LITERATURE REVIEW
Hunting and the Disturbance of Non-Hunted Species

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Summary

Hunting is an important economic, social and conservation activity that is widespread throughout Europe. While regular monitoring of the effects of hunting on hunted species occurs, research examining the effects of hunting on non-hunted species is very limited. These non-hunted species coexist alongside hunted species, and as some are vulnerable or threatened by extinction, it is important to determine if and how hunting has any consequences for non-hunted species.

Examination of the scientific literature on this topic has shown that hunting can cause behavioural responses and displacement of non-hunted populations. In ungulates, the few studies that have been carried out suggest that disturbance does have an impact on the population size (although further research is needed to confirm this), while in birds the literature suggests that disturbance does not cause declines in population sizes. It is worth noting that two reviews of the scientific literature have both found that non-hunting recreational activities, such as dog walking and wildlife viewing, can also have a significant impact on bird populations.

This review notes that displacement of bird populations does not have an impact on the population when refuge habitats are available or when carried out during times of low energy stress, but that disturbance during times of high energy stress (while reproducing, migrating or in winter) has the greatest impacts on populations. In this context, to avoid disturbance to non-hunted species, research suggests that:

- hunting should be limited in intensity through use of spatial restrictions or time intervals between hunting events;
- hunting should not occur during times of high energy stress.

This review also highlights that these practices are already implemented in most of Europe; continued implementation, further research and stricter enforcement of these rules would minimise further disturbance.

Finally, most studies examining the response of animal species to hunting disturbance appear to focus on bird species. It seems that studies of non-bird species are limited and that further research is therefore required on these species. This research would allow a better assessment of the impact of hunting disturbance on non-bird species and the development of species-appropriate management suggestions for non-bird species.

Introduction

Public awareness of wildlife and increasing ease of access to the countryside have been recognised as important factors contributing to quality-of-life and public health (Douglas, 2005), as well as being extremely important for the economy of rural areas (Bathe, 2007). Public involvement with nature and the countryside can also be expected to increase the ease of conservation efforts, both by raising awareness of conservation issues and building support measures in the general public, which may be translated into increased funding for conservation projects. It is therefore in the interest of conservation efforts to increase the public's participation with the natural environment.

Hunting is a highly popular form of nature recreation, one enjoyed by 7 million people in Europe (FACE, 2015). It is one of the oldest forms of consumptive use of renewable natural resources and provides significant social, cultural, economic and environmental benefits in different regions of Europe (Brainerd and Norwegian Assoc. for Hunting and Anglers, 2007; European Commission, 2008). European hunters are motivated by social and consumptive aspects and a passion for nature (Pinet, 1995). Sustainable hunting also represents a strong incentive to support the maintenance of habitats and species (MacDonald and Johnson, 2000; Stoate, 2002; Oldfield *et al*. 2003; Ewald *et al*. 2006; Scallan, 2012).

A study by BASC (The British Association for Shooting and Conservation) found that, in the UK, 87% of hunters agreed or strongly agreed that hunting provides benefits for the social fabric of the local community and 97% said it contributes to their personal wellbeing (BASC, 2013). Hunting is also an important economic activity: in the UK, hunting supports the equivalent of 74,000 full-time jobs (BASC, 2013) and the equivalent of 28,500 full-time jobs in France (BIPE, 2015). Hunting is also worth £2 billion to the UK economy (BASC, 2013) and €2.1 billion to the French economy (BIPE, 2015), all figures gross value added. Recent reports have suggested that, within the EU alone, hunting may be worth an estimated €16 billion (Kenward and Sharp, 2008) while, with careful management of over-abundant populations, hunting reduces the financial burden caused by these populations, costs governments would otherwise have to pay. Finally, hunting is also extremely important for conservation activity, for example, in the UK the hunting sector supports 16,000 full time conservation jobs and spends nearly £250 million on conservation work (BASC, 2013).

Both hunting and other recreational activities in the countryside have the potential to disturb wildlife, whether species are huntable or not. These disturbances may have a negatively impact on populations and the conservation of wildlife and therefore may affect the public's enjoyment of the countryside. However, it is often assumed that disturbance from hunting has an impact on populations of both hunted and non-hunted species, sometimes without scientific justification (Harradine, 1998), while potential disturbance from other recreational sources may be ignored or considered inconsequential. It is therefore very important to understand if and how hunting affects populations and how this potential disturbance compares to that of other activities.

Non-hunted species coexist alongside hunted species in the environment. While game species are often monitored and their populations regularly assessed to determine the effects and impacts of hunting, very rarely are such assessments conducted on non-hunted species. Hunting activities targeting game species have the potential to disturb populations of non-hunted species in a way that causes negative responses in their population size (and therefore conservation) simply by occurring in close proximity to the non-hunted species. As many species are not hunted, and as conservation measures may be in place to increase the population size of these species, it would therefore be especially important to determine if hunting activities threaten conservation efforts in protected, non-hunted species of conservation concern.

Whether this disturbance does impact upon non-hunted species is, however, unresolved. If disturbance has significant impacts on species' population sizes, then conservationists are justified in recommending more restrictive management measures such as limiting access to wildlife areas (Tuite *et al*. 1984; Klein *et al*. 1995). If impacts of disturbance on populations are trivial, then restrictive management measures cannot be justified as these would impose socio-economic and welfare costs unnecessarily, but, more importantly, the restrictions would be contrary to the view that access to the countryside should be increased (Gill, 2007).

