Urban Geese – looking to North America for experiences to guide management in Europe?

ANTHONY DAVID FOX

Department of Bioscience, Aarhus University, Kalø, Grenåvej 14, DK-8410 Rønde, Denmark.
E-mail: tfo@bios.au.dk

Abstract

Free-flying geese have become a problem in many parts of urban North America as a result of accidental escapes, deliberate (re-)introductions and colonisation by naturally expanding populations. In the last 25 years, the same problem is becoming manifest in Europe. Such urban goose populations tend to benefit from access to highly suitable managed, fertilised short-cut grasslands (available at, for instance, golf clubs, sports fields, industrial estates) and other productive feeding sites close to safe open-water night-time roost sites. This behaviour brings elevated reproductive success (due to reduced predation risk) and survival rates (due to reduced hunting and predation rates) compared to other goose populations. As a result, numbers have tended to increase as urban geese habituate to their proximity with humans. Fouling and contamination, disease and parasite transmission, impacts on biodiversity, public safety issues and simple nuisance factors represent some of the conflicts most frequently perceived and/or posed by increasing number of geese in urban environments. Literature reviews show that there are nutritional, energetic, foraging, thermal and fitness (both reproductive and survival) benefits for geese from using urban habitats compared to rural ones, underlining the potential for an increasing problem in the future. Solving urban wildlife issues is particularly challenging because sectors of the public may hold different views on the magnitude of the problem, and the urgency for and the nature of resolution. For this reason, management solutions to urban goose issues require sensitive and effective engagement with all stakeholders involved to ensure ownership of the process, to find solutions to opposing views and to gain agreement on the scale and nature of potential solutions prior to tackling problems. Potential local management mechanisms include removal of the food supply (*e.g.* by stopping provision of food, keeping potential feeding habitats in an unsuitable state, using chemical repellents, *etc.*), scaring and relocation/removal of geese from conflict loci, but all these actions have their limitations and costs. Population control includes rendering nests unproductive or chemical contraception, but in long-lived birds such as geese, elevating adult mortality is far more effective at reducing population size than reducing reproductive output. We need to improve our understanding of the population dynamics of urban goose populations, be better

able to communicate biological information to those charged with their management, have a better understanding of the values and perceptions of urban geese held by the wider public, and improve our ability to resolve conflicts between sectors of society with differing views on urban goose management, if we are to be better prepared for resolving such conflict in the future.

Key words: disease transmission, hunting, nest control, nuisance, population regulation, scaring.

Geese in urban areas have been an issue in North America for many years, with a burgeoning scientific literature going back to the 1980s, but it is only in the last 25 years that this subject has become an issue in Europe. Although not a single species problem, Canada Geese *Branta canadensis* in particular have become year-round residents in urban and suburban areas across the United States, raising concerns especially for human health and safety. Non-migratory geese exhibit high survival rates and locally high densities as a result of the availability of specific habitat mosaics, reduced predation and lack of hunting in urban and suburban environments (Balkcom 2010; Rutledge *et al.* 2013). Consequently, between 1990 and 2009, the estimated number of resident Canada Geese in the United States increased from two and a half million to more than five million birds (Dolbeer 2009). Given the increasing need to develop creative management interventions to resolve conflicts associated with these birds, it seems timely to review the literature and experiences from North America in preparation for potential future difficulties elsewhere in the Northern Hemisphere. This review attempts to synthesise and assess current knowledge of the subject, rather than to undertake a systematic all-encompassing survey of the existing literature, with the objective of offering guidance to a developing problem likely to require further actions in the future.

Why are societal issues relating to urban geese becoming more pressing?

