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Public attitudes towards "pest" management: Perceptions on squirrel management strategies in the UK

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ABSTRACT

The impacts of non-native, invasive grey squirrels (*Sciurus carolinensis*) on broadleaf woodlands and red squirrel population (*Sciurus vulgaris*) are well recognised among wildlife professionals, yet efforts to control the species across its expanding range require substantial time and resources. Through collaboration, wildlife professionals and communities can more effectively implement the population monitoring and control programmes necessary to conserve native species under threat. However, for such collaboration to be successful, wildlife professionals must first understand public attitudes towards grey squirrels, and the control methods available. Through a national level survey (n = 3758) we examine the UK public's attitudes to red and grey squirrels, and the acceptability of seven control methods. Results show that much of the public have little knowledge of the grey squirrel's negative impacts. In fact, contrary to the notion of a pest species, the presence of grey squirrels is often desirable. Furthermore, those control methods recommended by wildlife professionals are regarded by the public as some of the least acceptable. Those most accepting of controls include males, older generations, those most knowledgeable about squirrels and people who are aware of squirrel management being practiced in their local area. To foster more fruitful collaboration, wildlife professionals should raise awareness of why particular control methods are preferred, highlight the damage grey squirrels cause to other valued species, and offer local communities a variety of roles which contribute to the wider goal of native species conservation.

1. Introduction

Changes in wildlife abundance may induce changes in human perceptions, serving to redefine species as a precious resource to be protected versus a pest to be controlled (Destefano and Deblinger, 2005). For example, perceptions of white-tailed deer (*Odocoileus virginianus*), black bear (*Ursus americanus*), beaver (*Castor canadensis*), and Canada geese (*Branta canadensis*) have all been observed to morph as their populations and the subsequent frequency of interactions with humans have changed (Leong, 2009). The potential extent of these fluctuating perceptions is exemplified with the UK's red squirrels (*Sciurus vulgaris*), which were once regarded as vermin due to the damage they caused to planted trees and bird populations (Holmes, 2015). In fact, between 1903 and 1946, the Highland Squirrel Club received "tail bonuses" for killing around 102,900 red squirrels (Rotherham and Boardman, 2006). Today the red squirrel is protected under Appendix 3 of the Berne Convention (Convention on the Conservation of European Wildlife and Natural Habitats) and is a Priority Species within the UK (and therefore the subject of a Biodiversity Action Plan).

Despite the new found affection for the red squirrel, wildlife management that involves the eradication of one (non-native invasive) species to conserve another (native one) can be controversial, particularly when the targeted species has been prevalent in gardens, parks and the countryside for decades, as in the case of grey squirrel (*Sciurus carolinensis*) populations in the UK, Ireland and parts of Italy. The management of such species can be considerably more effective if there is collaboration between key stakeholders, notably local community members, relevant policy and decision-makers, scientists and management practitioners. For example, collaborative actions can influence the conservation success of red squirrels by improving the frequency and coverage of presence-absence monitoring (Shuttleworth et al., 2015; Goldstein et al., 2014). Yet the success of these collaborative actions may be underpinned by the social acceptability of what is trying to be achieved – in this case the eradication of grey squirrels where red squirrels are present (Bertolino and Genovesi, 2003).

In contrast to red squirrels, grey squirrels were introduced to Great Britain from North America on a number of occasions between 1876 and 1929, often as fashionable additions to wealthy estates (Middleton,

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1930; Shorten, 1953, 1954). Once a rare and novel curiosity, they proved well suited to the British landscape, and have now spread over most of England, Wales and southern Scotland. Similarly, the population in Ireland, arising from the release of six pairs of animals in 1911 (O´ Teangana et al., 2000), has continued to expand to the extent that complete eradication is no longer considered economically feasible (Goldstein et al., 2016). In Italy, the grey squirrel has been introduced on at least three separate occasions, initially in Piedmont in 1948, where colonisation has reportedly occurred at a rate similar to that seen in Britain (Currado, 1998; Bertolino and Genovesi, 2003). Although, Italy's grey squirrels are the only populations in continental Europe (Mitchell-Jones et al., 1999), models indicate that the species will cross the Alps and reach France by 2050, before spreading to Switzerland, and eventually much of continental Eurasia (Lurz et al., 2001a, 2001b; Bertolino et al., 2008, Di Febbraro et al., 2013). Introductions of grey squirrels have also occurred in South Africa and Australia (Bertolino, 2008) albeit with less success. Peacock (2009) recounts the eradication of grey squirrels from Melbourne, Ballarat and Adelaide citing (un) suitable habitat, predation, competition and control effort as the pivotal factors. Despite its failure to colonise in this instance, the grey squirrel remains of great concern and is duly included in the IUCN's international list of "100 worst invasive non-native species".

The grey squirrel's reputation as a pest is not exclusively attributable to its fecundity and expansive colonisation, but also the accompanying economic and ecological damage.

Squirrels remove bark from the main stem and branches in spring and early summer to feed on the sap and phloem underneath (Kenward, 1989). Historical data from surveys assessing presence of squirrel damage in Britain indicated 28% of the beech, 24% of the sycamore, and 7% of the oak were affected, resulting in an estimated loss of £10 million for that crop rotation (Mayle and Broome, 2013). Not only does bark stripping reduce the value of timber, it may also lead to infection and decay or breakage, potentially killing the tree. In some cases, squirrels actually function as a vector for the spread of tree diseases (Abbott et al., 1977). Woodland owners are now becoming increasingly reluctant to invest in planting broad-leaved trees because of the loss inflicted by grey squirrels when the trees reach the most vulnerable age, between 10 and 40 years old (Gill, 1992; Nichols and Gill, 2016). As well as the adverse impacts to trees it has long been suspected that grey squirrels have negatively impacted red squirrel populations (Shorten, 1962). It is now understood that grey squirrels compete with red squirrels for food and transmit the squirrel poxvirus (SQPV) which is fatal only to red squirrels (Gurnell et al., 2004; Rushton et al., 2006). It seems not all populations of introduced grey squirrels carry the virus, with no outbreaks having been reported in Scotland or Italy. However, in those areas where grey squirrels carry the virus, the replacement of red squirrels by grey squirrels occurs some twenty times faster (Gurnell et al., 2006). The loss and spreading of parasites from grey squirrels may also be detrimental to native red squirrels; through a phenomenon known as "enemy release" grey squirrels were noted to have lost some of their parasites following introduction to Italy, leading to increased reproductive viability for the individual and expansion of the population's range. Moreover, grey squirrels may harbour non-native parasites which are transmitted to red squirrels ("spillover") where the two species' ranges overlap. If red squirrels are maladapted to alien parasites there could be very severe ramifications for the population (Romeo et al., 2014, 2015).