Carefully balanced access to the countryside can be the best way to protect nature as it enhances its importance for society (King and Lester, 1995; Adams, 1997; Harradine, 1998; Gill, 2007) while preventing its overexploitation. It is therefore relevant and important to determine whether there are any effects of hunting on non-hunted species in order to prevent the placing of unnecessary restrictions on access to or activities within the countryside.

Hunting within Europe is legally regulated. Article 14 §1 of the Habitats Directive (Council Directive 92/43/EEC) states that hunting of huntable species must be:

> *"…compatible with their being maintained at a favourable conservation status."*

Article 7 of the Birds Directive (Directive 2009/147/EC) allows for the hunting of certain species, which is considered to constitute 'acceptable exploitation', due to the "population level, geographical distribution and reproductive rate" of these bird species throughout the European Community. More specifically, the Birds Directive states:

> *"Because of their high population level, geographical distribution and reproductive rate in the Community as a whole, certain species may be hunted, which constitutes acceptable exploitation where certain limits are established and respected, as such hunting must be compatible with maintenance of the population of these species at a satisfactory level".*

Further, it must be noted that, in Europe, restrictions exist on when you can hunt: Article 7 §4 of the European Commission's Birds Directive prevents hunting during the rearing season, the various stages of reproduction or during migration, and many countries have strict hunting seasons to implement this. In Europe, the hunting season ends one or two months (varying by country) before the start of the breeding and migration season except where national derogations apply. Hunting of European mammals is also temporally regulated: Article 14 §2 highlights that measures to ensure hunting does not threaten huntable species' favourable conservation status may include regulation of the hunting periods. These regulations via both the Birds and Habitats Directives restrict the occurrence of disturbance during times of high energy expenditure in order to reduce the impacts of disturbances on wildlife population sizes.

This literature review will therefore explore the effect of hunting disturbance on populations of non-hunted species and will highlight where further research may be required due to gaps in our current knowledge. Further, it discusses management recommendations designed to minimise the intensity of disturbance caused by hunting. Finally, it compares the impact of disturbance caused by hunting activities to that cause by some other recreational activities.

What constitutes disturbance?

In terms of defining disturbance, this review follows the widely accepted definition of Fox and Madsen (1997), which is also used by AWEA (the African-Eurasian Migratory Waterbird Agreement) in defining 'disturbance' as:

> *"Any human-induced activity that constitutes a stimulus (equivalent to a predation threat) sufficient to disrupt normal activities and/or distribution of waterbirds relative to the situation in the absence of that activity"* (Fox and Madsen, 1997).

A distinction exists between the effects of a disturbance and its impacts:

- Disturbance **effects** are modifications of species' behaviour and distribution and include escape responses.
- Disturbance **impacts**, however, are changes to population size and dynamics through changes to individual Darwinian fitness(see below).

Disturbance may or may not have an impact on the Darwinian fitness (hereafter fitness) of an individual. Darwinian fitness is the ability of an organism to produce viable offspring capable of surviving to the next generation (Collins English Dictionary) and considers both the lifespan of an organism and its reproductive success. Fitness is therefore determined by individual breeding success, survival and mortality.

An important element to consider when discussing disturbance is the 'carrying capacity' of an area. This is defined as the maximum number of individuals of a given species that can by supported by a given environment. This is affected by climate, rate of predation, abundance of diseases, food and water availability, bedding / nesting sites and material and any other resources that a species consumes (Dhondt A, 1988). Decreasing availability of these resources or increasing the harshness of the climate reduces the carrying capacity as the environment can now maintain fewer individuals. Finally, a 'hunted species' is generally taken to mean any legally huntable game species that is shot or shot at; it does not include illegally-hunted / poached species or any non-target species that are shot at.

Does hunting disturbance have an effect on non-hunted species?

It has been shown that hunting can have an effect on behaviour and species distribution of non-hunted species; although the existing research does not cover all taxa equally as it is heavily focused on birds. Amongst ungulates, a review of escape responses found that, while non-hunted ungulate species showed reduced escape responses from hunting compared to hunted species, there was still an evident disturbance effect (Stankowich, 2008). Further, hunting disturbance on roe deer in particular has also been shown to cause disturbance effects as defined above (Calenge *et al*. 2005).

Amongst birds, hunting has been shown to have an effect by causing a behavioural response or displacement in Galliformes such as turkeys and ptarmigan (Everett *et al*. 1980; Folk and Marchinton, 1980; Broseth and Pedersen, 2010), in Gruiformes such as coot (Holm *et al*. 2011; Martínez-Abraín *et al*. 2013), in Anseriforms such as ducks (Dooley, 2008; Dooley *et al*. 2010) and in waterbirds more broadly (Madsen, 1998). In general, it is well known that hunting activity causes birds to depart disturbed places and seek less disturbed ones (Bell and Owen, 1990; Madsen, 1995; Madsen and Fox, 1995; Madsen 1998; Evans and Day, 2001). Studies on quarry geese and dabbling ducks by Madsen (1998) and on protected crested coots (*Fulica cristata*) by Martínez-Abraín *et al*. (2013) that established hunting

refuges show this as both resulted in an increase in local waterbird populations while not affecting individual survival or breeding success.

