.348	0.390	0.436	0.400	0.430	0.467	0.427	0.468	0.512	7	9	10

Data analysis

All analyses were conducted in R 3.6.3 (R Development Core Team, 2020). For each owner and dog, a trajectory of the walk was created from the GPS locations using the function 'Track' in the package trajectories (Pebesma et al. 2018) and the overall distance travelled was extracted. The 'compare' function in the trajectories package was used to calculate the median distance between the tracks of a dog and their owner during the walk.

To estimate the impact of dog walking on bird nesting habitat, the 'buffer' function in the package raster (Hijmans 2020) was used to add a buffer around a spatial lines files of all observed walks for owners (to calculate disturbance by walkers), owners and dogs, and owners plus an additional 3 m buffer to simulate all dogs being on a lead. Three meters was chosen as while some dog leads for sale in the UK have a length of 5 m (Pets at Home 2023), it would be expected that dogs would spend a variable set of time either close to the owner or at the max lead length, so it was felt that 3 m was a reasonable estimate. This however is an overestimate, as the model uses the buffer of 3 m in all directions from the owner when at any point in time the dog would in reality be a one fixed distance point away from the owner. The size of the buffer was varied by the interquartile range of the sampled FIDs. The total area disturbed at least once was calculated using the 'area' function in the package raster. Using the buffer function with 'dissolve = FALSE', a raster of the number of walks which disturbed each area for a bird with the median FID was also calculated for recorded locations of owners and dogs, and a separate raster for owners plus an additional 3 m buffer to simulate all dogs being on a lead. To compare how the frequency of disturbance changed when dogs were off the lead, we cropped these rasters to the area which were disturbed at least once when dogs were on a lead. We then compared the mean number of walks which would disturb each 1m^2 in the two rasters (when dogs were onlead and offlead) for each site. Note that although this raster is referred to as 'offlead', some of the dogs may have been on a lead for all or part of their walk. A tutorial and code for used data processing, and an example data file is available here: https://github.com/SarahPapworth/dogwalkinganalysis/.

Results

Dog owner questionnaire

798 dog owners completed the questionnaire (Table 2). Most dog owners owned one (68%) or two (23%) dogs and walked them once (44%) or twice (56%) per day. Most

Table 2 Results of questionnaire surveys of 798 dog walkers in four lowland heathlands in the UK. The questionnaire took place between 19th June 2017 and 23rd September 2017

	Answer	*N*
How many dogs do you have with you? (*n* = 798)	1	543
	2	183
	3	48
	4	17
	5+	7
How often do you walk your dog(s)? (*n* = 731)	One a day	322
	Twice a day	409
How often do you walk your dog in woodland / heathland? (*n* = 735)	Twice a day	159
	Once a day	403
	Once a week	138
	Once a fortnight	21
	Once a month	14
On average what is the duration of the main walk? (*n* = 796)	< 30 min	56
	30–60 min	466
	1–1.5 h	230
	1.5–2 h	37
	2–3 h	7
Do you let your dog off the lead? (*n* = 795)	Yes, for the duration of the walk anytime of the year	678
	Yes, but only for part of the walk and during certain seasons	27
	Yes, but only for part of the walk any time of year	26
	No, stay on a fixed length lead	24
	Yes, for the duration of the walk, but only during certain seasons	20
	No, but they have an extendable lead	19
	Prefer not to say	1
Why do you let your dog(s) off the lead or not? (*n* = 522, can select multiple options)	Dog needs a lot of exercise	310
	More fun for the dog	94
	Area is safe	57
	Dog well behaved, returns when called.	18
	No particular reason	16
	Want to avoid any potential conflicts with wildlife	14
	Dog tends to wander too far	13
	Dog doesn't socialise well	12
	Prefer to have full control of the dog at all times just in case there is any issues	6
	Avoid ground nesting birds	5
	Don't want to worry what the dog is doing	3
	Prefer not to say	3
Why do you visit this particular park? (*n* = 670)	Close to home	301
	Area is safe	103
	Like the scenery	89
	Dogs can run free	81
	Like the woodland	36
	Close to friends	25
	Parking and facilities	20
	Like the wildlife	9
	No particular reason	5
	Like the grassland	1

walks (58%) were 30–60 min in duration and 85% of owners let their dog off the lead for the duration of the walk at any time of the year. Reasons for allowing their dogs off the lead include 'the need for a lot of exercise' (59%) and that 'it is more fun' for their dogs (18%). When asked why they visited this particular area, most people (45%) answered that it was close to home.