Efforts to control grey squirrels have been driven by desires to prevent damage to woodlands, reduce the loss of agricultural crops, and to conserve native red squirrel populations (Signorile and Evans, 2006; Gurnell and Pepper, 2016). Early attempts to encourage eradication through bounty schemes in Australia and Britain yielded vastly different results; in Adelaide grey squirrels were first seen in the wild in 1917. By 1920 a bounty scheme was introduced, and by 1922 the animals were eradicated (Peacock, 2009). In Britain a similar scheme was introduced in the 1950s but was abandoned later that decade having made negligible impact to a population that had already exploded beyond a containable size (Coates, 2011). In the 1960's warfarin – an established rodenticide – was increasingly used to control squirrels. Although regarded as the most cost effective means of protecting woodlands, its approval for use as a grey squirrel control method was withdrawn in 2015 amid concerns over lack of specificity and humaneness (Barr et al., 2002; Shuttleworth et al., 2017).

While the use of traps, shooting and drey poking (the disturbance of a nest with a pole) remain common forms of squirrel control, proposals to develop and apply fertility controls are now also being championed (Barr et al., 2002; Yoder et al., 2011). Contraception is generally regarded as a favourable means of wildlife control (Bremner and Park, 2007; Fitzgerald, 2009) though to be effective a vaccine may need to be long lasting or applied to a large proportion of the population. For example, a study on fox squirrels concluded that for a vaccine to reduce the population it must last at least two years or be applied to 71% of females (Krause et al., 2014).

The potential for pine marten (*Martes martes*) to act as a natural form of biocontrol is also being explored, particularly in Ireland where populations of the native predator have increased and expanded following the introduction of protective legislation in 1976 (O'Mahony et al., 2006, 2012). Research has shown a negative correlation between high density pine marten populations and grey squirrels, though precisely why this occurs is not entirely clear (Sheehy and Lawton, 2014, 2015). Sheehy et al. (2014) recently recorded the first evidence of the European pine marten preying on the grey squirrel, and found that grey squirrels are more likely to be preyed upon than red squirrels where the three species' ranges overlap. In addition, a reduced feeding rate in grey squirrels in response to marten odour has been observed, suggesting that the mechanism for the negative correlation may not be exclusively attributable to predation, but also disturbance (Flaherty, 2016). Whether such findings can be replicated in Wales, Scotland and Italy is the subject of ongoing research (Sheehy and Lawton, 2015).

Owing to its successful spread not only to woodlands but other rural and urban landscapes, grey squirrels can establish themselves as some of the most commonly sighted wild mammals in their new host countries (Wright et al., 2014; Flaherty, 2016). Although accounts of damage to buildings are occasionally reported, grey squirrels are seldom regarded as a nuisance in urban areas. The wider public therefore may not share the same negative experiences with squirrels as those involved in woodland management or conservation, and many may be unaware of the need for squirrel control at all.

This study assesses how people value red and grey squirrels, and explores knowledge, opinions and beliefs about grey squirrel management. By assessing the UK public's attitudes towards squirrels and their management we seek to answer the following research questions.

i) How familiar are the public with squirrels and how are the two species valued?
ii) What are the most and least acceptable forms of control method, and why?
iii) How do attitudes differ in respect of demographics, connectedness to nature, and knowledge of squirrels?

Additionally, we consider what these findings mean for wildlife managers who are likely to require public support and collaboration in order to conserve the native red squirrel populations.

2. Materials and methods

2.1. Survey design and sampling

To address the research aims, a survey composed of 30 questions was organised into five sections; demographics; interest in woodlands and forests; attitudes towards wildlife; management of squirrels; and trust and communication. Some of the questions (e.g. those pertaining

to interest in woodlands and forests) had already proved suitable through inclusion in previous research, whereas others were included as a means of testing hypotheses and comparing findings from similar studies. The key dependent variable – acceptability of grey squirrel controls – was measured using a 5 point Likert scale (1 = highly acceptable, 2 = acceptable, 3 = neither acceptable nor unacceptable, 4 = unacceptable, 5 = highly unacceptable). A literature review and discussion with wildlife professionals culminated in seven control methods being included in the survey: planting trees that provide grey squirrels with no food; contraception; kill traps (snap traps); shooting; live capture and subsequently destroyed; biological control (e.g. introducing predators such as pine marten); and warfarin poison. While some of these controls may be unrealistic in practice as a consequence of current regulations, landholder agreements or the difficulty involved in implementation, their inclusion is nevertheless valuable for means of comparing the relative acceptability among the public. By considering what makes a given practice acceptable, we also offer wildlife managers the opportunity to consider altering their strategies or outreach so as to improve the acceptability of the methods they choose to employ. To this end, respondents ranked the importance of five factors (see Fitzgerald, 2009) in their decision to both support and oppose control methods (effectiveness, cost, humaneness, specificity and safety).

To assist wildlife managers in effectively directing outreach and engagement efforts we considered several independent variables; age, gender, connection to nature, knowledge of squirrels and their management, and presence of squirrel species in respondents' local area. Previous research has concluded that older people and males are more likely to support controls for non-native species (Bremner and Park, 2007; Sharp et al., 2011). In our survey, age was recorded using the brackets featured in the census (0 = under 18; 1 = 18–24; 2 = 25–34; 3 = 35–44; 4 = 45–54; 5 = 55–64; 6 = 65+). Those under 18 were removed from the dataset, while those who preferred not to state their age bracket were excluded only from analysis requiring age data. Similarly those who chose not to identify as male (=1) or female (=2) were excluded from analysis reliant on gender data.

Evidence suggests that acceptance of human involvement in invasive alien species control is more likely to exist among those with a strong connection to nature (Sharp et al., 2011). We used two lines of inquiry to generate measures for this variable. Firstly, respondents stated whether their job involved elements of countryside management (1 = yes; 2 = no). Secondly, the frequency of visits to woodlands and forests was considered (1 = several times a week; 2 = more than once a month; 3 = once per month; 4 = less than once per month; 5 = never).

Support for controls has also been found to be positively associated with perceptions of a species as a pest, and knowledge of control methods (White and Whiting, 2000; Loker et al., 1999; Bremner and Park, 2007). Since grey squirrel control methods and red squirrel conservation activities are both currently being employed in those areas of the UK where greys are regarded as posing a threat to reds, we included a number of measures for knowledge of squirrels, their impacts, and vulnerability. Firstly, awareness of i) red squirrel conservation activities and ii) grey squirrel control programmes in respondents' local area (1 = yes; 2 = no). Secondly, respondents' self-reported level of knowledge about a relationship between red and grey squirrel populations (1 = I did not know there was a relationship; 2 = heard about it but know little, 3 = know something; 4 = know a lot). Finally, we considered whether the presence of different squirrel species as reported by respondents is associated with acceptability of the different controls methods (1 = red squirrels only; 2 = grey squirrels only; 3 = red and grey squirrels; 4 = no squirrels, 5 = don't know). To avoid influencing responses, the survey did not provide any information on the impacts, populations or origins of red and grey squirrels.