Hunting has also been shown to have disturbing effects even at long distances from the hunting location. For example, a study comparing the disturbance responses of coastal birds to walking and wildfowling found that wildfowling regularly disturbed birds 200m away (Collop, 2015).

Despite the extensive scientific work done on the effects of disturbance on birds, and to a lesser extent on ungulates, there seems to be limited research undertaken on the effects of hunting or non-hunting disturbance on other non-hunted species such as rodents, small or large carnivores, reptiles, amphibians or invertebrates.

In the case of ungulates and birds, however, it can be concluded that hunting disturbance does have an effect on non-hunted species in that it elicits behavioural responses and can result in displacement as has been shown above.

Does hunting disturbance have an impact on non-hunted species?

That disturbance causes behavioural responses or displacement of populations is unequivocal; however, disturbance is only of conservation concern when it causes an impact on the population level (Gill *et al*. 1996). Thus, it is apparent from the literature that behavioural responses or movements between habitats in non-hunted species are not a cause for conservation concern if this effect does not translate into decreased survival rate, decreased reproductive success or increased mortality. That behavioural responses or movements between habitats result in population decreases must be statistically shown, it cannot be assumed to have occurred.

It is possible that displacement forces the disturbed species onto sub-optimal habitat that has a lower carrying capacity than the previous habitat (i.e. it cannot support the same population size due to e.g. reduced food availability). In this case, disturbance would lead to decreased population size and displacement would have an impact on a population. A study of non-hunted roe deer (*Capreolus capreolus*) in a landscape hunted for boar (*Sus scrofa*) and hare (*Lepus europaeus*) found that hunting disturbance in winter caused the deer to find refuge in a protected area situated in sub-optimal habitat at a snow-covered hill-top (Grignolio *et al*. 2011). This likely exposed them to harsh environmental conditions while simultaneously reducing the available food supply. Furthermore, uphill movements may have an important energy cost, especially when undertaken in an adverse season (Grignolio *et al*. 2011). However, this outcome cannot be assumed to be true as no data exists regarding the nutritional reserves of the deer and it was not statistically tested in the study in question; further research is needed to test this hypothesis. Thus, in the case reported in Grignolio *et al.* (2011) it cannot be concluded that disturbance would have resulted in a decreased population size. It can, however, be suggested that the increased density of the deer population in the protected area likely led to knock-on effects to the local ecology. Increased herbivore density can lead to over-browsing, changes in vegetation (Milchunas and Lauenroth, 1993), soil compaction due to trampling which can affect burrowing invertebrate communities (Bromham *et al.* 1999; Wardle *et al.* 2001) and decreased litter accumulation which can affect detritivore communities (Bromham *et al*. 1999; Andersen *et al*. 2001). Increased large herbivore densities have also been shown to negatively affect communities by reducing diversity in small mammals (Flowerdew and Ellwood, 2001) and birds (Fuller, 2001). Further research may be necessary to statistically test these possible outcomes.

Hunting disturbance on non-hunted species can have an impact on the population if the escape response initiated by hunting uses valuable energy supplies that would reduce subsequent survival rates. A study examining roe deer survival after their introduction to the 'Petit Luberon' state forest in southern France found introduced animals had unexpectedly low survival rates during the autumn and winter, while having very high survival rates during the spring and summer. It was concluded that this increased mortality was most likely caused by increased movement and resulting energy demands from disturbance from wild boar hunting that occurs in the area during the autumn and winter months (Calenge *et al*. 2005). Thus, for ungulates, hunting disturbance on non-hunted species can be of conservation concern.

However, evidence suggests that it is unlikely that human-imposed energy demands have an impact on the population size of birds. An analysis of studies investigating bird energy intake and expenditure conducted by Boos *et al*. (2002) strongly suggested that anthropogenic activities considered as sources of disturbance (including hunting) generally have very low or no impact on the survival and initiation of nesting of birds because they do not impact on energy balance. This is partly due to the fact that hunted areas usually have populations lower than the habitat's carrying capacity, thus there is an excess of nutritional energy available for consumption. The review by Boos *et al*. (2002), however, only assessed the literature examining birds; limited research has been conducted regarding human-influenced energy use in non-bird species.

In addition to this, a large body of evidence suggests that displacement in birds is short-lived and that once a source of disturbance has ended, the population rapidly returns to the preferred habitat in anywhere from one day to three weeks (Andersson, 1977; Bregnballe and Madsen, 2004; Jettka, 1986; Gerhard, 1994; Dooley, 2008; Dooley *et al*. 2010). This makes it unlikely that disturbance causes an impact on the population size of birds by minimising the length of time disturbed birds would be forced to spend on sub-optimal habitat.

Furthermore, evidence suggests that a decrease in body mass of disturbed birds, that may be interpreted as a precursor to decreased survival of the animal (and therefore would represent a population impact), may actually be adaptive (i.e. resulting in increased fitness). Studies conducted by Zimmer *et al* (2010; 2011a; 2011b) found that disturbance affected energy balances in common teal (*Anas crecca*) and tufted ducks (*Aythya fuligula*) by resulting in decreased food intake and body mass when compared to an undisturbed group; however, this reaction was found to be adaptive and resulted in an increase in fitness in the birds. This was because the loss of body mass enabled a more favourable wing loading, increased power for flight, enhancing flight performances and thereby reducing predation risk. It must, therefore, be considered that decreases in food intake and body mass of disturbed animals as a result of disturbance may not be evidence of a negative impact of disturbance as might otherwise have been thought.