Most (but not all) Northern Hemisphere wild goose populations currently show generally favourable conservation status, and in recent years many populations have increased rapidly in numbers and distribution (Fox & Madsen 2017; Fox & Leafloor 2018). These increases are likely in part due to the ability of these highly mobile herbivores to exploit pulses of food availability (typically above-ground primary production of graminoids, but also seeds, fruits and below-ground storage parts of plants) separated in time and space. In the last 100 years geese have proved themselves especially adept at exploiting these traits offered within artificial habitats created by humans, pre-eminently in agricultural landscapes (Fox *et al.* 2017; Fox & Abraham 2017). Northern Hemisphere farmland offers field units of crops specially bred for enhanced productivity with high nutrient/energy content, raised in single species monocultures to which geese are

perfectly adapted to food gathering. Hence, increasing goose populations contrast with those of many other avian species with which they share the same farmland landscape (*e.g.* Green *et al.* 2005). By accepting a degree of human disturbance, the colonisation of the urban landscape is merely an extension of that of the agricultural one, potentially with added benefits (see below), despite the fact that, in the past, geese typically avoided human habitation and urban areas in their choice of foraging sites (*e.g.* Rosin *et al.* 2012; Zhang *et al.* 2019). For geese, which specialise in grazing on closely-mown, fertilised lawns that commonly occur adjacent to open water bodies in urban landscapes (*e.g.* in public parks, golf courses, industrial estates and residential areas), these habitats provide perfect opportunities for them to feed, preen, loaf, drink, bathe and roost at sites in close proximity to each other. Such a functional landscape, invariably associated with a lack of hunting (because of safety issues associated with dense human populations in built-up areas) and reduced risk of natural predation (because of generally lower predator densities in such areas; Conover & Kania 1991), potentially offers fitness benefits over equivalent rural areas where the same feeding opportunities may occur but at the cost of exposure to hunting and higher predation risk.

How has the problem of urban geese come about?

Canada Geese (as well as other goose species) have been introduced as exotic ornamental waterbirds to many parts of Europe over centuries (Madsen & Andersson 1990). However, many North American urban goose populations can be traced back to more recent (re-)introductions of Giant Canada Geese *Branta canadensis maxima* or its western large-bodied counterpart *B. c. moffitti* to enhance hunting and wildlife opportunities across the continent in areas where they were either extirpated or not present in recent times (Conover & Chasko 1985; Conover 1992; Holevinski *et al.* 2006). For instance, Canada Geese were introduced into the Fraser Valley (British Columbia, Canada) in the late 1960s and early 1970s to provide a harvestable surplus in areas open to hunting and to provide wildlife viewing opportunities. Subsequent landscape urbanisation, high goose fecundity and survival, diminution of hunting, and exploitation of vacant habitat in urban areas led to a rapid increase in the goose population to the point where the geese were causing multiple problems to different sectors of society (Breault & McKelvey 1991). However, other geese have colonised urban environments naturally from other non-breeding habitats. For example, marked Cackling Geese *Branta hutchinsii* resighted overwintering in urban areas of one city (Lubbock, Texas) originated from summering areas across the Canadian Arctic from western Canada to Baffin Island (Ray & Miller 1997) and a different population of the same species breeding in Alaska has also spread to many urban areas of Oregon (Mini 2012; Harrington 2016). Arctic-nesting Lesser Snow Geese *Chen caerulescens caerulescens* which were "never observed using a golf course habitat" (Moul & Elliott 1994) in Richmond (British Columbia, Canada) in the early 1990s are now very

common visitors to golf courses there, as well as to recreational grassland areas, roadside verges and garden lawns (often within a few metres of busy roads, residents and pedestrians) throughout the area (D. Bradbeer, pers. comm.; Stevick 2017).

Such developments have been common and widespread throughout North America, but are only now beginning to emerge in Europe. Here geese are showing increasing use of urban environments – for example, Barnacle Geese *Branta leucopsis* first colonised the Helsinki area of Finland in 1989. There the species has benefitted from nesting on small islands in lakes in public areas that provide urban lawns for brood-rearing in relatively predator-free environments (Väänänen *et al.* 2011). Similarly in Germany, reintroduced Greylag Geese *Anser anser* have developed the habit of wintering in Munich, where they feed in the parks of the city (Kleinhenz & Koenig 2018). Although the precise origins of many urban goose populations may be obscure, some are derived from artificial introductions, escapes from captivity or natural colonisation by wild populations, resulting in a variety of species now being associated with urban and suburban landscapes (as in the United Kingdom, see Delany 1993).

Why the concerns about urban geese?