The survey was tested and revised through piloting with project partners, colleagues and Toluna Analytics – a specialist panel survey company. Following the pilot, a sample was drawn from Toluna's panel of registered respondents and two collaborative partners over a two-week period in October 2015. Panel members were invited to participate via an email which included a link to the online survey hosted on Toluna's platform. Responses were reviewed twice each day and assessed in relation to pre-set census-derived quotas to ensure a sample reflective of the wider population in respect of gender, region and age bracket. Toluna subsequently made efforts to stimulate responses from demographics that had not reached their quota (i.e. further direct and automated email invitations were sent).

2.2. Data analysis

We converted response frequencies from the sample to percentages to provide an overview of the public's familiarity with squirrels and the regard in which the two species are held. Similarly, we converted the Likert responses relating to the relative acceptability of the seven control methods to percentages to allow for straightforward comparisons between the respective methods' levels of acceptability. We subsequently considered these findings alongside respondents' ranking of Fitzgerald's (2009) five factors (effectiveness, cost, humaneness, specificity and safety) supposed to influence an individual's decision to support or oppose a control method. Furthermore, we employed ordinal logistic regression using the polr() function in the nnet package (Venables and Ripley, 2002) in the statistical programme R (R Core Team, 2017) to explore whether the acceptability of each control method differed significantly in respect of age, gender, connectedness to nature, knowledge of squirrels, and type of squirrels present in the respondents' local area. This analysis allowed the most important determinants of attitudes to emerge and also revealed interactions between independent variables. To enact the analysis, we treated acceptability of different control methods as ordered factors, ranked from 1 to 5 (highly unacceptable to highly acceptable). We then used these ordered factors as the response variable for the ordinal logistic regression for each control method in turn. For squirrels in local area, we converted the data to a binary response of “reds absent” and “reds present” in order to meet the assumptions of ordinal logistic regression. For each control method, we applied a series of ordinal logistic regression models to the data, allowing two-way interactions between the relevant explanatory factors (age, gender, connectedness to nature, knowledge of squirrels, and type of squirrels present in the respondents' local area as main effects, plus two-way interactions of these factors). We carried out analysis of variance on the variables, using likelihood ratio chi square tests to determine significance (included where $p < 0.05$, (Anova() function in the car package (Fox and Weisberg, 2011) in R). Non-significant main effects and interactions were dropped from each model, resulting in a best fit model for each control method. We then tested the assumption of proportional odds for each best fit model by ensuring the linearity of the cumulative logit probabilities for each main effect or interaction.

Having determined the best fit model for each control method, we performed post hoc tests on each factor (e.g. age) or interaction between factors (e.g. age:gender) to compare the different groups (subsets within the significant factor or interaction, e.g. female versus male), with back-transformation of the least square mean logits to proportions (lsmeans (Lenth, 2016) and multcompView (Graves et al., 2015) packages in R). Although significant differences apply across the response scales (highly unacceptable to highly acceptable), for the purposes of data visualisation, we cut data between “unacceptable” and “neither acceptable nor unacceptable”, such that the proportions represented the cumulative probability of responses for each group who regarded the respective control method as unacceptable or highly unacceptable could be presented graphically.

Table 1
Sample characteristics including descriptive statistics for independent variables and expected relationship with dependent variables.

Characteristic of respondent	Response category	n (/3758)	Percentage of sample	Expected association between variable and acceptability of control methods
Gender	M	1765	47.0	+
	F	1987	52.9	−
	Total	3752	99.8*	
Age	18–24	369	9.8	−
	25–34	613	16.4	
	34–45	610	16.3	+/−
	45–54	723	19.3	
	54–65	629	16.8	
	65+	804	21.5	+
	Total	3748	99.7*	
In a job that involves countryside management	Yes	381	10.1	+
	No	3377	89.9	−
	Total	3758	100.0	
Frequency of woodland visits	Several times a week	462	12.3	+
	More than once a month	1137	30.3	
	Once a month	699	18.6	+/−
	Less than once a month	1184	31.5	
	Never	276	7.3	−
	Total	3758	100.0	
Knowledge of a relationship between red and grey populations	Did not know there was a relationship	834	11.1	−
	Heard about it but know little	1355	18.0	
	Know something	1330	17.7	
	Know a lot	239	3.2	+
	Total	3758	100.0	
Knowledge of grey squirrel control programmes in local area	Yes	189	5.0	+
	No	3569	95.0	−
	Total	3758	100.0	
Knowledge of red squirrel conservation in local area	Yes	365	9.7	+
	No	3393	90.3	−
	Total	3758	100.0	
Presence of squirrels in local area	Red squirrels only	213	5.7	
	Grey squirrels only	2542	67.6	
	Red and grey squirrels	531	14.1	
	None	172	4.6	
	Don't know	300	8.0	
	Total	3758	100.0	

* Remaining respondents selected 'prefer not to say'.

3. Results

3.1. Sample characteristics

A total of 3758 people over the age of 18 completed the survey, of which 53% were females and 47% were males. The percentage of respondents from each region of the survey also closely matched the 2011 UK census data, as did the percentage of respondents within each age band. An overview of the sample and variables is shown in Table 1.

3.2. Use and connection to the countryside

Two measures for respondents' connectedness to woodlands, forests and the countryside were collected. Firstly, in terms of employment, 10% of respondents reported to be working in an occupation which involves aspects of countryside management. Secondly, when asked how frequently they visit woodlands or forests, 43% of the sample visit more than once a month. The remaining respondents visit once a month (18%) or less frequently (31%), while 7% never visit at all.

Many respondents reported multiple reasons for visiting woodlands and forests, the most common being recreation (75% of the sample), relaxation (50%) and to view wild animals and plants (29%). It is also notable that the public as a whole place great importance on woodlands and forests more generally, with over 80% of respondents agreeing that they are important places for: relaxing; exercising; having fun; learning about nature; wildlife habitat; and making a positive contribution to living environments.

3.3. Squirrel knowledge and attitudes

Most respondents reported that they are aware of squirrels in their local area, with the majority stating that there are only grey squirrels in their locality (68%). Relatively few claimed to live in areas with both red and grey squirrels (14%), and fewer still in areas with only reds (6%). < 10% stated that they live in areas without squirrels, although a further 8% did not know which squirrels, if any, were present. In addition, responses showed that the countryside is the preferred setting for seeing squirrels, followed by local parks and lastly respondents' gardens. When comparing desire to see a) grey squirrels and b) red squirrels in these settings, reds were consistently more desirable (between 27% and 28% for any given setting). However, this is not to say that grey squirrels are undesirable; a substantial number of people like or would like to see grey squirrels in their garden (47%), local parks (57%), and the countryside (58%).

