Reducing risky interactions: Identifying barriers to the successful management of human–wildlife conflict in an urban parkland

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Handling Editor: Sarah Crowley

Abstract

1. Managing activities that result in human–wildlife conflict is a challenging goal for modern scientists and managers. In recent years, the self-motivated feeding of wildlife by humans has garnered popularity but with consequent risks for the health and safety of both parties. This has resulted in calls for management in areas of high contact, for example, parklands. Traditional controls are typically utilised (i.e. signage, patrols), yet their success is varied, leading to a rise in research aiming to improve them. This research has primarily focused on language and design, with little attention paid to the role that audience type (i.e. international tourists vs. locals/residents) may play in their success. Proportions in audience type present can vary both between parks and spatially within a single park, however, controls are usually applied homogeneously with no consideration for how response may vary between these groups.

2. Here, we performed a robust before–after study across two summers using a wild fallow deer population in a public park that are commonly fed by visitors as our model. We deployed controls, following best practice as outlined by the literature, and tested their overall effectiveness. We then identified key areas with differences in visitor type proportions and tested for variation in success between them.

3. We found that the numbers of visitors feeding the deer significantly decreased overall after the introduction of controls, although interactions were not eliminated entirely. We discovered that the effectiveness of these controls varied with changes in visitor type, with the most positive effects occurring in areas with more international tourists and no significant effect occurring in areas dominated by resident visitors. Notably, of the food offerings remaining, the proportion of foods that could be perceived as ‘nutritionally beneficial’ increased in
both sites, marking overall changes in the behaviours of even those visitors who refused to stop feeding.

4. These findings highlight the importance of target audience research in human–wildlife conflict management. We recommend that authorities aiming to reduce these interactions perform systematic surveys to identify the audience type present and cater controls accordingly to maximise their success.

**KEYWORDS**

human–wildlife conflict, signage, ungulates, wildlife feeding interactions, wildlife management

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### 1 INTRODUCTION

Reducing activities that result in human–wildlife conflict is a major challenge now faced by scientists and wildlife managers (Dickman, 2010; Frank et al., 2019). This conflict occurs when the behaviours of either humans or wildlife impact negatively on the needs or health of the other (Mekonen, 2020) and is becoming increasingly common in areas where contact rates between humans and wildlife are high (Frank & Gilkman, 2019). One of the rapidly emerging sources of human–wildlife conflict is the feeding of wild animals by self-motivated humans (Dubois & Fraser, 2013), a phenomenon that is gaining popularity in recent years (Senigaglia et al., 2020).

These interactions have been documented in multiple species across terrestrial, aquatic and aerial environments (Brookhouse et al., 2013; Dayer et al., 2019; Padovani et al., 2021; Pagel et al., 2020; Usui & Funck, 2018), with national and public parks being popular targets (Marion et al., 2008). Humans risk injury from these interactions as animals become accustomed to utilising humans as a food source (Burns & Howard, 2003; Kofron, 1999) and disease transfer is also an associated risk (either directly, e.g. through contact or saliva, or indirectly, e.g. through insect bites) (Moscardo et al., 2006). There are also risks for the wildlife involved, including malnutrition (Marion et al., 2008; Orams, 2002), inter-species competition (Jones & Reynolds, 2008; Parsons et al., 2006), habituation (Higham & Shelton, 2011) and changes in social (Bryant, 1994) and stress behaviours (Marechal et al., 2011). Additionally, it has been shown that only a subset of a population interacting with humans utilise this unnatural food source with implications for greater variance in individual fitness, ergo establishing human feeding as a driving force for artificial selection of behavioural traits (Griffin et al., 2022). Although some positive effects may occur (Goddard et al., 2013; Soulsbury & White, 2015), these risks, combined with application of the precautionary principle (Ziegler et al., 2019), have led to these interactions typically being prohibited by park officials (Marion et al., 2008). However, to be deemed successful this prohibition needs to be effectively communicated to the public and needs to result in a reduction in the activity.