GPS tracking

During 185 walks, the median distance between the paired dogs and owners over the entire walk ranged between 0 and 134 m, with a median of 20 m. Mean walk length was 56 ± (SD) 23 min. The mean of the maximum Euclidean distance from the start point of the walk was 961 ± (SD) 486 m for the 162 owners, and mean total distance walked was 3748 ± 1684 m. The mean of the maximum Euclidean distance from the start point of the walk was 966 ± (SD) 491 m for the 185 dogs, and mean total distance walked was 3809 ± (SD) 2180 m.

Across all sites and all flight initiation distances, larger areas were disturbed at least once when dogs were off leads compared to our counterfactual where dogs were on 3 m leads (Table 1; Fig. 2). In addition to a larger overall area experiencing disturbance, areas were disturbed more frequently when dogs were off the lead (Fig. 3). These changes in the total area and frequency of disturbance were observed across all sites. At Wildmoor common, the average 1m^2 area of the reserve was disturbed by more than 5 of the 32 walks recorded (Fig. 3), with more frequent disturbance and a greater area disturbed than if dogs were kept on a lead (Fig. 4). The total area disturbed was even greater at Snelsmore Common; when dogs were off their leads, the sampled walks disturbed 98% of Snelsmore Common for birds with a flight initiation distance over 12 m (Table 1).

Discussion

Dogs walking off the lead caused a significant reduction in undisturbed potential breeding habitat available for birds in the lowland heath habitats studied here. Dogs walking off the lead cause more disturbance by area (up to 21% more disturbance) when compared with dogs on a lead and most dog owners were found to be allowing their dogs to walk off a lead for the duration of their walk, at any time of the year. This increase in area disturbed was most severe in Chobham Common, Surrey, which is most likely a consequence of the large area of the site and the lower density of paths available. Across all sites, most dog owners walked their dogs off lead because they considered that their dogs needed a lot of exercise and that they felt it was more fun for their dogs.