Population-level studies testing whether the absence of hunting disturbance causes a response in the individual fitness of non-hunted species found no statistically significant results suggesting it did. For example, a study on the effects of a hunting moratorium on protected (i.e. non-hunted) crested coots (*Fulica cristata*) in eastern Spain found that the four year hunting ban did not affect survival of birds, nor did it increase the breeding population size (Martínez-Abraín *et al*. 2013). While the moratorium did increase the size of the wintering population, this was concluded to be due to displaced birds being attracted to the site, not increased reproduction (Martínez-Abraín *et al*. 2013). Similar results were found by Madsen (1998); increased local waterbird populations after formation of hunting refuges was concluded to be due to the reduced displacement from disturbance, not an increase in survival or breeding success. Finally, in the USA, three studies of non-hunted wild turkeys showed that even

intensive hunting for large and small game species does not appear to adversely affect established populations of turkeys (Everett *et al*. 1980; Folk and Marchinton, 1980; Reed and Guynn, 1990).

The available scientific literature therefore suggests that hunting disturbance can have an impact on the fitness of ungulates, and therefore may have an impact on population sizes. It is, however, unlikely that hunting disturbance has an impact population sizes of birds as the existing scientific literature has found no evidence of hunting disturbance resulting in reductions in individual fitness.

However, it must be noted that short-term displacement can result in individuals relocating from preferred habitat to areas of poorer quality and lower carrying capacity and therefore may have an indirect impact on individual fitness; further research is required to test this hypothesis.

Management suggestions: minimising disturbance impact on non-hunted species

By examining the studies concluding that disturbance does have an effect or an impact on non-hunted species, the following section discusses management suggestions that have been made for hunting practices that would minimise the level of disturbance experienced by non-hunted species. The largest proportion of research on disturbance has been conducted regarding disturbance of bird species; the management suggestions below are therefore mainly based on evidence collected from studies conducted on birds. Broad suggestions based on this data can be applicable to non-bird species; however, the details of an implemented management suggestion would have to be based on species-specific research.

It is important to note that the scientific evidence the following management suggestions are based on is mainly derived from studies of hunting disturbance on non-hunted species; however, it is supplemented by studies of non-hunting disturbance, and disturbance of hunted species.

Management suggestion: Limit disturbance intensity by reducing hunting frequency or implementing spatial hunting restrictions

The literature shows that reduced hunting frequency or intensity (through use of temporal or spatial hunting restrictions) limits disturbance intensity. In birds, hunting with time intervals between hunting events has been shown to reduce disturbance. For example, hunting waterfowl with intervals of 1-4 weeks between hunting events allows population densities to reach previous levels, minimising disturbance by allowing them access to their preferred, presumably optimal habitat (Andersson, 1977 in; Jettka, 1986; Gerhard, 1994; Bregnballe and Madsen, 2004). The interval required for bird densities to reach pre-hunting levels is therefore relatively short, but may be longer for other species. The appropriate time interval for a species can be determined by species-specific research.

Spatial restrictions can also help to reduce the impact of hunting disturbance by allowing animals to relocate to a nearby refuge. That said, for species that are not as mobile as birds, the quality and accessibility of the habitat individuals displace to is of key importance, as the lack of mobility means species may have to remain in the refuge for an extended period of time and that they will be less able to move to them. If the refuge habitat is of poor quality (i.e. has a low carrying capacity) then the population may decline as individuals die of starvation, predation, disease or other factor that affects carrying capacity (Grignolio *et al*. 2001). If the refuge habitat is far away or access is difficult (e.g. fences, roads or poor quality habitat prevents access) individuals will struggle to reach it and may die en

route. It is therefore important that hunted areas are in close proximity to high quality refuge areas where non-hunted (and hunted) species can displace to in times of disturbance and not suffer population declines.

It is worth noting that spatial hunting restrictions are already in place in many parts of the EU. In France, a percentage of all hunting land must be kept hunting-free, this allows disturbed species to use it as a refuge as described above. In the rest of the EU, many hunted areas are near protected areas, both because the land around a protected area often has larger populations of huntable species due to spill-over and as a conservation measure to allow non-hunted species to seek refuge.

In summary, the literature suggests that disturbance from hunting on non-hunted species can be reduced by limiting disturbance intensity through reduced hunting frequency or use of spatial hunting restrictions. However, spatial hunting restrictions, such as those recommended, are already common within the EU.

Management suggestion: Reduce hunting at times of high energy stress

The scientific literature shows that disturbance, of any kind, during times of high energy stress has been shown to have the most severe impacts on populations. Energy stress occurs at times of high energy demand such as breeding or migrating (Randolph *et al.* 1977; McWilliams *et al.* 2004) or low energy supply such as in winter or during severe climatic or weather events (West *et al*. 2002; Goss-Custard *et al.* 2006). Few studies have examined the effect of hunting disturbance during times of energy stress; however disturbances of any kind during these times often have a population impact.