Responses to a series of statements designed to elicit attitudes towards red and grey squirrels further support the idea that reds are the more valued of the two species (Fig. 1). For example, a greater proportion of participants agree that reds are more likely than greys to positively impact the local economy (55% vs. 23%), and less likely to be deserving of controls when found to be causing damage to woodland (32% vs. 55%), or if they become overabundant (23% vs. 51%). In addition, 82% of the sample agreed that reds are endangered and should be conserved, while 62% agreed that greys should be controlled if impacting reds. However, 22% of respondents admitted to being completely unaware of a relationship between red and grey squirrel populations, while only 6% reported to “know a lot” about this topic.

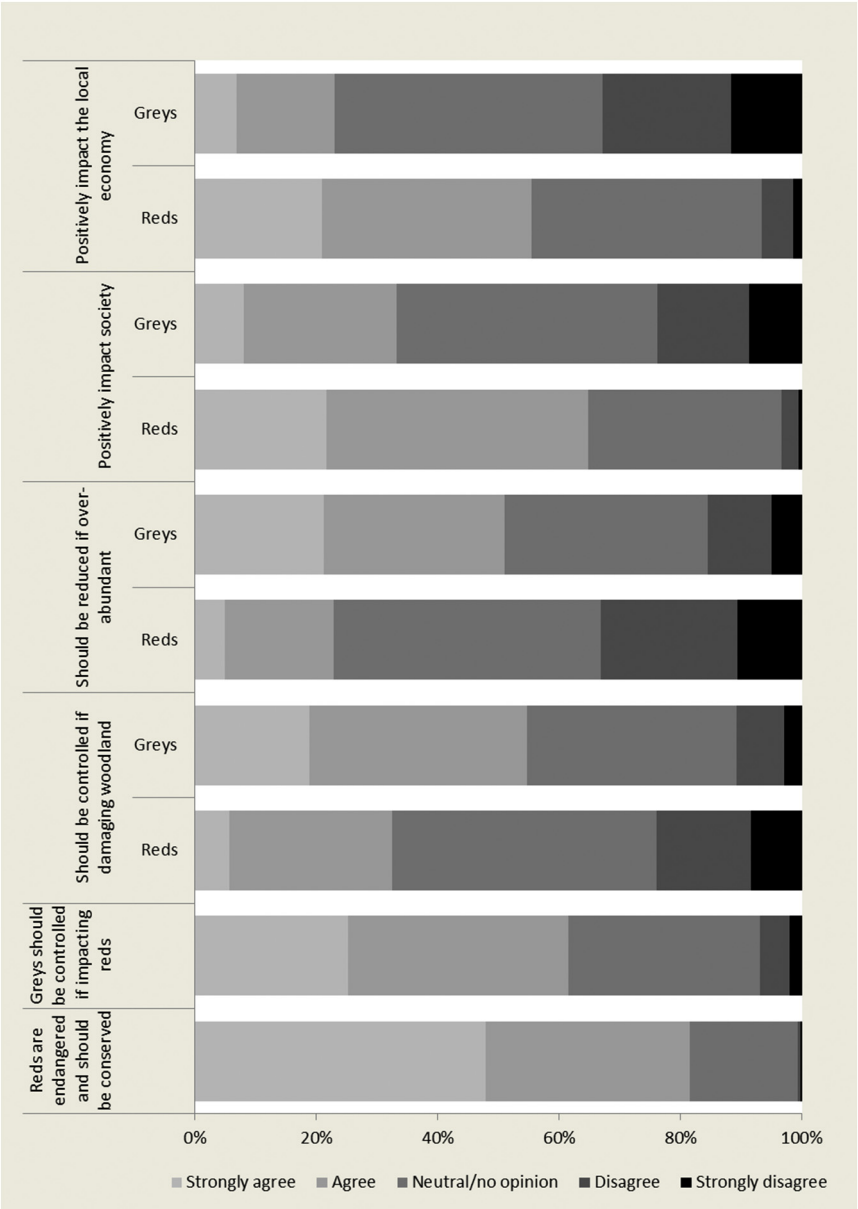

Fig. 1. Attitudes towards red squirrels (*Sciurus vulgaris*) and grey squirrels (*S. carolinensis*) among the British public (n = 3758).

Forty-two percent disagree that the two species can easily co-exist in the same area, in comparison with 18% who think co-existence is easily possible. The remaining 40% neither agreed nor disagreed, further highlighting the public's lack of knowledge on the subject.

Notably, 59% of respondents agree that it is important to conserve both red and grey squirrels. A further 33% deem themselves as being neutral or having no opinion, while only 8% disagree with this notion.

3.4. Awareness of squirrel management and control methods

Television, newspapers and the internet emerged as the three most common sources of information about the countryside and wildlife. However, there is relatively little trust placed in the media to provide reliable information about squirrel conservation and management (only 33% agreeing that this is the case). Government also fosters little trust on these matters (28%), while environmental groups (73% strongly agree or agree), the forest industry (73%) animal welfare groups (68%) and scientists (61%) are considered substantially more reliable.

Awareness of squirrel management activities in the respondents' area is very low, with only 10% aware of red squirrel conservation activities, and fewer still (5%) aware of grey squirrel control programmes. Whether this is due to a scarcity of local activities or that such activity is going unnoticed was not assessed. When presented with the seven control methods, awareness of their use in the context of squirrel management was found to be low. Shooting, kill traps, and live capture (and subsequently destroyed) are the most familiar to the sample (45%, 39% and 36% having at least heard of their respective use as a means of grey squirrel control).

3.5. Acceptability of control methods

One quarter (25%) of respondents agree or strongly agree that 'there should be no management of squirrels and nature should be allowed to take its course'. Thirty-six per cent disagree or strongly disagree with this statement, while the remaining 39% are of neutral or no opinion.

With regard to the publics' decision to a) support and b) oppose control methods, five factors were ranked by their level of importance in making these decisions. In both cases, humaneness emerged as the

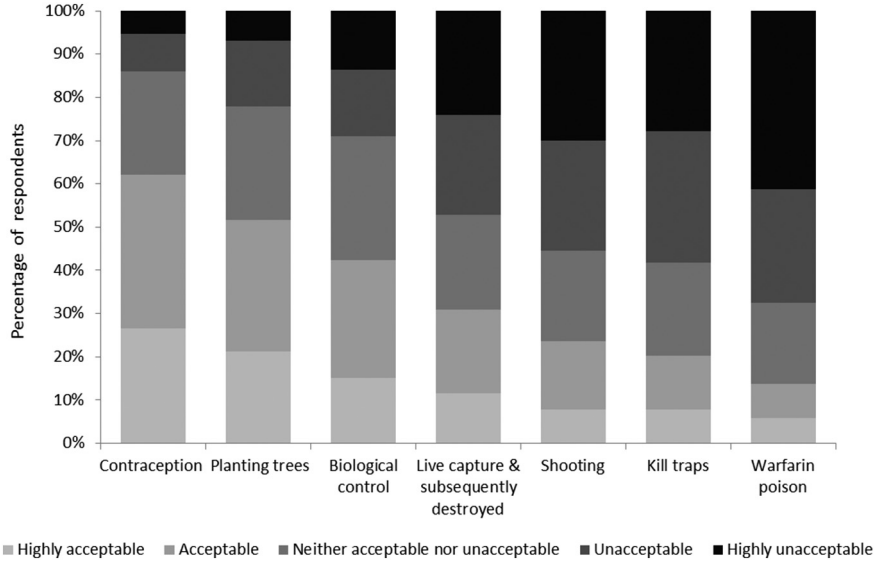

Fig. 2. Perceived acceptability of squirrel control methods among the British public (n = 3758).