The presence of (especially abundant) species close to dense human populations can create conflict, forcing resource managers to address issues relating to urban wildlife (*e.g.* Ditchkoff *et al.* 2006), although the nature of the conflict can be varied. In the case of urban geese, it can be mainly distilled into four (not necessarily mutually exclusive) major categories:

Fouling and contamination

Geese typically defecate every 3.5–15 min (*e.g.* Owen 1971; Fox & Kahlert 1999) and faeces can cause fouling/contamination as well as visual and olfactory offence to the general public at recreational grasslands where goose flocks feed intensively (Allan *et al.* 1995) They create special hazards to playing on golf courses, football pitches and baseball fields by reducing the aesthetic value and recreational potential of such areas and posing a potential health hazard (Conover & Chasko 1985; Forbes 1993, and see below). The import of nitrogen and phosphorus from adjacent foraging habitats can also promote the undesired eutrophication of urban lakes (Scherer *et al.* 1995; Moore *et al.* 1998; Birch & McCaskie 1999), potentially inhibiting recovery measures in such situations (Nürnberg & LaZerte 2016).

Disease and parasite transmission

Disease and parasite transmission carried by free-living urban geese to other wildlife, humans, pets or domestic animals is potentially extremely serious. Hence, the deposition of goose faeces in public places offers a potential source of disease infection and parasite infestation to humans and other organisms. Coccidioisis, avian influenza virus (AIV), schistosomes, chlamydiosis, salmonella and avian cholera, as well as a range of other bacterial and viral pathogens have all been shown to have be carried and potentially spread by geese (*e.g.* Guth *et al.* 1979; Skene *et al.* 1981; Friend 1987; Gomis

et al., 1996; Smith *et al*. 1999; Salthoun *et al*. 2000; Dieter *et al*. 2001; Kullas *et al*. 2002; Kassa *et al*. 2001; 2004; Jellison *et al*. 2009; Rutledge *et al*. 2013; Gorham & Lee 2015). Transmission of disease and parasites to humans is not well documented, and probably rarely occurs, but seems plausible, creating an expectation of a problem (Luechtefeld *et al*. 1980; Wobeser & Brand 1982; Hill & Grimes 1984; Pacha *et al*. 1988; Graczyk *et al*. 1997). Particular concerns relating to urban geese have been raised because AIV prevalence is higher amongst Canada Geese from urban locations than those in rural areas (Kistler *et al*. 2012). However, a recent comprehensive literature review suggests that the scientific evidence for geese playing an active role in transmission of disease to other geese, animals and humans is restricted to findings of antibiotic resistance, AIV in humans (Hsu *et al*. 2017), and *Campylobacter* and *Salmonella* within geese (Elmberg *et al*. 2017). Nevertheless, a prevalent response is to invoke public health issues as a reason for control of urban geese, even in the absence of a scientifically verified problem.

Effects on other features of biodiversity

Persistent heavy grazing by geese tends to result in relatively uniform grass swards, low in species and structural diversity often inhibited from flowering and seeding, which likely affects other elements of the associated biota and potentially broader ecological services (see review in Buij *et al*. 2017). Although apparently not studied widely in urban settings, persistent goose grazing, especially in areas close to water affects the physiography and physical nature of vegetation that results in dominance of graminoid or occasionally other undesirable species at cost to vegetation diversity, the invertebrates that inhabit such swards and potentially other grazing species. Heavy grazing, trampling, puddling and concentrated faecal deposition may remove vegetation or inhibit desirable vegetation regeneration (*e.g*. Baldwin 2004).

Public safety

Large numbers of large-bodied geese within the confines of an urban landscape can create unusual conflicts with society through collisions with vehicles or (especially with goose families crossing roads) by causing road chaos and accidents, while aggressive parents have been recorded attacking pedestrians in protection of broods (Paulin & Drake 2003). When attracted to airports, goose presence raises serious flight safety issues, although most airports employ expensive, sophisticated but effective methods to eliminate this risk (Conover & Chasko 1985; Dolbeer *et al*. 2000; Dolbeer 2009; Bradbeer *et al*. 2017). Geese habituated to humans may show no fear and be extremely aggressive towards people and simply the noise that large aggregations of geese can produce may also constitute a nuisance in urban settings (Smith *et al*. 1999).