Disturbance during the reproductive period can have a negative effect on initiation of reproductive behaviour (such as nesting or mating rituals), reproductive success, investment in offspring and their survival. A study of disturbance's impacts on reproductive success in black-crowned night-herons (*Nycticorax nycticorax*) showed that disturbance leads to increased chick mortality, nest failure and ultimately reduced breeding success (Bennett *et al*. 2011). A similar study in red deer (*Cervus elephus*) showed that repeated disturbance and displacement by humans during the 3-4 week period of peak calving resulted in decreased calving success (Phillips and Alldredge, 2000).

Disturbance during times of low energy supply such as harsh winters can also have a negative impact on survival. A modelled study of Eurasian Oystercatchers (*Haematopus ostralegus*) shows that in winters with good feeding conditions, birds can be disturbed up to 1-1.5 times per daylight hour before they die of starvation due to reduced energy intake; in bad years this maximum possible rate drops to 0.2-0.5 times per hour (Goss-Custard *et al*. 2006).

In order to reduce the impacts of hunting disturbance, hunting should not occur at these times of high energy stress. Evidence that reduction of disturbance during these times results in increased individual fitness and reduces disturbances impacts on populations can be seen in a study of Oystercatchers: year-round disturbance caused impacts on the population size, while eliminating disturbance in late winter virtually removed any population consequences (West *et al*. 2002).

It must be highlighted that mechanisms to reduce disturbance during times of high energy stress are already in place in much of Europe. In Europe, the hunting season ends one or two months (varying by country) before the start of the breeding and migration season except where national derogations apply. The following literature shows that, in birds, this is early enough to allow animals to accumulate energy reserves and therefore not negatively affect the population size. For example, a study of pink-footed geese (*Anser brachyrhynchus*) found that they are capable of building reserves sufficient to

survive migration in 1-3 weeks (Madsen, 1995). Studies of bird species have also shown that endogenous nutrient availability (reserves stored within the body) does not limit clutch size or egg formation in northern shoveler ducks (*Anas clypeata*) or in Arctic waders; therefore, body condition (potentially affected by disturbance) does not affect reproductive success in these species (MacCluskie and Sedinger, 2000; Klaassen *et al*. 2001). Similar results have been found in a study of greater snow geese (*Chen caerulescens atlanticus*), a mixed endogenous-exogenous breeder (energy for breeding comes from both stores in body tissues and that taken in by concurrent feeding), where body condition was found to not affect clutch size; however, it must be acknowledged that reduced body condition resulting in lower chick survival later is still possible (Bety *et al*. 2003).

Furthermore, at national level, many countries have regulations preventing hunting during harsh weather conditions. Some examples are that in the UK after 7 consecutive days of severe weather BASC calls for a voluntary restraint which is generally well-followed by hunters and after 14 severe weather days there is a statutory suspension of all waterfowl hunting, while in the Republic of Ireland all hunting is temporarily halted after a prolonged spell of cold weather and continues once the weather improves. Similar systems to this exist in France, Italy and Belgium where hunting is illegal when snow has fallen. As long as these regulations are respected hunting disturbance is unlikely to negatively affect populations.

In summary, the literature suggests that disturbance from hunting on non-hunted species can be reduced by reducing hunting at times of high energy stress. However, as highlighted, hunting is illegal during times of high energy requirement (e.g. during migration) and many countries possess mechanisms to reduce hunting disturbance during times of low energy availability.

How does hunting disturbance compare to other disturbance?

Hunting is often the focus of public attention regarding disturbance of wildlife; however, as the existing literature shows, this may be without scientific justification. It is worth examining how other sources of anthropogenic disturbance affect non-hunted populations and may be interesting to compare these to the level of disturbance caused by hunting.

A review of the recreation ecology literature published in English language academic journals identified 33 papers from 1978 to 2010 that examined the effects of wildlife viewing, hiking, running, cycling, canoeing, horse riding and dog walking on numerical abundance or density and on reproductive success of birds (Steven *et al*. 2011). Of these 33 papers, 28 (85%) found negative responses in numerical abundance or density of birds to these recreational activities, and of these 33 papers 28 also found negative impacts of these activities on bird reproductive success. A second review of studies examining the impact of investigators (scientists), recreationalists and aircraft disturbance on colonially-nesting waterbirds from 1971-98 found negative impacts on populations of penguins, pelicans and other Pelecaniformes, gulls as well as other Charadrigormes and herons and other Ciconiiformes (Carney and Sydeman, 1999).

It therefore appears that, in birds, non-hunting recreational activities represent significant sources of disturbance, which, it has been shown, can result in population impacts. It is worth noting that these activities may be less regulated than hunting: walkers, dog walkers, water sports and wildlife observers are often active throughout the whole year, including during times of high energy stress. However, in many cases procedures are in place to reduce the disturbance caused by these recreational visitors.

Limitations and areas of future study

In examining the literature, this review has sought to assess the effects of hunting disturbance on all non-hunted species from a wide range of groups; however, this has not been possible for the majority of species. Overwhelmingly, the existing research has been conducted on the effects of disturbance on birds. This bird bias is even more pronounced when examining the impacts of disturbance rather than the effects; while escape response of non-bird animals has received some attention (mostly on ungulates), the impacts of hunting disturbance on non-bird populations has been the focus of limited research and only one study could be found on this topic. The appeared scarcity of research on the effects of disturbance on species other than birds represents a gap in scientific knowledge.