The most commonly deployed tools for the management of these human–wildlife interactions are traditional ‘internal’ controls (i.e. controls that can be applied to a set localised area such as a park: signage, posters, ranger patrols/talks; Cole, 1995; Marion et al., 2008; Orams, 1996; Saunders et al., 2019). The reasons for utilising these controls are clear; they are easy to deploy, cost-effective (Choquette & Hand, 2021) and generally have a positive effect (Hockett & Hall, 2007; Marion et al., 2008; Sullivan et al., 2004). However, they are not always effectively observed by the public and rarely entirely alleviate the issue at hand (Dickman, 2010; Greason & Jurin, 2012; Porter & Howard, 2002; Weiler et al., 2015). For this reason, research interest has developed around identifying ways to improve the effectiveness of these tools, primarily by identifying barriers to their success.

One thing that has been emphasised is the need for in-field, passive collection methodology when establishing the level of success a control has in reducing human–wildlife feeding interactions. Many studies aiming to test the general effectiveness of these controls in human–wildlife feeding interactions have relied heavily upon zoo-based data (Parker et al., 2018) rather than in-field studies and visitor opinion polls and surveys (Hockett & Hall, 2007; Mallick & Driessen, 2003) for results. However, visitor surveys and questionnaires may carry a degree of unreliability due to the risk of bias, inaccurate recollection and dishonesty in responses (Aucote et al., 2012; Choi & Pak, 2005). It has, therefore, been advised that direct, in-field observations be utilised preferentially to ensure that the true effect on visitor behaviour be extracted (Marion et al., 2008).

Research has also focused on ways to improve the controls themselves, including through the inclusion of educational content (Baruch-Mordo et al., 2009), testing different types of messaging (Ballantyne & Hughes, 2006; Hockett & Hall, 2007; Steckenreuter & Wolf, 2013; Winter et al., 1998) and the importance of location in deployment (Geller et al., 1973; Hall et al., 2010). These studies have touched upon how visitor response may vary across different ages, sexes and between lone visitors versus groups (Kernan & Drogin, 1980; Porter & Howard, 2002), yet different aspects of visitor demographics remain understudied. For example, some research has indicated that the success of traditional controls, and signage in general, may be impacted by visitor type (Hall et al., 2010; Muñoz et al., 2019). For example, there is the potential for repeat visitors to become ‘sign blind’ (i.e. no longer notice the controls in place; Greason & Jurin, 2012) or for tourists to misinterpret signage messaging (Aucote et al., 2012). Additionally, locals tend to gain a sense of ownership of these areas (McKercher, 1996), which

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may either counteract or support willingness to follow prohibitions. However, currently standardised management controls are typically implemented homogeneously across a single study site, and then often replicated in other sites (Saunders et al., 2019), without critical assessment or consideration for how visitor type (i.e. local or ‘resident’ visitors vs. international tourists), and therefore their responses, may vary spatially. This follows a common mistake in management; that being that assumptions are made by conservationists and managers regarding visitor attitudes and responses, without sufficient testing for variation between them (Dickman, 2010). To simplify, it is necessary for managers to ‘know their audience’ (Ballantyne & Hughes, 2006) and determine whether management success varies in areas with low versus high levels of ‘residents’ or international tourists across a single site (Muñoz et al., 2019). The reason that we recommend this be tested first in a single site, rather than through cross-site analysis, is because different sites may vary enormously in terms of cultural context (Dickman, 2010; König et al., 2020), established local norms and knowledge (potentially due to differences in historical management campaigns; Manfredo et al., 1995), and overall numbers of visitors. These additional variables may obscure the role that visitor type plays in the success of management if a cross-site study was to be performed. However, unravelling their role in a single site holds important implications for the potential need to vary control design both within and between sites depending on differences in the proportions of visitor type present.