Conflicting public attitudes to urban geese

Although the goose problems listed above may provide convincing arguments against tolerating geese in urban settings, many sectors of society place a value on the presence of geese, even if these belong to

an invasive alien species. Many folk enjoy the sight of free-flying large birds, which bring a hint of wilderness to the city environment, and children like to feed geese and get close to such wild animals. Hence, any attempts at resolving conflicts associated with urban geese fundamentally need to address local public attitudes and respect differences of opinion, which can be both strong and highly contradictory. For instance, a major survey undertaken by Coluccy *et al.* (2001) in central Missouri on the presence of Giant Canada Geese found that three-quarters of respondents were aware of these birds, 68% enjoyed their presence and 42% were satisfied with numbers at their current level. However, among the smaller proportion of landowners and respondents reporting property damage, respondents wished for fewer geese in the future and were more likely to describe geese as a nuisance. With the exception of implementing traditional hunting techniques and the introduction of regulations to restrict residents from feeding geese, lethal and non-lethal management alternatives generally were viewed adversely (Coluccy *et al.* 2001). Interestingly, support for lethal alternatives increased when it could be demonstrated that: 1) geese were causing serious damage, 2) lethal methods were the only viable means of control, and 3) geese were killed humanely and processed for human consumption through local food pantries or homeless shelters. Respondents reporting property damage were also more likely to support lethal alternatives. Forty-eight percent of respondents indicated that landowners should not expect compensation for damage to their property caused by geese. However, hunters and respondents who reported property use by geese viewed government agencies as financially accountable for damage (Coluccy *et al.* 2001).

What features of urban landscapes are advantageous to geese?

Seen from a goose perspective, facets of the urban environment offer a perfect combination of reliable feeding sites (*e.g.* highly fertilised closely-mown lawns such as golf courses, football pitches, spilled grain in railway marshalling yards) in close proximity to areas of persistent open water. An added attraction in winter is that such waters may be maintained ice-free during sub-zero air temperatures because of elevated urban temperature, or because of warm water discharge into rivers and lakes from industry, water treatment facilities, coolant water systems, domestic outflows and power plants. Such open water areas in North America during periods of sub-zero air temperatures are an added incentive there for geese to infiltrate urban settings and may enable geese to winter far to the north of their range in otherwise ice-locked habitats.

Geese utilise terrestrial habitats by day and resort to safe roosts at night, which typically are stretches of open water that offer safety from predators. The proximity of these two areas reduces the energy expended on flying between feeding/roosting sites twice daily. Hence, compared to rural geese, urban geese often may have highly restricted core home ranges (*e.g.* Groepper *et al.* 2008; Rutledge *et al.* 2015; Dorak *et al.* 2017) because of the nature of the urban landscape mosaic. Their daytime

"foraging" areas may be surprisingly devoid of disturbance; for instance, geese in the Detroit area use roof-tops (potentially for thermoregulation benefits, Dorak *et al.* 2017) and industrial estates, where ornamental ponds are set in the private grounds of lawns associated with building complexes, which may be heavily fenced, often guard-protected and hence relatively rarely visited by the general public.

In public parks, humans, and especially families with young children, may actually be attracted by the presence of geese, with the result that the birds habituate to human activity and may even become dependent upon them for the provision of reliable sources of artificial but highly nutritious food (which may also reduce goose foraging times), especially when other food is rendered inaccessible, such as during periods with deep snow. Hunting is generally not permitted in such built-up areas due to human safety considerations, so unlike geese flying out to agricultural areas on the fringes of towns, geese remaining in urban areas can functionally isolate themselves from the effects of hunting (*e.g.* Dorak *et al.* 2017). Indeed, nuisance goose sites were more likely to be in towns where hunting was restricted compared to randomly selected sites, suggesting that hunting may reduce local nuisance goose problems either by reducing population size or (more likely) by increasing the birds' wariness of humans, making them less willing to occupy sites used by people (Conover & Kania 1991).

The relatively few North American predator species present in urban environments (such as Red Fox *Vulpes vulpes* and Raccoon *Procyon lotor*) are rarely capable of depredating nests defended by parent geese, especially of the larger Canada Goose races (Brown 2000), but as Coyotes *Canis latrans* begin to colonise urban areas to a greater extent, these could have effects on both nest and adult survival (Brown 2000). Recent increasing numbers of Cackling Geese using urban habitats in the Willamette Valley, Oregon, USA were considered to result partially as a response to increasing Bald Eagle *Haliaeetus leucocephalus* numbers in habitats outside of town (Harrington 2016). Harrington (2016) concluded that, ultimately, use of urban areas by Cackling Geese would increase (despite the equivalent nutritional quality of forage between the two landscapes types), because urban Cackling Geese achieved undisturbed higher net energy gain (in the absence of eagles) compared to those foraging on protected refuges where they were disturbed frequently by eagles.