The literature has shown that some management suggestions can be made that can be applied to non-bird species from the existing, bird-biased research. However, these recommendations may have limited relevance to non-bird species as they are based on the assumption that other groups will respond to hunting disturbance in the same way as those studied. Considering the extreme ecological differences between invertebrates, birds, amphibians, mammals and reptiles, this assumption should be made with caution.

Future studies must attempt to fill the gaps in the list of species for which the impacts of disturbance have been examined. As many non-bird species coexist alongside hunted bird species, it is extremely important that research be conducted assessing the effects of hunting disturbance on groups such as invertebrates, birds, amphibians, small mammals and reptiles as the current scientific literature on these species is lacking. This would enable the formulation of species-appropriate management suggestions to minimise hunting's disturbance of these species and allow these suggestions to be incorporated into hunting (and non-hunting) management plans.

Additional research is also necessary to statistically test for any impact of the displacement of individuals onto sub-optimal habitat by hunting disturbance, such as that recorded by Grignolio *et al*. (2011) in the study of non-hunted roe deer, on mortality. Such research would help examine any indirect impacts of hunting disturbance on non-hunted species

Conclusion

In conclusion, this literature review has noted the importance of assessing the effects and impacts of hunting disturbance on non-hunted species, while also making some links to disturbance caused by other recreational activities.

The available literature has shown that hunting does have a disturbance effect, by causing a behavioural response or a relocation of disturbed animals away from sources of disturbance.

Scientific evidence has also suggested that hunting disturbance can have an impact on the population sizes of non-hunted ungulates by resulting in increased energy expenditure from escape responses during times of low energy availability such as autumn and winter months; however, as this conclusion is based on a single study further research is required.

Conversely, the available literature suggests that disturbance may not have an impact on the population size of bird species as disturbance is unlikely to significantly affect individual energy use or availability, while studies testing whether disturbance has an impact at a population level have found no evidence that disturbance results in changes in population size that were driven by changes to individual fitness. This is summarised by Sokos *et al.* (2013):

> *"Hunting may influence migratory bird behaviour and movements, but studies have not found a corresponding increase in non-hunting mortality factors or any reduction in feeding, body condition, breeding success and any long-term population decrease."*

Some solutions have been discussed which include: i) limiting disturbance intensity by use of reduced hunting frequency or spatial hunting restrictions, and ii) reducing hunting at times of high energy stress. This review has highlighted that such recommendations are already followed in many European countries, but their continued implementation and stricter enforcement is necessary to minimise hunting disturbance as much as possible.

This literature review has also considered the level of disturbance caused by some other non-hunting human recreational activities, such as dog walking, cycling and wildlife viewing, and it has been shown that many of these result in significant negative impacts to wildlife population sizes. This is of conservation concern as non-hunting recreational activities may be less regulated than hunting, allowed to occur during times of high energy stress and usually allowed in protected areas while hunting is not for fear of disturbance to wildlife.

Finally, this literature review has highlighted the fact that research on disturbance, both hunting and non-hunting, seems to be focusing on birds. This bias exists despite the fact that birds only make up a small proportion of animal species. In order to formulate recommendations to minimise hunting and non-hunting disturbance on species other than birds, it is extremely important that more research is conducted within these groups as the current absence of data represents a major gap in scientific knowledge.

References

Adams WM. 1997. Future Nature: A Vision for Conservation. Earthscan Publications, London, UK, pp. 226

Andersen H, Bakker JP, Brongers M, *et al*. 1990. Long-term changes of salt marsh communities by cattle grazing. *Vegetatio* 89: 137–148.

BASC (The British Association for Shooting and Conservation). 2013. *The Value of Shooting* [pdf]. BASC. Available at <http://basc.org.uk/wp-content/uploads/downloads/2014/07/The-Value-of-Shooting2014.pdf> [Accessed 04.07.15]

Bathe G. 2007. Political and social drivers for access to the countryside: the need for research on birds and recreational disturbance. *Ibis* 149: 3-8

BIPE. 2015. Evaluation de l'impact économique social et environnemental de la chasse française. Available at: http://www.chasseurdefrance.com/wp-content/uploads/2015/07/05_Etude_BIPE_Resultats_globaux_8_Juillet_2015.pdf (accessed 08.10.16)

Bell DV and Owen M. 1990. Shooting disturbance-A review. In Matthews. G.V.T. (ed.) Managing Waterfowl Populations: 159-171. Proc. IWRB Symp.. Astrakhan 1989. IWRB Special Publication 12. Slimbridge. U.K.: International Waterfowl and Wetlands Research Bureau.