Here, for the first time, we perform a unique study using a before–after experimental design across the period of two summers, aiming to step away from questionnaire-based surveys. Instead, we opt to explore the true effects, or lack thereof, of strictly managed internal controls (designed following recommended best practice) on the number of human–wildlife feeding interactions on the ground. Our model site, a popular urban park at the edge of a capital city, is characterised by 10 million visitors per year, including both residents and international tourists. This affords us the opportunity to explore how management success may vary across space within the park coinciding with natural variations in the proportions of visitor type present. We propose one of the major, unidentified barriers to the success of commonly used internal management controls. Specifically, our goals are:

(i) To establish internal controls, following best practices recommended in the literature, and test whether their application was successful across the site overall.

(ii) To examine whether the success of our controls varied between sites that have different proportions of visitor type (residents vs international tourists).

(iii) To determine whether applied controls had other impacts across these sites outside of general decreases in food offerings; namely, through changes in the types of foods being offered as those visitors’ who did not wish to stop feeding instead may have opted to offer what they perceived to be a more ‘responsible’ foods (i.e. more ‘nutritionally beneficial’ food types).

2 | METHODS

2.1 | Study site and population

The study was performed in Phoenix Park, a 707 ha walled, urban park located in Dublin, Ireland. The resident fallow deer herd currently consists of approximately 600 free-ranging individuals, having originally been established in 1662 by the Duke of Ormond as a hunting population (Office of Public Works, 2020). Today, they are a popular viewing target for the estimated annual 10 million visitors to the Park; with approximately 24% of visitors coming specifically to view the deer and others often viewing them opportunistically while attending other attractions (e.g. the local zoo, visitor centre and general sightseeing; Yu and Griffin, unpublished survey data). In recent years, according to observations by park rangers and officials, the practice of feeding the deer has become increasingly popular with social media and word of mouth being listed as the primary motivators in visitor surveys (Yu and Griffin, unpublished survey data). Visitors typically enter the Park either with food specifically purchased for feeding or do so opportunistically with food items brought for their own consumption. The rise in these occurrences has led to considerable animal welfare and human safety concerns. These include fear and injury to humans during engagement with the deer (as reported in local and national newspapers: Donoghue, 2021, O’Hanlon, 2020) and the risk of injury to the deer as visitors chase or hit out at them (observed in the field). Consequently, park management has prohibited feeding of the deer but, due to local legislation, park officials cannot introduce monetary penalties so management is reliant upon cooperative, public education-based strategies.

The variation in visitor type between the side of the Park utilised by the male deer (eastern) and the side utilised by the female deer (western) has been documented through questionnaire surveys (n = 481 surveys overall; 290 in the male deer sector and 191 in the female deer sector) carried out by co-occurred research (Yu and Griffin, unpublished survey data). Residents make up approximately 62% of visitors surveyed in the male side of the Park, with the remaining identifying as international tourists. The number of residents in the female side of the Park was considerably higher, at 90%. The higher proportion of international tourists on the male side (38% vs. 10% on the female side) is likely due to it being more easily accessible from the city through the main gates of the Park. In contrast to this, the female side of the Park likely has high levels of residents as it is surrounded by residential areas and estates.

2.2 | Data collection—Feeding interactions

This study was designed using a before–after experimental approach. Initial observations were performed to establish a baseline of the levels of feeding interactions occurring in the Park in May–August 2018, prior to the release of management controls. These controls were then implemented across early-mid 2019 and repeat
observations were performed in May–August 2019 to test their effectiveness. Fallow deer naturally sexually segregate (Ciuti et al., 2004), and the male and female areas within the Park were identified through consultation with the ranger team and our own pilot surveys. The parts of the Park within these male and female areas that are open to public access were divided into sectors and a stratified a priori schedule was followed to ensure equal sampling of the Park over all times of the day and days of the week. If no deer were present in the starting sector, then the remaining sectors were walked systematically until a herd was found, with a herd being defined as a group of 2+ individuals within 50 m of each other and within view of each other.

Once a herd was found, we documented the herd size, the start and end time of the observation and the location of the herd. Observations of the herd continued until the scheduled end time or until the herd diverged or merged with another herd, at which point we terminated the observation and began a new one. While observing a herd, scans were performed every 15 min to document the number of people within a 250 m radius of the edge of the herd as a proxy for people presence in the Park. The number of people exercising and how many dogs there were being walked was also noted. If visitors approached the herd for a feeding interaction, the number of people involved in that interaction was recorded. Additionally, the types of foods that the visitors offered the deer and their quantities were also noted. This information was documented with the aim to later determine whether the types of food offered were influenced by signage (even if the overall proportion of people approaching was not reduced).