most important factor. Control methods are also more likely to be supported if proven to be effective (56% ranking it as the most or second most important factor in their decision to support a control method), and more likely to be opposed if they lack specificity, i.e. do not distinguish between pests and other non-target species. Cost and safety were found to be the least influential factors in respondents' decision to both support and oppose a control method.

Those control methods which do not involve any direct killing (contraception and planting trees to limit available food) are considered the most acceptable, while lethal methods rank as the least acceptable. For example, more than two-thirds of the sample (67%) consider warfarin poison as either unacceptable or highly unacceptable, whereas the corresponding figure in the case of contraception is only 14% (Fig. 2). Notably, biological control e.g. pine marten is the most acceptable lethal control, proving more acceptable than the more commonly practiced live capture (and subsequently destroyed), and shooting methods.

3.6. Determinants of control acceptability

With regards to main effects, most of the seven factors are significant drivers of responses across the majority of control measures, with the exception of frequency of woodland visits and reds present in local area; these two factors are not significant predictors of responses as main effects in any of the seven control measures (see Figs. 3 and 4). The most common significant two-way interaction effects are age:-gender, countryside management job:knowledge of red conservation, knowledge of red-grey relationship:knowledge of grey control programmes and age:knowledge of red conservation (":" indicates two-way interaction, Fig. 4); these interactions were significant for at least three of the control measures.

Gender proved to be an important determinant of acceptability for all of the control methods (contraception: $p \leq 0.1$; all other controls: $p < 0.001$, see Fig. 3), with males being significantly more likely than females to perceive the methods as acceptable. Acceptability of control methods was also found to be positively associated with age ($p \leq 0.001$, see Fig. 3), with the exception of warfarin poison, which is largely perceived as unacceptable across all age brackets.

When examining measures of connectedness to nature, those employed in an occupation involving countryside management were found to be more likely to be accepting of five of the seven control methods (all except planting trees and biological control e.g. pine marten). However, frequency of woodland visits had no significant impact on the likelihood of deeming any of the controls acceptable. Thus, when it comes to associations between control measure acceptability and connectedness to nature, the findings suggest that it is not visits to the countryside that are important but rather the understanding and the experience that can be gained through, for example, an occupation involving countryside management. Indeed, experience of countryside management may also have served as a reasonable proxy for ecological knowledge. Instead, knowledge of squirrels and their management was explored using three measures. Knowledge about the relationship between red and grey squirrel populations emerged as a significant factor for acceptability of all seven control methods, with greater knowledge being positively associated with acceptability (warfarin $p < 0.05$, all other controls $p < 0.001$). Knowledge of red squirrel conservation activities in respondents' area was positively associated with acceptability for five of the control methods (all except live traps and kill traps), whereas knowledge of grey squirrel control programmes in respondents' area was positively associated with acceptability for four of the control methods (all except biological control e.g. pine marten, contraception and warfarin).

The importance of awareness of squirrel control and conservation activities within respondents' local areas on perceptions of control acceptability was further underlined through analysis of two-way interactions, for example; of those most knowledgeable about shooting and contraception, those aware of grey squirrel control programmes operating in their local area are significantly more likely to find these two controls acceptable. Similarly, those employed in a job involving countryside management were found to be significantly more likely to perceive kill traps as acceptable if aware of red squirrel conservation activities in their local area (Fig. 5). Acceptance of warfarin is also higher among those aware of red squirrel conservation activities operating in their local area for particular age groups (those 18–34 years old and 54–65 years old).

Finally, no significant relationship was found between acceptability of the controls and presence of squirrels in respondents' area (reds present or reds absent). *Re*-analysis exploring the relationship using presence and absence of grey squirrels also proved insignificant. However, in the case of biological control e.g. pine marten, those with moderate knowledge of the relationship between red and grey squirrel populations ("know something") were found to be significantly more likely to consider biological control as unacceptable when aware of red squirrels in their locality (Fig. 6). This may indicate that these individuals are concerned about the impact of biological control on the native red squirrel populations.