Bennett VJ, Fernandez-Juricic E, Zollner PA, *et al*. 2011. Modelling the responses of wildlife to human disturbance: An evaluation of alternative management scenarios for black-crowned night-herons. *Ecological Modelling* 222:2770-2779

Bety J, Gauthier H and Giroux J-F. 2003. Body Condition, Migration, and Timing of Reproduction in Snow Geese: A Test of the Condition-Dependent Model of Optimal Clutch Size. The American Naturalist 162 (1): 110-121

Boos M, Arnauduc JP, Robin JP. 2002. Effects du derangement sur l'énergétique chez les oiseaux et les possibilities de compensation nutritionnelle. Rapport final de convention de recherche CNRS/FNC

Brainerd S. and Norwegian Association for Hunting and Anglers. 2007. European Charter on Hunting and Biodiversity. Adopted by the Standing Committee of the Bern Convention at its 27th meeting in Strasbourg, 26-29 November 2007. Available at: http://www1.nina.no/lcie_new/pdf/634991504714143702_Hunting_Charter[1].pdf

Bromham L, Cardillo M, Bennett AF, *et al.* 1999. Effects of stock grazing on the ground invertebrate fauna of woodland remnants. *Australian Journal of Ecology* 24, 1999–2007

Broseth H and Pedersen H. 2010.Disturbance effects of hunting activity in a willow ptarmigan *Lagopuslagopus* population. *Wildlife Biology*16(3):241-248

Bregnballe T and Madsen J. 2004. Tools in waterfowl reserve management: effects of intermittent hunting adjacent to a shooting-free core area. - Wildl. Biol. 10: 261-268

Calenge C, Maillard D, Invernia N, *et al*. 2005. Reintroduction of roe deer *Capreolus capreolus* into a Mediterranean habitat: female mortality and dispersion. *Wildlife Biology* 11(2):153-161

Carney KM and Sydeman WJ. 1999. A Review of Human Disturbance Effects on Nesting Colonial Waterbirds. *Waterbirds: The International Journal of Waterbird Biology* 22 (1): 68-79

Collins English Dictionary - Complete and Unabridged 10th Edition. HarperCollins Publishers. http://dictionary.reference.com/browse/darwinian-fitness (accessed: January 07, 2016).

Collop C. 2015. Wintering birds and disturbance – How does wildfowling compare to walking on the beach? *Presentation delivered at BASC's recreational disturbance symposium, London. 26th June 2015*

Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora

Dhondt AA. 1988. Carrying capacity: a confusing concept. *Acta oecologica. Oecologia generalis* 9 (4): 337-346

Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds (codified version)

Dooley J. 2008. MALLARD RESPONSE TO EXPERIMENTAL HUMAN DISTURBANCE AND NON-BREEDING SURVIVAL ALONG THE SOUTH PLATTE RIVER IN COLORADO.*Department of Fish, Wildlife, and Conservation Biology, Colorado State University* Thesis

Dooley JL, Sanders TA and Doherty PF. 2010. Mallard Response to Experimental Walk-In and Shooting Disturbance. *J. Wildl. Manage*. 74:1815-1824

Douglas I and UK MAB. 2005. *Urban Greenspace and Mental Health* [pdf]. UK MAB Urban Forum. Available at <www.psykinfo.regionsyddanmark.dk/dwn109162> [Accessed 04.07.15]

European Commission. 2008. Guidance document on Hunting under the Birds Directive. Report by the European Commission. Available at: http://ec.europa.eu/environment/nature/conservation/wildbirds/hunting/docs/hunting_guide_en.pdf

Evans DM and Day KR. 2001. Does shooting disturbance affect diving ducks wintering on large shallow lakes? A case study on Lough Neagh, Northern Ireland.*Biological Conservation*98: 315-323

Everett DD, Speake DW, and Maddox WK. 1980. Natality and mortality of a north Alabama wild turkey population. *Proc. Natl.* Wild Turkey Symposium. 4:117-126.

Ewald J, Callegari S, Kingdon N, *et al*. 2006. Fox-hunting in England and Wales: Its Contribution to the Management of Woodland and Other Habitats. *Biodiversity and Conservation* 15: 4309-4334.

FACE (The European Federation of Associations for Hunting and Conservation). 2015. Available at: www.face.eu [Accessed 06.01.16]

Flowerdew JR and Ellwood SA. 2001. Impacts of woodland deer on small mammal ecology. *Forestry* 74 (3): 277-287

Folk RH and Marchinton RL. 1980. Effects of intensive deer hunting on behavior of wild turkeys. *J. Wildl. Manage*. 44:398-402

Fuller RJ. 2001. Responses of woodland birds to increasing numbers of deer: a review of evidence and mechanisms. *Forestry* 74 (3): 289-298

Gill JA. 2007. Approaches to measuring the effects of human disturbance on birds.*Ibis* 149(Suppl. 1): 9-14.

Gill JA, Sutherland WJ and Wastkinson AR. 1996. A method to quantify the effects of human disturbance on animal populations.*Journal of Applied Ecology* 33: 786-792

Grignolio S, Merli E, Bongi P, *et al*. 2011.Effects of hunting with hounds on a non-target species living on the edge of a protected area. Biological Conservation 144: 641–649

Harradine J. 1998: Managing waterfowl hunting disturbance. The pragmatic approach. *Game and Wildlife Science* 15: 897–904.