All these features combine to suggest that the greater use of urban versus rural habitats within winters, with falling temperatures and increasing snow depth, are a direct result of foraging, thermal and/or survival benefits from utilising these areas in preference to rural areas. As a result, studies are beginning to emerge that have been able show demographic advantages to using urban landscapes as breeding habitat or non-breeding habitat (*sensu* Alerstam & Högstedt 1982) as described below.

Effects on reproduction

Most studies contrasting Canada Goose nesting success in different areas have demonstrated that nesting success is higher in urban, commercial and industrial areas

than in comparable rural situations within the same populations (*e.g.* Smith *et al.* 1999; Cline *et al.* 2004; Guerena *et al.* 2014, 2016). Geese will inevitably attempt to increase the probability of survival year-round (below), but there is also likely strong selection for geese to return to breeding areas in good body condition to defend nesting territories at the earliest possible time (Kokko 1999; Alerstam & Lindström 1990). Hence, the fittest birds are likely to remain as high up the migration corridor as possible to gain maximum advantage of the prevailing conditions. In North America, the existence of urban areas provides a toe-hold at latitudes north of other traditionally occupied agricultural landscapes by likewise supplying nutritional, energetic, foraging and thermal benefits for geese, which may lead to improved survival and, in the case of those individuals breeding in urban environments, enhances breeding success as well.

Effects on survival

Balkcom (2010) showed that despite similar site fidelity rates of Canada Geese in urban and rural areas in Georgia, survival rates were strikingly higher among urban geese (mean ± s.e. = 0.958 ± 0.020) which were not exposed to hunting pressure and did not experience the same rates of natural mortality as rural geese (mean annual survival rates of 0.682 ± 0.049). Similarly, Canada Geese that remained within the Greater Chicago Metropolitan Area showed winter survival of 100% (*i.e.* within urban areas) compared to 48% (95% CI = 16–82%) amongst those individuals that emigrated (Dorak *et al.* 2017), and Beston *et al.* (2014) likewise found higher survival rates (and lower harvest rates) amongst marked resident Canada Geese in urban New Jersey compared to those marked in rural areas more accessible to hunting. Hunting harvest contributed less to urban goose morality than for rural birds in the same population (Beston *et al.* 2015). Luukkonen *et al.* (2008) showed that female Canada Geese breeding in parks subject to nest destruction tended to remain to moult locally, whereas rural-nesting females whose nests were destroyed were more likely to undertake moult migration to remote areas. As a result, overall survival between May and November in breeding areas where hunting was permitted was lower than for resident birds, which remained where they were and where hunting was restricted (0.60, 0.42–0.75 95% CI *versus* 0.93, 0.84–0.97). Relying on hunters to control an urban goose population by targeting these birds on occasions when they fly out to the surrounding area will likely fail, because hunters cannot concentrate upon the specific population to a sufficient level to elevate mortality, especially if an element of the population remains in urban areas inaccessible to hunters (Conover 1987). Indeed, the opposite may occur, because geese naturally tend to seek out areas with lowest hunting activity (Beaumont *et al.* 2013), so are likely to be increasingly attracted to such areas in urban settings and less likely to persist in areas subject to persistent hunting pressure.