All behavioural observations were carried out at a greater distance than that entered by visitors in order to avoid impacting the herds’ behaviour or associated interactions (whereas in contrast, visitors got extremely close, <5 m). Observations were non-invasive and conducted under research permit UCD AREC-E-18-28. Observers remained passive and did not interact with either the deer or the public. The full data collection protocol can be found in Griffin et al. (2022).

2.3 | Application of controls

The management controls selected for implementation were new signage, distribution of an infographic, distribution of a poster and the performance of targeted ranger patrols. Our management strategy modelled those recommended by the literature; a combination of direct (prohibition and ranger patrols) and indirect controls (specifically through signage, posters and infographics generated under the guidance of a trained product designer). We modelled our messaging to incorporate both educational and persuasive statements and applied signage spatially based on the findings of these previous studies (Ballantyne & Hughes, 2006). Signage was designed to be two-sided and A3 in size, secured with two poles to ensure better endurance. One side was designed as a universal symbol, yellow in colour to attract attention (Camgöz et al., 2004), with the other side providing information on why not to feed the deer (Figure 1a,b respectively). The infographic and poster were made for distribution to businesses present within the Park (Supporting Information S1). The infographic provided detailed information for business workers to use as a visual aid when communicating with visitors. The poster presented simple, key messages intended for passive communication on walls and doors. Rangers performed patrols, stopping when a feeding interaction was spotted to communicate with the visitors that the activity was prohibited within the Park.

Ranger patrols commenced on 25 January 2019 and occurred every 1–4 days, with rangers documenting the locations of interactions in logbooks to inform future patrols. Copies of the infographic and poster were distributed on 14 May 2019, with the infographic being distributed to all businesses present in the Park (16 individual
copies in total distributed to 11 businesses; note that each business received at least one copy, with larger businesses or those who requested extras receiving more). The poster was given specifically to businesses identified as having only short contact times with visitors, therefore requiring a tool with more concise information, and with space to hang them up (10 copies to five businesses; approximately two each). Signs were put in place on 23 May 2019, at a density of 70 signs per 5 km². Notably, 12 of these signs were placed along the main road through the park at intervals of approximately 350 m. The locations of the remaining 58 signs were not evenly distributed (Figure 2a) and were instead selectively placed on walkways to, and around the perimeters of, areas with high deer density observed during the previous season of data collection from May to August 2018 (Figure 2b).

2.4 | Data handling and analyses

Data analyses were performed in R 4.0.5 (R Core Team, 2021). Our observations occurred during peak visitor hours within the Park (i.e. 8:30am to 5 pm). Each row of our dataset represented the entire observation period of an individual herd, with the final dataset being composed of 450 individual herds or rows. The total number of people who approached to feed each herd was extracted to be used as our response variable. We opted to use the number of people who interacted overall (e.g. as opposed to the number of groups who approached) for several reasons. First, from a wildlife management perspective the more people that there are in contact with the resident wildlife, the higher the risk that an injury may occur to either party (even if this is only a single, large group of people). Additionally, during fieldwork observations we noted that smaller units of people often converge on each other by a group of deer with a high rate of flux and social exchange of food, meaning that group sizes of humans could range from a single person to tens of people coming and going from a single congregation. For this reason, tracking this as one large group was misleading, and instead it was more logical to track the total number of people who came and went. Additionally, previous studies have shown that the deer have a maximum saturation of people after which incidences of begging decrease as they move away (Griffin et al., 2022), which could potentially indicate that high numbers of humans may result in stress for the deer, another welfare concern.