Holm TE, Laursen K and Clausen P. 2011. The feeding ecology and distribution of common coots *Fulicaatra* are affected by hunting taking place in adjacent areas. *Bird Study* 58: 321-329

Jettka H. 1986.Jagdstreckenauswertung der Stockenten (Anas platyrhynchos L.) in einemRevier des Münsterlandes in Nordrhein-Westfalen. - ZeitschriftfürJagdwissenschaft 32: 90-96

Kenward R and Sharp R. 2008. Use Nationally of Wildlife Resources Across Europe, 117-132.: in Manos, P. and Papathanasiou, J. [eds.] (2008) GEM-CON-BIO: Governance and Ecosystems Management for the Conservation of Biodiversity. Thessaloniki

King ES and Lester JN. 1995. The value of salt marsh as a sea defence. *Marine Pollution Bulletin* 30: 180-189.

Klaassen M, Lindstrom A, Meltofte H and Piersma T. 2001. Arctic waders are not capital breeders. *Nature* 413: 794

MacCluskie MC and Sedinger JS. 2000. Nutrient reserves and clutch size regulation of northern shovelers in Alaska. *Auk* 117: 971-979

MacDonald DW and Johnson PJ. 2000. Farmers and the Custody of the Countryside: Trends in Loss and Conservation of Non-productive Habitats 1981- 1998. Biological Conservation, 94, 221-234.

Madsen J. 1995. Impacts of disturbance on migratory waterfowl. *Ibis* 137: S67-S74

Madsen J and Fox AD. 1995. Impact of hunting disturbance on waterbirds - a review. *Wildlife Biology* 1: 193-207

Madsen J. 1998. Experimental refuges for migratory waterfowl in Danish wetlands. II. Tests of hunting disturbance effects. *Journal of Applied Ecology* 35 (3): 398–417

Martínez-Abraín A, Viedma C, Gómez JA, *et al*. 2013. Assessing the effectiveness of a hunting moratorium on target and non-target species. *Biological Conservation* 165: 171–178

McWilliams SR, Guglielmo C, Barbara P, *et al.* 2004. Flying, fasting, and feeding in birds during migration: a nutritional and physiological ecology perspective. *Journal of Avian Biology* 35: 311-393

Milchunas DG and Lauenroth WK. 1993. Quantitative effects of grazing on vegetation and soil over a global range of environments. *Ecological Monographs* 63, 327–366.

Oldfield TEE, Smith RJ and Harrop SR *et al*. 2003. Field Sports and Conservation in the United Kingdom. *Nature*, 423, 531-533.

Phillips GE and Alldredge AW. 2000. Reproductive Success of Elk Following Disturbance by Humans during Calving Season. *The Journal of Wildlife Management* 64 (2): 521-530

Pinet JM, 1995. The hunters in Europe. Report: 1-12. Federation of Associations for Hunting and Conservation of the E.U. (FACE).

Scallan D. 2012. The Place of Hunting in Rural Ireland. Unpublished PhD thesis. Department of Geography, College of Arts, Social Sciences and Celtic Studies, National University of Ireland Galway.

Randolph AA, Randolph JC, Mattingly K, *et al*. 1977. Energy Costs of Reproduction in the Cotton Rat, *Sigmodon Hispidus. Ecology* 58 (1): 31-45

Reed DJ and Guynn DV. In: Eversole, Arnold G., ed. Proceedings of the forty-fourth annual conference: Southeastern Association of Fish and Wildlife Agencies. 1990 October 21-24; Richmond, VA. Baton Rouge, LA: Louisiana Department of Wildlife and Fisheries: 304-309

Sokos CK, Birtsas PK, Connelly JW, *et al*. 2013. Hunting of migratory birds: disturbance intolerant or harvest tolerant? *Wildl. Biol*. 19: 113-125

Stankowich T. 2008. Ungulate flight responses to human disturbance: A review and meta-analysis. *Biological Conservation* 141 (9): 2159-2173

Stoate C. 2002. Multifunctional Use of a Natural Resource on Farmland: Wild Pheasant (Phasianus colchicus) Management and the Conservation of Farmland Passerines. Biodiversity and Conservation, 11, 561-573.

Steven R, Pickering C, Castley GJ. 2011. A review of the impacts of nature based recreation on birds. *Journal of Environmental Management* 92 (10): 2287–2294

Tuite CH, Hanson PR and Owen M. 1984. Some ecological factors affecting winter wildfowl distribution oninland waters in England and Wales, and the influence of water-based recreation. *Journal of Applied Ecology* 21:41-62.

Wardle DA, Barker GM, Yeates GW, *et al*. 2001. Plant removals on perennial grassland: vegetation dynamics, decomposers, soil biodiversity, and ecosystem properties. *Ecological Monographs* 69: 179–188.

West AD, Goss-Custard JD, Stillman RA, *et al*. 2002. Predicting the impacts of disturbance on shorebird mortality using a behaviour-based model. *Biological Conservation* 106 (3):319-328

Zimmer C, Boos M, Poulin N, *et al*. 2010. Evidence of the Trade-Off between Starvation and Predation Risks in Ducks. *PLoS ONE* 6(7): e22352. doi:10.1371/journal.pone.0022352

Zimmer C, Boos M, Bertrand F, *et al*. 2011a. Behavioural Adjustment in Response to Increased Predation Risk: A Study in Three Duck Species. PLoS ONE 6(4): e18977. doi:10.1371/journal.pone.0018977

Zimmer C, Boos M, Petit O, *et al*. 2011b. Body mass variations in disturbed mallards *Anas platyrhyncos* fit to the mass-dependent starvation-predation risk trade-off. *Journal of Avian Biology* 41: 637-644