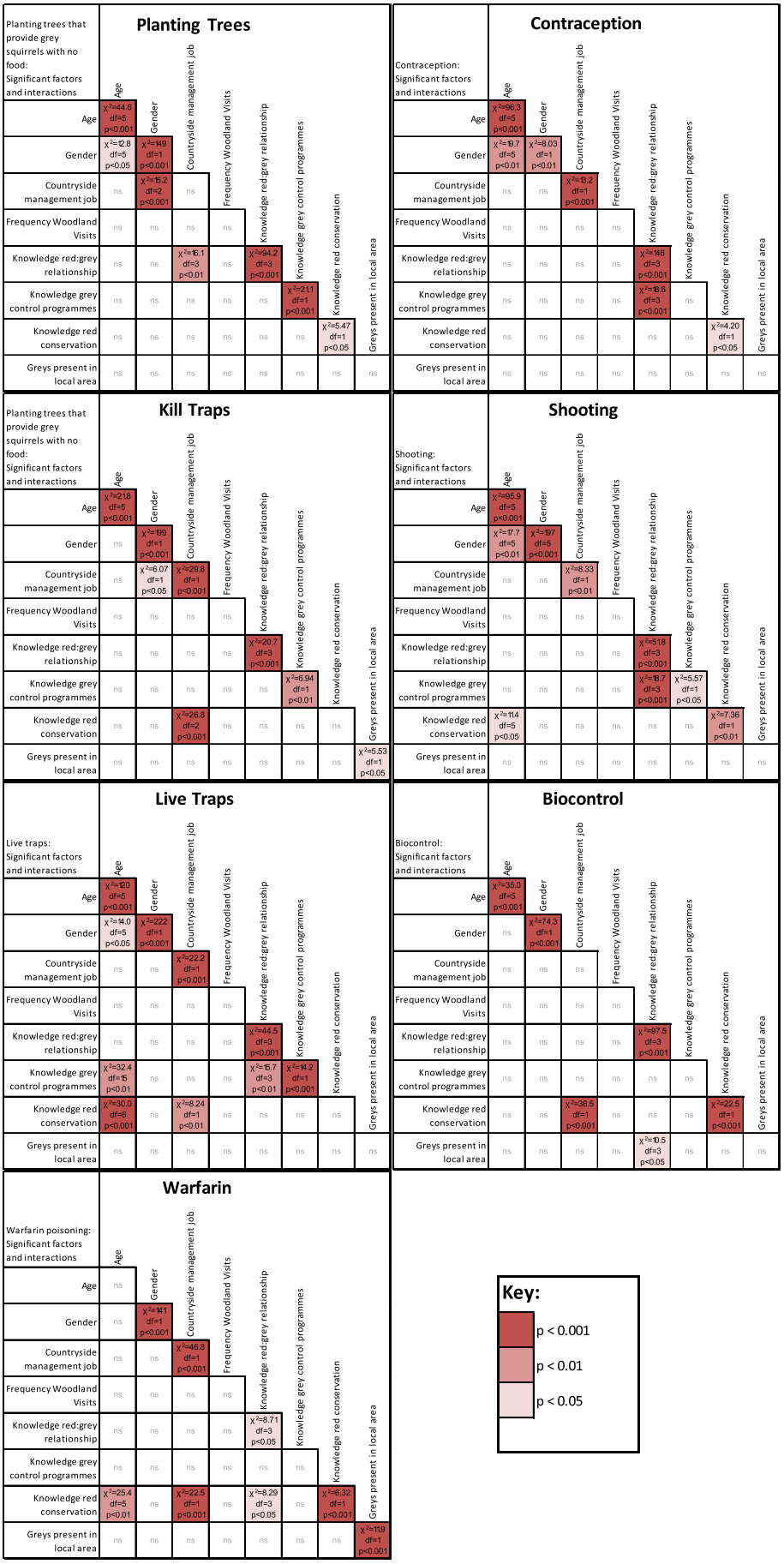

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Fig. 3. Significant factors as main effects and two-way interactions for determining attitudes (highly unacceptable to highly acceptable) towards squirrel management for seven control methods (n = 3758 for each method). Top diagonal (e.g. Age:Age) indicates significance of factor as a main effect only with no interaction. Results indicate likelihood ratio chi square tests and their significance.

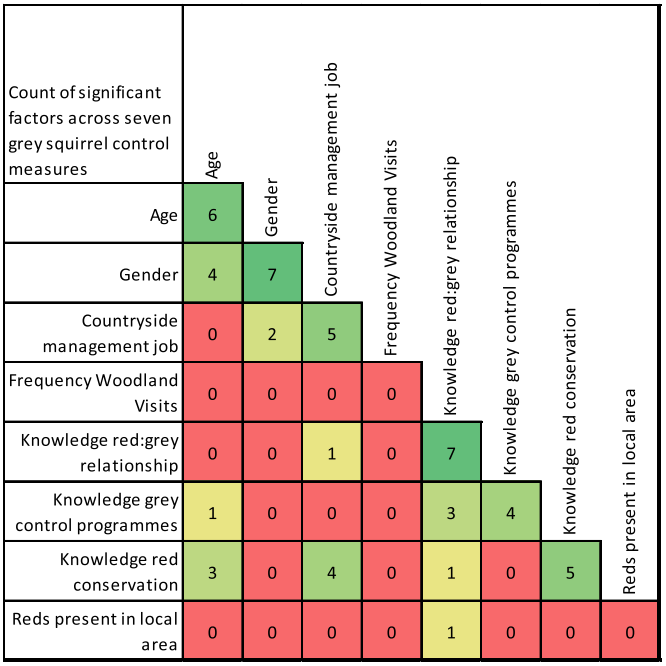

Fig. 4. Count of significant (p < 0.05) factors as main effects and two-way interactions for determining attitudes (highly unacceptable to highly acceptable) towards squirrel management across the seven control measures (red-amber-green scale; red = significant in 0/7 control measures, dark green = significant in 7/7 control measures). Top diagonal (e.g. Age:Age) indicates factor as a main effect only with no interaction. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

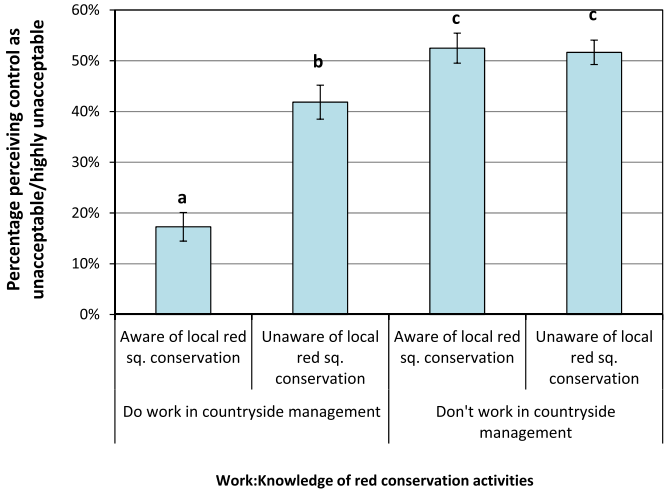

Fig. 5. Estimated mean percentage of individuals who perceive kill traps as an unacceptable method for grey squirrel control. Error bars = standard errors. Lettering (a–c) shows significant differences across groups (those not sharing a letter are significantly different).

4. Discussion

Public awareness of, and attitudes towards, squirrels and their management will likely underpin the public's willingness to support wildlife managers in their efforts to protect red squirrel populations.

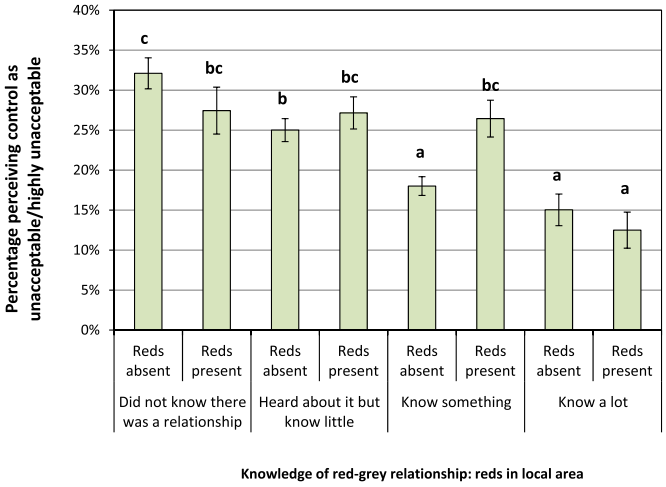

Fig. 6. Estimated mean percentage of individuals who perceive biological control e.g. pine marten as an unacceptable method for grey squirrel control. Error bars = standard errors. Lettering (a–c) shows significant differences across groups (those not sharing a letter are significantly different).