In terms of numerical predictors, the total number of people present across all scans during that observation was extracted as we expected the number of people feeding to increase as total visitors in the Park increased. This meant that results would not be affected if visitor rates varied between seasons as this was included in the model, for example, if visitor numbers happened to decrease in the second season after the introduction of controls, we could ensure that any decrease in the number of people feeding was because of the effects of the controls as opposed to simply being because there were less people around to feed. Notably we removed the number of people exercising and one person per dog present from the total as these individuals are highly unlikely to approach the deer and are, therefore, not truly available as potential feeders. We also included the initial GPS location of the herd, as we anticipated a spatial effect depending on the location within the park (i.e. accessibility). For each herd, we extracted the total herd size as we theorised that larger herds would make more visible targets for visitors to approach to feed. We extracted the month as we believed there may be variation in the types and behaviours of visitors as the summer progressed. We noted the total amount of time that each herd was monitored for, as herds that were observed for longer were more likely to be fed. We also extracted the central time-point of the observation as we theorised that there could be a temporal effect on numbers of people feeding depending on the time of day.

In terms of categorical predictors, we extracted whether that herd had been observed before or after the final introduction of our management controls (i.e. 23 May 2019). We also included whether it was a weekend or a weekday, as we predicted that feeding would increase during weekends. We also extracted the sex of the herd, as male fallow deer generally tend to get closer to human dense areas than females (Ciuti et al., 2004). We screened these candidate predictors for collinearity (Dormann et al., 2013), and dropped sex of the herd as it was collinear with the GPS location of the herd due to the natural sexual segregation within the Park.

We modelled the number of people approaching to feed the deer using a generalised additive model (GAM) with the function gam from the mgcv package. Due to the nature of our response variable, the model was built with a Poisson distribution of errors which was then changed to quasi Poisson to correct for over-dispersion. We included smoothing functions to allow for nonlinear relationships in our non-categorical predictors. We included the select = TRUE implementation to allow for automated model selection; that is, optimised selection criterion for smoothing terms, which allows for those that do not meet the criteria to be penalised from the model (Wood, 2017).

Given the noted differences in proportions of visitor type between the male and female sides of the Park, we re-ran the same model, but with the data collected from male herds only and then female herds only. This resulted in two additional models, aiming to identify whether the effects varied with visitor types between these two areas. Finally, we categorised the food offered on both sides of the Park into two types; foods that may be perceived as being nutritionally beneficial (i.e. fruit, vegetables, etc.), and foods that may be seen as nutritionally detrimental (i.e. bread, biscuits, chocolate, sweets, etc.). The proportion of each of these categories offered was then qualitatively calculated for male and female herds before and after the introduction of controls.

3 | RESULTS

3.1 | Sample sizes

We originally designed our experiment to cover 96 days of data collection—48 days prior to the introduction of controls and 48 after. However, a combination of cancelled days due to weather and delays...
FIGURE 2  Map showing the locations where signs (design displayed in Figure 1) were placed, and questionnaire survey sites used to establish the visitor demographics in different areas of Phoenix Park (a). Signs were placed along the main road and around areas commonly used by fallow deer herds as recorded during the first data collection season, with each herd represented by a point on the map (b). Note the striking sexual segregation with female and male herds located in the western and eastern sectors of the Park respectively.
in the distribution of controls resulted in a slightly imbalanced collection across 91 days (54 days before the introduction of management controls and 37 after). Approximately 570 h of data were collected altogether (354 h before management introduction; 216 h after). The resulting dataset was composed of 450 rows with each representing a different herd; this covered 227 female herds (which included sub-adult males still remaining with mother groups and the occasional buck) and 223 male herds. During our ‘before stage’, 136 female herds and 138 male herds were observed, with 91 female herds and 85 male herds being observed after the introduction of management controls. A total of 20,933 visitors were observed over the two summers, with 11,786 people being observed prior to the release of management and 9147 people being observed after.