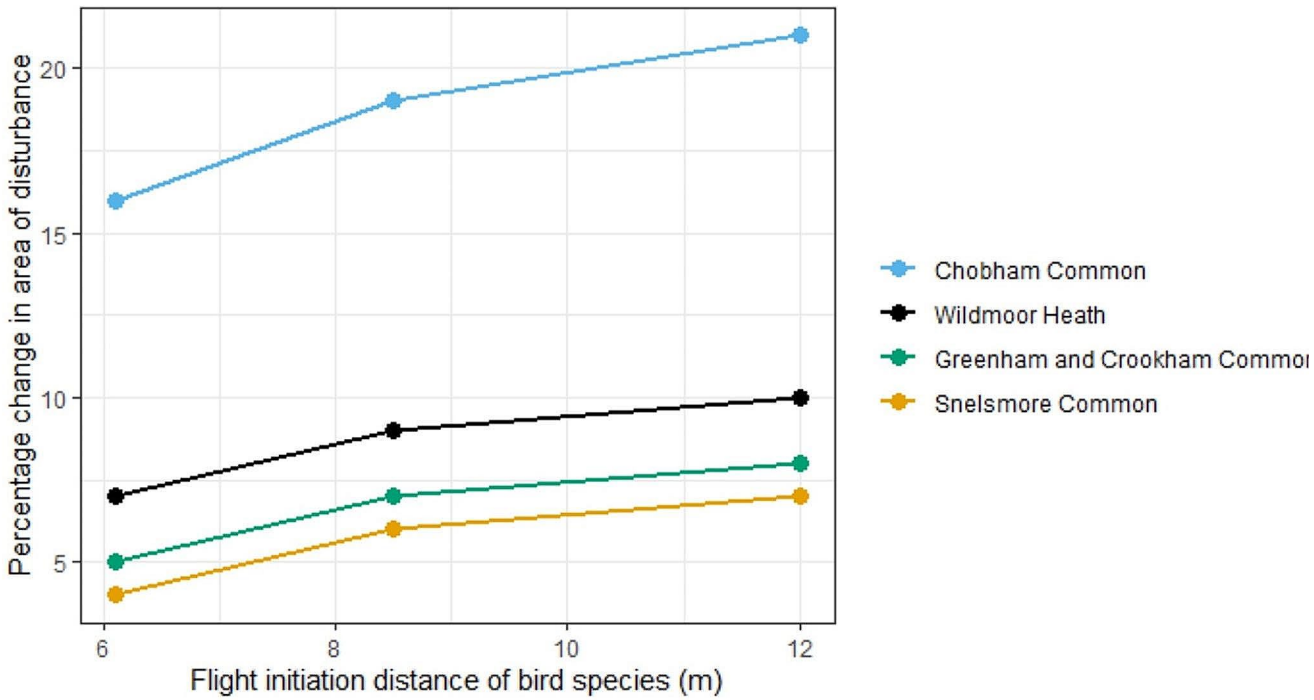

Fig. 2 Percentage increase in area disturbed at least once, by sampled walks with dogs off the lead, in comparison with a counterfactual analysis of the same walks if owners kept dogs on a 3 m lead, showing impact for birds with different flight initiation distances. Change in area shown for the four sites, and for species with different flight initiation distances. Data and number of walks sampled at each site shown in Table 1

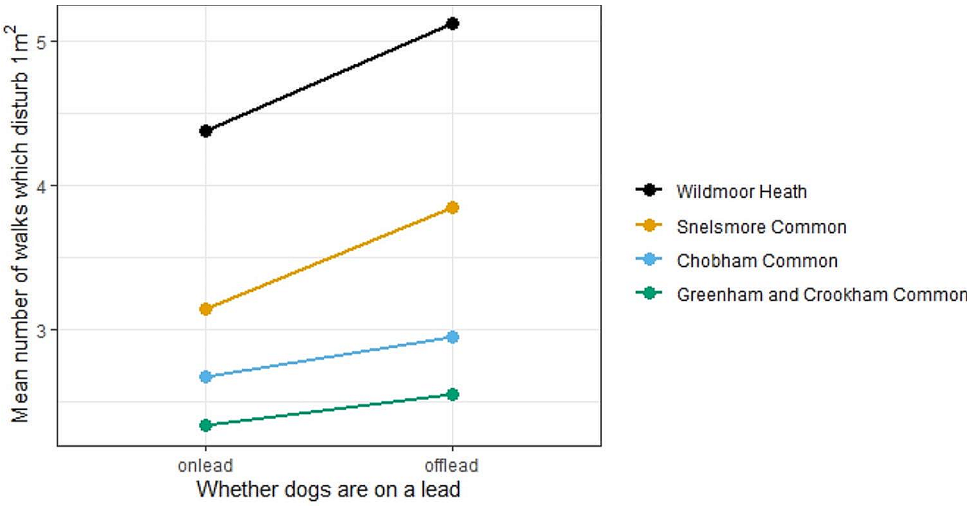

Fig. 3 Change in mean number of walks which will disturb a metre squared when dogs are walked off the lead, compared with a counterfactual analysis of the same walks if owners kept dogs on a 3 m lead, for birds with a flight initiation distance of 8.5 m. Calculations restricted to areas which would be disturbed at least once if dogs were kept on the lead. Number of walks sampled at each site shown in Table 1

Although this study was conducted during the period when signage requested owners keep dogs on a lead, 85% of owners did not comply (and 94.5% did not comply on occasion), a higher estimate than previous studies in Australia which have also found a lack of compliance with guidance for dog owners to keep their dogs on a lead (Schneider et al. 2019; Guinness et al. 2020).

With the significant decline of many bird species and rare habitats such as lowland heaths, additional stressors, like disturbance through recreational dog walking could have consequences for bird conservation, especially in the breeding season (Banks and Bryant 2007). This is especially the case for habitat specialist species such as the European nightjar and Dartford warbler. Given that pressure exists to build more housing in countries such as the UK, and compelling evidence that compliance with dog walking regulations is at best weak (this study, Schneider et al. 2019; Guinness et al. 2020), it is vital to address these issues to find a balance between nature recreation and conservation.