Approaches to conflict management

Having acknowledged the existence of a problem with urban geese that needs to be

managed, several fundamental issues have to be considered. One of the first is to determine the scale of the problem. Is this a minor issue creating local conflict, which although serious, is highly limited in time or space? Alternatively, is this a widespread and developing problem, constituted by a discrete group of geese throughout the year, at many localities, which generate multiple and potentially escalating conflicts that necessitates more coordinated management? Having established the scale of the problem, it is also essential to ensure effective and open engagement with all the relevant specialist interest groups and stakeholders that have an interest in the geese from the very start of the process. Management of urban and suburban goose populations takes place under the very watchful eyes of many people, some of whom may not have developed views about the geese until faced with control actions that potentially precipitate strong opinions. It is therefore all the more vital to engage in an open consultation and to plan and manage the process with a clear understanding of the scale and strength of the problem and the desirable outcomes, considering carefully how to gather the key players and actors, as well as more passive observers, into an effective decision-making process. It is also essential to determine and come to a consensus upon the precise nature and scale of the problem, long before embarking on the process of defining actions. It is important that, in the development of a plan of action, all parties acknowledge the overriding importance of defining the problem, sharing knowledge and maintaining transparency at all levels of decision-making throughout (*e.g.* Berkes *et al.* 2003; Armitage *et al.* 2009). The early establishment of a form of working group (involving stakeholders, statutory agencies, NGO representatives and experts) is also required to establish trust between all the parties, engage interested parties and to structure, negotiate and implement a plan of action, which embraces broad agreement about the required outcomes of management at appropriate scales, as exemplified by the International Species Management Plan for the Svalbard population of the Pink-footed Goose *Anser brachyrhynchus* at the population level (Madsen & Williams 2012), but also manifest at national and local levels (Tombre *et al.* 2013). Care needs to be taken to respect the values and opinions of different groups; the same group of geese may be seen by managers as "pests" causing "problems", by golf clubs as a financial cost, by baseball players as a "nuisance", by poultry owners as a source of disease, yet by some local residents as a precious contact with nature and wilderness. Adopting a type of structured approach ensures buy-in from all interested parties, recognises and reconciles opposing opinions and secures a common ownership of the process at appropriate levels that will be needed to contribute to success. From these foundations and discussions, agreement can gradually be found, upon which to base: 1) attainable and well-defined objectives, 2) appropriate actions needed to reach these objectives over a specified time span, and 3) monitoring mechanisms to track progress against an agreed timetable. These objectives have to be agreed by all the relevant parties, and take account of other biodiversity, socio-

economic, recreational and other societal interests. Agreements must ideally include very specific targets. These could be reducing numbers of geese in a specific area to a specific proportion of current levels, stopping fouling of a given area of a golf course, or reducing a discrete flock of geese and stabilising it at an agreed level. Establishing such targets provides a clear basis for measuring progress towards particular success criteria, but also requires appropriate monitoring and reporting mechanisms as part of the process.

One mechanism for ensuring delivery is to apply an adaptive management approach, implemented for decades in the management of North American waterbirds (*e.g.* Nichols *et al.* 2007), but only recently applied in Europe to goose populations with particular management challenges (*e.g.* Madsen & Williams 2012; Johnson *et al.* 2016; Madsen *et al.* 2017). This approach provides a framework for decision-making in circumstances where there are major difficulties in deciding between options (for instance because of potentially conflicting management objectives). It is also robust to uncertainties about the biological system at the heart of the problem and with predicting the specific outcomes of management interventions. Because of its long history of application in North America, adaptive management has evolved a formal and structured process to reduce uncertainty by iterative monitoring, adjustment and by "learning by doing" in a way that improves management over time to hone in on the objectives set for the process (Nichols *et al.* 2007; Williams & Brown 2012). Its development has identified the core need to involve stakeholders to engage in the processes described above, to learn not to fear uncertainty, but to develop, test and implement actions, which once monitored and evaluated, provide insight for taking the process forward, thus working towards the effective collaborative management of challenging situations such as those created by urban geese. This is important in situations where contrasting cultural and political standpoints and values may provide apparently insuperable impediments to successful outcomes, but where an adaptive management framework can provide a democratic, open and accountable mechanism for resolving conflict Folke *et al.* 2005; Stringer *et al.* 2006; Reed 2008).

Some potential management approaches

Once geese have begun to create conflicts in an urban context, what management tools are available to deal with the conflict within the context of some form of management plan? There exist many guidelines (*e.g.* Gosser *et al.* 1997), but the management objectives and their effectiveness depend on the scale of the problem and the outcomes envisaged. However, interventions can be divided into those that can be implemented on a local scale, which are largely concerned with removing geese from a particular target area to remove local conflict, and those that tackle the issue at a population level. Implementation of local solutions is likely to simply relocate the problem elsewhere, rather than solving the conflict as a whole, so other lines of attack are necessary to deal with issues at the population scale (discussed later below).