3.1.1 | Modelling the effects of management overall

We fit the full GAM with the following structure:

\[
\text{No. of people feeding} \sim f_1(\text{herd size}) + f_2(\text{monitoring time}) + f_3(\text{log[people available + 1]}) + f_4(\text{time of the day}) + f_5(\text{eastning, northng, } k = 100) + \text{month} + \text{time of the week} + \text{stage of intervention} + (\text{quasi Poisson corrected}),
\]

where \(f_1, f_2, \ldots, f_5\) are smoothing functions to allow for nonlinear relationships depicting the variation in number of people feeding depending on herd size, amount of time the herd was monitored for (monitoring time), the number of people available to feed (people available, log-transformed), the time of the day (in hours) and the location (eastning and northng coordinates fitted as an \(x, y\) spline and 100 knots to accommodate spatial patterns), with month (May, June, July), time of the week (weekday or weekend) and stage of management intervention (before or after) included as categorical fixed effects, and a quasi-Poisson distributed error. The model explained 73% of the deviance and parametric estimates are shown in Table 1 (left panel).

After controlling for the effect of the month (Table 1), with a trend for more people to feed in July (Figure 3a), and controlling for the effect of time of the week (Table 1), with a significant increase in the number of people feeding on weekends (Figure 3b), we found a significant decrease in the number of people feeding after the introduction of management controls (Table 1 and Figure 3c). In terms of approximate significance of smoothing terms (Table 1), we found that the number of people feeding significantly increased as herd size (Figure 4a), monitoring time (Figure 4b) and number of people present (i.e. available to feed) (Figure 4c) all increased. Time of the day (Table 1) showed a significant increase in the number of people feeding throughout the morning, with peaks in afternoon and early evening (Figure 4d). Finally, the location of the herd was also significant (Table 1), indicating a heterogeneous distribution of hotspots of feeding behaviour (spatial splines not shown here but could be used by local managers to concentrate the tourist monitoring efforts on a site-specific basis).

3.1.2 | Modelling male and female herds only

Our model analysing only male herds explained 75.6% of the deviance (Table 1, middle panel) and we found that the stage of management was the only significant parametric predictor remaining, with the number of people feeding decreasing significantly after release of controls (Figure 5a). This suggests that male observational data, collected in the sector with higher levels of international tourists, are the main drivers of this pattern recorded in the full model. For the approximate smoothing terms, herd size was no longer significant compared to our full model, but monitoring time, number of people available, time of day, and location still were (Table 1, Supporting Information S2).

Our model with only female herds explained 85.5% of the deviance (Table 1, right panel), and time of the week was the only significant parametric predictor, with more feeding occurring on the weekends. The introduction of management controls was not significant (Figure 5b) in this area dominated by resident visitors, and neither was the time of the month. Monitoring time also decreased in significance, however, herd size, number of people available, time of the day and location of the herd all confirmed the trends from our full model (Table 1, Supporting Information S3).

3.1.3 | Other changes in human behaviour: types of food give to the deer

Prior to the introduction of management controls, 57% of food given to the male herd was made up of food types that are generally perceived as ‘nutritionally beneficial foods’, such as fruit and vegetables \((n = 1271)\) of 2240 food items given to deer by the public. However, the female population, which is fed more so by resident visitors, was receiving comparatively higher levels of perceived nutritionally beneficial foods overall at 64% \((n = 1641)\) of 2562 food items, that is, 7% higher than the males overall. After the introduction of management controls, the proportion of perceived nutritionally beneficial foods being offered to males increased by 6% \((n = 909)\) of 1444 food items). Similarly, the proportion of perceived nutritionally beneficial foods offered in the female area increased by 5% \((n = 1590)\) of 2304 food items).

4 | DISCUSSION

Our results show that (i) the introduction of traditional, internal controls did significantly reduce feeding of the targeted deer population overall, although it did not alleviate the issue entirely, that is, a subset of park visitors continued to feed the deer, as was expected. When comparing our different sites within the Park with different proportions of visitor types (areas of the Park with the male deer population vs. the females), we uncovered that (ii) these internal controls were most successful in areas with higher levels of international tourists (male deer area), with residential visitors...
**TABLE 1** Parameters estimated by the generalised additive model explaining the numbers of visitors feeding the deer in Phoenix Park (Dublin, Ireland) as a function of the stage of intervention (before and after the application of internal management controls) along with a suite of parametric and non-parametric confounding predictors