Although there are data available about flight initiation distances, few studies specifically look at changes in response to dogs, nor examine differences between or within bird species at different points in the year (Livezey et al. 2016). Disturbance to nesting birds in the breeding season, for example, causes heightened vigilance (Randler 2006). Birds are able to assess risks from different human-related activities and will modulate their responses according to this risk (Lethlean et al. 2017). In the case of recreational dog walking, this disturbance could be almost constant in some areas with high numbers of dogs being walked. This is likely to significantly reduce the habitat available to breeding birds, as there is some evidence that birds will preferentially choose to nest in areas with less disturbance (Knight and Fitzner 1985). Our findings here show a considerable reduction in the total area of undisturbed habitat in lowland heaths, caused by recreational dog walking with dogs allowed to roam off a lead.

It could be hypothesized that as dog walkers spend regular time in natural environments, that they may have a more positive attitude towards nature and conservation and that this may improve their own health and wellbeing (Martin et al. 2020). In this study we found that most owners visited the heathland sites because they were close to home and safe, but many also appreciated the scenery. Despite this, Fischer and Kowarik (2020) interviewed dog walkers in five European cities to see if they viewed natural spaces differently to other groups. They found no difference, emphasising the challenges faced for those who manage lowland heathland habitats in trying to balance the dual use of wildlife and dog walkers. Utilising data generated using the methodologies presented here and following the analysis in the online tutorial which accompanies this paper, land managers can make informed decisions about management by combining information about potential disturbance caused by dog walking with data on species presence. For example, our mapping suggests that owners tended to follow existing paths (Fig. 4), implying that land managers could reduce disturbance by closing access to pathways (particularly more minor desire paths or game trails) leading to sensitive areas for wildlife in the breeding season.

As well as a need to understand the disturbance caused by dog walking, we also need to understand more about how to effectively enable behaviour change in dog walkers. Developing interventions which change human behaviours to benefit biodiversity conservation is an emerging area of interest (Travers et al. 2021) which can benefit from insights developed for other fields, such as climate change mitigation (Balmford et al. 2021). Testing which interventions to change dog owner behaviour will work, for whom, and in what contexts is therefore crucial. Observed compliance with dog restrictions is low across studies (Schneider et al.