Our analyses demonstrate that the public see much value in trees and woodlands and the social, cultural and economic benefits they provide, even if they do not frequently visit these places. Similarly, while respondents on the whole have little exposure to red squirrels (relative to greys), the species is undoubtedly highly valued and the majority of respondents feel efforts should be made for them to be conserved. However, there is limited knowledge of, and exposure to, how such conservation is achieved.

Although a majority of respondents are aware of grey squirrels in their local area, awareness of squirrel management taking place here is low, both in terms of programmes to control grey squirrels, and how these assist the conservation of reds. Indeed, other studies indicate that knowledge of wildlife control programmes among the public is generally low (Bremner and Park, 2007; Defra, 2009). Greater knowledge about pest species, their impacts and the effectiveness of different management appear to be key determinants of control acceptability (Bremner and Park, 2007; Akiba et al., 2012). In a survey of the Scottish public on attitudes towards management of non-native invasive species, Bremner and Park (2007) found that prior knowledge of grey squirrel control programmes correlated with increased levels of support. Other studies have also shown links between knowledge or awareness and support for animal controls. For example, White and Whiting's (2000) research into preferences for badger culling found that respondents who favoured either a widespread cull or experimental trials over no culling tended to be more knowledgeable about levels of tuberculosis in cattle, citing this as the primary factor guiding their preferences. Similarly, Sharp et al.'s (2011) study into factors influencing public preferences for invasive alien species management revealed that educated individuals with experience in park management are more accepting of any hands-on management used to maintain ecosystem integrity. Our study demonstrates that knowledge of ecology (e.g. population interactions) is a reliable predictor for perceptions of control acceptability, whereas factors such as frequency of woodland visits and local presence of threatened or pest species are less influential. This is perhaps because woodland visits and the witnessing of a so-called pest species don't in themselves result in an appreciation of its negative implications, which would likely raise the perceived acceptability of controls (Loker et al., 1999; Fitzgerald, 2009; Farnworth et al., 2014).

Affection towards a species – and the perceived acceptability of controlling the population – may be determined by a species' reputation as well as any personal experience of negative impacts. For example, Verbrugge et al. (2013) demonstrated that control methods tend to be supported where a species is seen as a potential risk to ecological or human health. However, the study also found that eradication was predominantly opposed for species with a high "cuddliness" factor, such as mammal and bird species, even if the species was non-native. Others have similarly found that the species in question influenced levels of support for controls, signifying that some controls are deemed more appropriate for one species than another (Bremner and Park, 2007; Glas, 2016). Contrary to the grey squirrel being perceived as a pest, a substantial proportion of our sample expressed a desire to see grey squirrels in various settings, and presumably derive pleasure from their presence. These beliefs and values can have a strong influence over preferences for management, including the use of control methods (Shine and Doody, 2011). Fuller et al. (2015) and Fraser (2006) found that ethical and moral beliefs in particular have a strong influence on social acceptability of controlling species. Thus, while wildlife managers may insist that grey squirrel control is necessary for the protection of red squirrels (Bertolino and Genovesi, 2003), exposure to the two species may mean they both become highly valued by the public (Rotherham and Boardman, 2006). Furthermore, where a species is established, people tend to value them more and be less accepting of the need for controls, even if it is an invasive, non-native species (Rotherham and Boardman, 2006). It is therefore important for wildlife managers to appreciate that the grey squirrel's label as a "pest" is not unanimously understood or accepted, and to be mindful of this fact when communicating and engaging with the public.

Older age and male gender have recurrently been associated with greater support for controls (e.g. Akiba et al., 2012; Fraser, 2006; Bremner and Park, 2007). Rotherham and Boardman (2006) hypothesise that the propensity for older generations to support controls for non-native species may be underpinned by first-hand recollections of a time when the native species they are displacing were much more common. Alongside these factors our analysis also demonstrates that employment in a profession involving countryside management and knowledge of an interaction between native and non-native populations are important determinants of perceived control acceptability. While it may seem somewhat paradoxical that those most knowledgeable and interested in nature and wildlife are most accepting of lethal control methods, comparable associations are not uncommon in similar studies (Koval and Mertig, 2004; Farnworth et al., 2014). One possible explanation for this finding is that this sub-population likely has a more holistic understanding of the benefits and disbenefits associated with non-native invasive species such as the grey squirrel, including their impacts on native species and the wider environment – in this case red squirrels and broadleaf woodlands. Thus, the inclination to be more accepting of controls is perhaps a result of concern for native or threatened species rather than an intrinsic dislike of those species judged to be in need of control. This assertion is bolstered by Barr et al.'s (2002) survey of organisations and individuals expressing an interest in squirrel management and conservation, which revealed a preference for maintaining a balance of the native and non-native populations, rather than the wholesale eradication of the latter.

In addition to the aforementioned role of "targeted species type" in perceived acceptability of controls (Bremner and Park, 2007; Verbrugge et al., 2013), numerous studies have shown that the characteristics of the controls themselves can influence acceptability. For example, Reiter et al. (1999) found that the public ranked human safety as the most important consideration when selecting a management method in response to wildlife damage, followed by level of animal suffering, effectiveness, environmental impacts, severity of problem, and ability to target the specific problem animal. Notably, lethal methods of control tended to be simplistically regarded as inhumane while non-lethal methods were likely seen as humane (Reiter et al., 1999). Our consideration of the five factors highlighted by Fitzgerald (2009) revealed humaneness, specificity and effectiveness to be the key characteristics influencing public support or opposition to control methods. In light of Reiter's findings, it is likely that those methods we found to be most accepted (the non-lethal methods) are also those perceived to be most humane. Other studies highlighting the public's preference for non-lethal control methods (König, 2008; Dandy et al., 2011; Dandy et al., 2012), and specifically those highlighting an aversion to poison on the grounds of a lack of humaneness (Barr et al., 2002; Fraser, 2006), lend further credence to the notion that lethal methods may be viewed as intrinsically inhumane. This poses a challenge for wildlife professionals when attempting to gain public support, as their management of grey squirrels routinely involves the use of lethal methods such as shooting and live capture with subsequent dispatch. However, as knowledge of control measures is currently very low, and because acceptability tends to increase with greater awareness and knowledge (Bremner and Park, 2007), it is plausible that perceptions around the controls could be altered through fostering greater understanding. Given that environmental groups (along with the forest industry) were found to be the most trusted sources for the provision of reliable information about conservation and management, many wildlife professionals will already be well placed to meet this challenge.