<table>
<thead>
<tr>
<th>Parametric</th>
<th>Full model</th>
<th>Male-only model</th>
<th>Female-only model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Predictors</strong></td>
<td><strong>Estimate</strong></td>
<td><strong>Std.Error</strong></td>
<td><strong>t value</strong></td>
</tr>
<tr>
<td>Intercept</td>
<td>1.0339</td>
<td>0.1498</td>
<td>6.9</td>
</tr>
<tr>
<td>Month [June]</td>
<td>-0.1441</td>
<td>0.1414</td>
<td>-1.019</td>
</tr>
<tr>
<td>Month [July]</td>
<td>0.3047</td>
<td>0.1555</td>
<td>1.959</td>
</tr>
<tr>
<td>Time of the week [Weekend]</td>
<td>0.4338</td>
<td>0.1247</td>
<td>3.478</td>
</tr>
<tr>
<td>Stage of intervention [After]</td>
<td>-0.3709</td>
<td>0.131</td>
<td>-2.831</td>
</tr>
<tr>
<td><strong>Smooth terms</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>s(Herd size)</td>
<td>1.5928</td>
<td>9</td>
<td>0.733</td>
</tr>
<tr>
<td>s(Monitoring time)</td>
<td>0.8587</td>
<td>9</td>
<td>0.729</td>
</tr>
<tr>
<td>s(log(people available+1))</td>
<td>1.387</td>
<td>9</td>
<td>11.132</td>
</tr>
<tr>
<td>s(Time of day)</td>
<td>5.8649</td>
<td>9</td>
<td>4.489</td>
</tr>
<tr>
<td>s(easting, northing)</td>
<td>38.8133</td>
<td>99</td>
<td>1.03</td>
</tr>
<tr>
<td>Observations</td>
<td>450</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deviance explained</td>
<td>73%</td>
<td></td>
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</tbody>
</table>
FIGURE 3  Plots depicting the parametric effects of (a) month, (b) time of the week and (c) stage of intervention, that is, before and after the application of management controls, on the number of people feeding the resident fallow deer herd in Phoenix Park, Dublin, as predicted by the generalised additive model. Bars represent 95% confidence intervals around parameter estimates (note that reference categories are set to zero).

FIGURE 4  Effect plots depicting smoothing splines estimated for (a) herd size, (b) monitoring time, (c) number of visitors present and therefore available to feed and (d) time of day on the number of people feeding the resident fallow deer herd in Phoenix Park, Dublin, as predicted by the generalised additive model. Effect predicted patterns were depicted along their 95% confidence intervals.
not responding effectively to this form of management (female deer area). We also found that (iii) those individuals that continued to feed the deer across both sites, including the female area with its high levels of resident visitors, may have attempted to improve their behaviour by opting to bring what could be perceived as more ‘healthy’ or responsible food offerings, as opposed to clearly nutritionally detrimental food items (e.g. chocolate). This indicates that the lack of effect in the female area was not due to resident visitors failing to notice applied controls (e.g. through ‘sign blindness’ caused by repeat visits) but instead that they consciously chose to continue feeding despite it, albeit with attempts to do so more responsibly. Notably, a change in the type of food offered is not the goal of these management campaigns as the continued contact between humans and animals means that the health and safety concerns for both remain (Burns & Howard, 2003; Kofron, 1999; Marion et al., 2008; Moscardo et al., 2006; Orams, 2002) and as it was these changes were quite limited in our site, with a 5%–6% change overall.

Research has shown that different types of audiences hold different value systems and, therefore, require different, tailored messaging for the same effect to be achieved (Hine et al., 2016; Miller et al., 2018). For unfamiliar signage (and other visual controls, i.e. posters), clarity of purpose and consistent messaging is what is important in order to inform behaviours (Ballantyne et al., 2009; Meis & Kashima, 2017), in this case allowing international tourists who are unfamiliar with the signage to successfully interpret and obey its messaging. Conversely, it is documented that repeat visitors may benefit from more persuasive messaging that focuses on fostering ownership of the park and its associated species and promotes the benefits of compliance (Steckenreuter & Wolf, 2013).