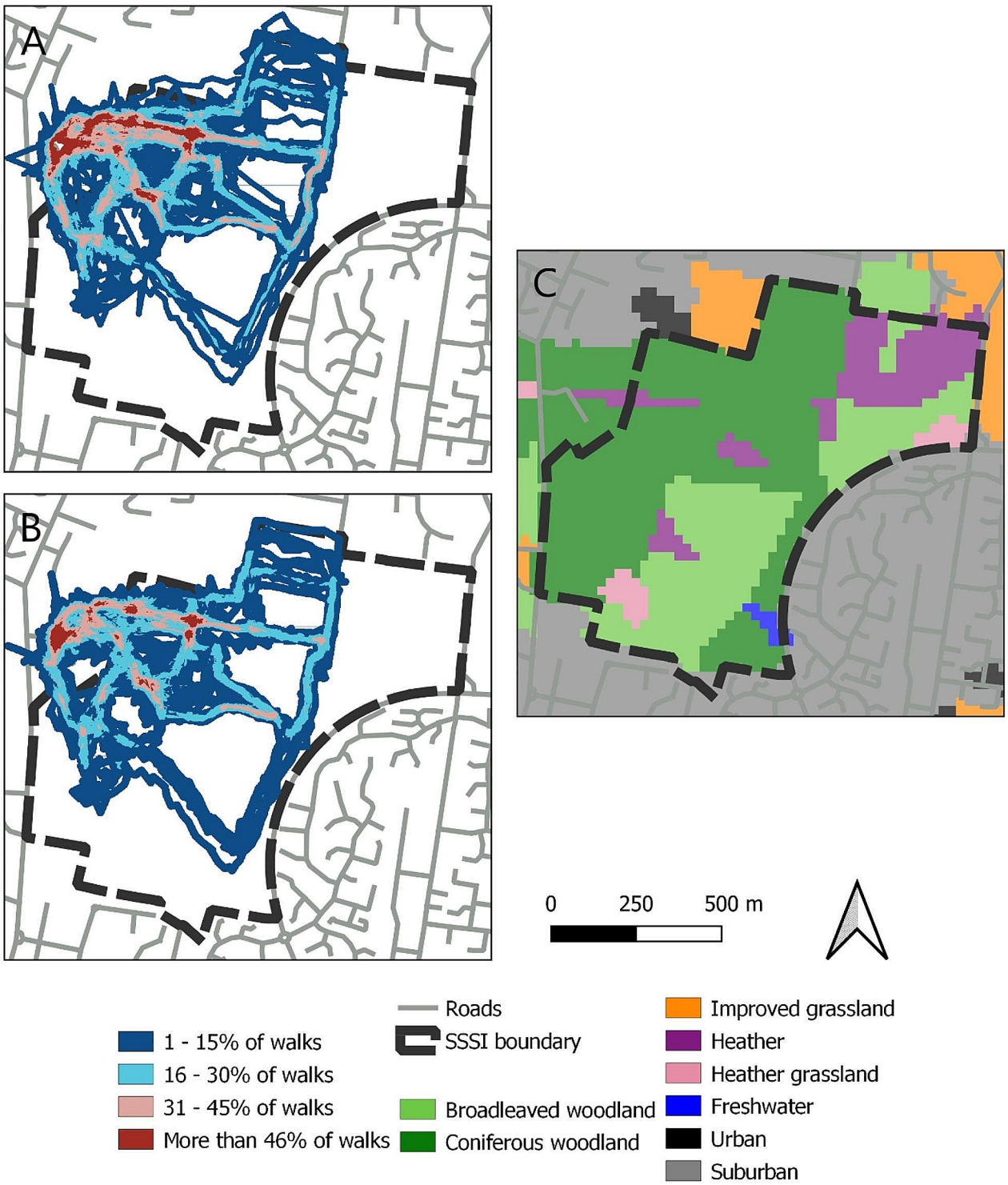

Fig. 4 Percentage of walks which disturb areas in Wildmoor heath, for the recorded dog and owner tracks (A) and if the dogs were kept on a 3 m lead (B), for birds with a flight initiation distance of 8.5 m. Land cover types in 2017 at 25m^2 resolution are shown on the right (C), from Morton et al. (2020)

2019, Guinness et al. 2020; Dowling and Weston 1999), but even low compliance with restrictions on areas of use and enforcement of leads is associated with increased chick survival (Dowling and Weston 1999). Our findings show that potential disturbance caused by dogs could be reduced with dogs being kept on a lead, and so could be an important management action in areas of significant value to nature. Such challenges are unlikely to decline in the near future, given suggestions that changes in working patterns following the Covid-19 pandemic has resulted in increased rates of dog ownership in the UK (PDSA 2022).

Conclusions

With high dog ownership numbers in many countries globally (Gompper 2014) it is imperative to understand more about the potential disturbance caused. Dog walking also has other consequences for habitats alongside the disturbance caused. Dog predation of wildlife does occur (Gompper 2021) and there are consequences to dog defaecation (De Frenne 2022) and the transfer of veterinary medicines (Diepens et al. 2023). Many land managers are confronted with providing recreational spaces for the public, while also providing space for nature; demands that can be in opposition. SANGs could be a way to address these conflicting demands, by providing alternative sites for people to walk their dogs (Thames Basin Heaths Partnership 2023), but other measures are also needed in areas such as lowland heaths to reduce disturbance caused. These could include diverting the public along particular routes, helping to reduce pressure on areas that are most sensitive to wildlife. With greater knowledge of how owners and their dogs are using a site (supplementary materials are available to allow implementation of this approach) managers can use the available information to decide how to manage their land to maximise use and minimise harm.

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Author contributions R.L. Thomas and M.D.E. Fellowes conceived the ideas, and designed the methodology and supervised data collection; R.L. Thomas and S.K. Papworth were responsible for different analyses; R.L. Thomas led the writing of the manuscript. All authors contributed directly to the drafts and gave final approval for publication.

Data availability Tutorial, code and example data file available at: https://github.com/SarahPapworth/dogwalkinganalysis/. This link includes more methodological details for interested parties to allow them to duplicate these methods and outputs. This includes the data, annotated R scripts, and further methodology.

Declarations

Conflicts of interest The authors have no conflicts of interest.

Competing interests The authors declare no competing interests.

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