Wildlife managers could also grow public support through consideration of alternative controls which are perceived as either more humane or more natural than the currently favoured practices (Fraser, 2006; Dandy et al., 2012). For example, there is emerging evidence that when pine martens are located in areas with red and grey squirrels, red squirrels are able to thrive while grey populations crash (Sheehy and Lawton, 2014). However, our analysis indicates that there could be a degree of trepidation about introducing pine marten to areas currently occupied by red squirrels, perhaps because of a fear that they too may be predated. Undoubtedly, further studies are needed on the social and environmental impacts of pine marten reintroduction and translocation. Contraception could also come to represent a more palatable form of control for wildlife managers, with our findings and those of other studies indicating that this approach would be viewed as humane and acceptable relative to other methods (Barr et al., 2002; Wilkinson and Fitzgerald, 2006). Despite some encouraging research and development (Yoder et al., 2011), at this time no licenced contraception product is currently available for use with grey squirrels. Furthermore, as it is likely that a large proportion of the population would need to be made infertile in order for populations to be reduced (Krause et al., 2014), it would be imprudent to rely too heavily on contraception alone. In fact, as a standalone method, region-wide intensive and coordinated culls would have the greatest impact on grey squirrel populations (Goldstein et al., 2016), suggesting that wildlife managers will come to see contraception as an addition to established approaches rather than an alternative. Although a potentially slow and costly approach, habitat alteration through, for example, planting trees favourable to red squirrels or unfavourable to greys would also likely prove an accepted means of control. Purposeful reduction of habitat quality for pest species has been suggested as an acceptable means of control in other circumstances, including with urban foxes in Germany (König, 2008).

While contraception, pine marten and habitat alteration are not presently relied upon in the case of grey squirrel control, communication by recognised and trusted bodies about why a particular method is being used and why alternative methods may be inappropriate or ineffective could increase public confidence in the actual approach taken (Defra, 2009; Stankey and Shindler, 2006). Such communication would prove particularly fruitful if it were to reach and be absorbed by the large proportion of the public who are uncertain about the acceptability of the various control methods. These people represent an important target group for outreach as they are likely to be more receptive to information and engagement than those with pre-existing opinions about whether a particular method or wider goal is acceptable.

When developing appropriate educational and informative

programs, wildlife professionals should be aware that different stakeholders have remarkably different perceptions about the impacts and benefits caused by invasive alien species (García-Llorente et al., 2008). Furthermore, while it is clear that there is substantial scope for increasing the public's knowledge on squirrels and their management, it is known that the provision of information alone rarely changes people's attitudes (e.g. Rogers et al., 2013). In those cases where information has been observed to change attitudes, it has been delivered directly to recipients in experiments rather than through wide-reaching public campaigns. Even in these cases, it is not clear whether the impact on attitude is enduring (see for example the studies of Draheim et al. (2011) and Reimer et al. (2014) on coyotes (*Canis latrans*) and eastern hellbenders (*Cryptobranchus alleganiensis)* respectively). However, if the information addresses the values and concerns held by each section of the public and is location and situation specific, it can be a starting point for greater community engagement and ownership (Lauber and Knuth, 2004; Fraser, 2006; Stankey and Shindler, 2006; Selge et al., 2011).

One way to ensure that wildlife management takes into consideration local interest and concerns is to follow a collaborative management approach which involves participatory processes designed to form relationships built on trust, while offering greater involvement of local people in decision-making. Agency-community collaboration can also lead to co-management that goes beyond stakeholder input or involvement in decision making about management objectives and actions, and includes appropriate sharing of responsibility for implementation and evaluation. Decker et al. (2005) therefore contend that there is a growing role for wildlife agencies in facilitating the development of local capacity by filling information needs and encouraging democratic processes so that individuals and groups can effectively inform and participate in collaborative efforts. Certainly in those localities where the public are aware of red squirrel conservation activities or grey squirrel control programmes there is greater acceptance for controls, including lethal varieties. This is indicative of the potential value communication, engagement and collaboration can bring to wildlife managers and conservation, and is an area warranting further research so that motivations and attitudinal shifts in the context of pest management can be better understood.

5. Conclusions

Community support is often crucial to the success of conservation aims. This is certainly true in the case of red squirrel conservation which necessitates substantial periods of time being devoted to tasks such as monitoring and grey squirrel control. Gaining support for these activities is complicated by the public's marked variation in attitudes towards squirrels and their management. Although red squirrels are valued more highly than their grey counterparts, the grey's portrayal as a pest is far from being unanimously accepted by the public as a whole, many of whom appear to have limited knowledge or experience of the species' negative consequences. Perhaps partly for this reason, a substantial proportion of the public actually have a desire to see grey squirrels.

Increasing public awareness of the damage pest species, such as the grey squirrels, cause to valued resources (including the red squirrel population and woodlands) represents one means by which wildlife managers can seek to develop acceptance for their stance and activities. This is particularly relevant given that a majority of respondents agree that i) grey squirrels should be controlled if impacting reds, and ii) red squirrels are endangered and should be conserved. While the provision of information does not necessarily lead to changes in attitudes or behaviour, it is a necessary component in justifying the implementation of control programmes, i.e. as a means of protecting other species, habitats and livelihoods. It is also noteworthy that awareness of control and conservation activities within an individual's local area is often positively associated with acceptability for controls. The extent to which this association is a result of greater community awareness about the squirrel species, or some combination of social factors (affiliations with those involved in the activities, a sense of purpose for those involved themselves etc.), requires further investigation. Regardless of what the precise mechanism for the association may be, wildlife managers may wish to consider investing greater effort in informing and involving their respective communities in the hope that local support will snowball.

The fact that wildlife professionals favour what the public perceive as some of the least acceptable control methods may prove to be a challenge when seeking to engage and collaborate with communities. The public have a strong preference for humane control methods, with those not reliant on direct killing, or not involving killing at the hands of people, being regarded as the most acceptable. However, these alternative controls may be uncommon or unviable owing to the time and cost involved in implementation (habitat alteration), a lack of scientific advancement (contraception) or uncertainty over implications and effectiveness (biological control). Given this predicament, there is a need to present communities with robust evidence to demonstrate that any preventative action and other non-lethal methods have been tried and failed, or at least thoroughly evaluated (Defra, 2009; Dandy et al., 2011). Moreover, the importance the public attaches to “humaneness” in their decision to support and oppose control methods highlights the need to resolve any confusion around the notions of *lethal* and *inhumane*. There is evidence to suggest that these terms may presently be considered by some publics as being synonymous. If a distinction can be successfully made and demonstrated, perhaps even those who remain staunchly opposed to direct involvement in lethal controls will become open to more circuitous contributions to control efforts, such as participation in the presence-absence monitoring of pest and threathened species. Event organisation, data entry and other administrative duties are further examples of tasks which could be legitimately portrayed as serving a conservation goal without active involvement in the dispatch of animals. Owing to the fact that management methods requiring ongoing effort typically receive less support (Dandy et al., 2012), understanding the motivations of those involving themselves in such activities (often voluntarily) should be considered a key area for further research. Not only would further research complement this study in informing wildlife professionals about public attitudes and behaviours, it would also be pertinent in the wider sphere of pest management, and specifically to those concerned with the establishment and spread of charismatic, non-native and invasive species.

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