However, when an individual, such as a resident or local, utilises a space regularly, certain activities can become established as habitual behaviours (Hughes et al., 2009) and an associated sense of ownership of the area may prevent compliance of restrictions (Steckenreuter & Wolf, 2013). Repeat visitors are also documented in other areas as have a tendency to ignore signage pertaining to their established behaviours, for example regarding trail-use management (Hockett et al., 2017) and human– wildlife interactions (Greeson & Jurin, 2012), meaning that in this case changes in messaging may not be a viable solution for residents who already habitually feed local wildlife. In our study, we incorporated different types of messaging to encompass all audience types, including persuasive, emotive and prohibition statements, and, as this literature would suggest, these failed to reduce feeding interactions in areas with high levels of residents.

Having established this, we would recommend that managers conduct research with resident visitors to determine what is driving their behaviour, and adapt controls accordingly to push behavioural responses in the desired direction. As the literature indicates that local social norms may also be driving this continued behaviour, we would also recommend examining other approaches such as recruiting community champions and performing local school talks and/or media campaigns to encourage shifts in social pressures. The usage of well-trained park personnel has been shown to majorly contribute to visitor satisfaction (Fletcher & Fletcher, 2003), and the use of visual controls to reduce issues such as littering have been seen to have most success when combined with direct, individual contact with a park ranger (Manning, 2003). Ranger patrols were utilised as part of this study, but notably factors such as time dedicated to

![Figure 5](image-url)
other responsibilities limited how often they could patrol for feeding interactions, as is standardly the case in busy parkland areas. It may be beneficial for park managers to increase investment in ranger numbers and patrols in areas with high levels of resident visitors, in order to determine whether this successfully reduces the occurrence of these interactions.

Performing a study such as ours can also provide important information on temporal trends in feeding in these areas. For example, our models indicate that the female population is fed significantly more on the weekends, which is likely when residential visitors frequent the park during their off work, as opposed to international visitors who can come at any time. Additionally, feeding increased over the course of the day as opposed to during early mornings, during days where visitor rates (people present) were high, and in the month of July when families and couples are likely to be taking time off. Managers may, therefore, benefit from increasing ranger patrols during these time periods to further reduce the occurrence of feeding.

Additionally, while Phoenix Park cannot introduce monetary fines to create consequences for non-compliance, other sites may find it useful to explore this as an option. As previously mentioned, we encountered unforeseen delays in the output of our controls, due to the complexities associated with designing and distributing them. We would, therefore, also advise that managers take potential delays into consideration when designing their own control release timetables to ensure further success.

**AUTHORS’ CONTRIBUTIONS**

L.L.G. and S.C. conceived the study; L.L.G., A.H. and K.C. collected the data on feeding interactions; M.A. and L.L.G. designed controls and signage; P.M. managed implementation of controls within the study site; L.L.G. and S.C. analysed the data; L.L.G. and K.C. managed and produced spatial components; L.L.G. wrote the manuscript revised by S.C.

**ACKNOWLEDGEMENTS**

We thank the Office of Public Works, Ireland, for support (grant 19730). We extend a special thanks to Margaret Gormley (Chief Parks Superintendent), Maurice Cleary, Terry Moore and each of the OPW staff in Phoenix Park for their continued efforts to implement controls. We thank SBES in UCD for co-funding this project. We also thank all the other field workers and volunteers who helped in collection: We are indebted to Zhuzhu Yu for performing the visitor demographic surveys.

**CONFLICT OF INTEREST**

The funders had no role in study design, decision to publish or preparation of the manuscript. Paul McDonnell has been included as a co-author due to his contributions to the creation of the controls, as well as managing their implementation. However, he had no role in study design, data analysis or their interpretation, and ergo this study has no resultant conflict of interest.

**DATA AVAILABILITY STATEMENT**

Data are available on the Dryad Digital Repository at [https://doi.org/10.5061/dryad.tb2rpb02z](https://doi.org/10.5061/dryad.tb2rpb02z).

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**REFERENCES**


SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher’s website.