Local scale solutions

Elimination of human provision of food

Many urban park and lake landscapes bring geese into close contact with humans, and the inescapable attraction to humans of feeding geese. Artificial feeding exacerbates problems by providing nutrition and energy without foraging effort/cost as well as enhancing loss of fear of humans. Eliminating such food sources is an obvious means to remove a source of nutrients/energy and cause of habituation, but may be unpopular with the public without adequate education campaigns. Conover (1999) found that methiocarb and dimethyl anthranilate cause short-term discomfort for birds and were potentially compounds that could be used to make geese avoid food handouts from humans, but there has been insufficient research to confirm whether this might be a viable option to dissuade geese from taking food from people.

Habitat management

Geese need space to land and take off; they are uncomfortable feeding in areas where their view of potential predators is poor and this is easily induced by increasing vegetation cover. Planting shrubs and small trees along lake shorelines and throughout adjacent open grassland feeding areas can be effective in creating areas for predators to hide in, which dissuades geese from using such areas (Conover 1987). Unfortunately, planting shrubs on a recreational field is neither practical nor appropriate and may have other consequences. In North America, crime rates in open urban spaces are correlated with visual depth created by vegetation cover (Cooper 1998), so public acceptance of such management may be subject to other considerations. Maintaining grass swards at 15 cm in length will reduce its attractiveness to feeding geese but may directly conflict with current public use and may still not deter some Canada Geese (Cooper 1998). Other methods used to make turf less attractive to feeding geese include reducing fertiliser use, cessation of watering and planting less palatable species (Washburn & Seamans 2012), or even eliminating grass by converting swards to unpalatable dicotyledonous species (*e.g.* Common Periwinkle *Vinca minor*, Japanese Pachysandra *Pachysandra terminalis*; or Ivy *Hedera helix*; Conover 1987, 1991), although such management may again conflict with local community objectives. In one study, 94% of goose damage complaints occurred during late spring and summer (brood-rearing and moulting periods), suggesting that habitat modification during this period offered greatest possibilities for limiting damage (Cooper 1998). However, such options are expensive, need long-term investment to be successful and are often less attractive to landowners than the trouble caused by the geese. Also, while such actions may be acceptable to private landowners, they may be less feasible on many public use areas.

Unimpeded access between terrestrial feeding areas and their open water refuge from threats in the terrestrial environment is highly favoured by goose species. Geese prefer leaving waterbodies by walking from the shoreline directly onto surrounding lawns or other habitats to graze, seeking an unobstructed view to remain vigilant for potential predators. Creating barriers

between these two important features of goose habitats, or other habitat modification to inhibit movement between them, reduces goose use of both feeding areas and open water. Discouragement of geese from using a water body can be achieved by cessation of mowing to the shoreline in conjunction with planting of shrubs, hedging and fence erection. Removal of islands and floating nest sites also discourages use during breeding and as loafing sites throughout the year. As an extreme measure, waterbodies (especially artificial ones) could be removed entirely, but such drastic management is also unlikely to be acceptable to local communities (Conover 1987). Alas, features making park grasslands and lakes attractive to geese are also often those that attract people to such urban recreational areas.

Fear-provoking stimuli to keep geese away

Scaring techniques to displace geese from their normal routine can also displace geese from sensitive land areas. This can be effective because rapidly moving unfamiliar objects can potentially pose a threat to survival, to which geese respond by flying elsewhere. Multiple costs to the geese (in terms of energy invested in flight and loss of feeding time in favoured habitats) mitigate against incurring such costs by avoiding such stimuli and shifting elsewhere. However, this only "works" as a management tool as long as geese recognise the stimulus as a threat, and the costs of avoiding that threat are less than those of feeding elsewhere; if they habituate to such a scaring device, it loses its effectiveness. Objects that are moved by the wind have been deployed because of their low maintenance (*e.g.* scarecrows or stripped plastic streamers, flags, Mylar tape, balloons, kites tied to stakes) and are popular, but generally only effective in the short-term because geese quickly learn that these devices pose no threat (Hygnstrom *et al.* 1994; Hadidian *et al.* 1997). Lasers have proved effective at moving Canada Geese from night roosts < 6 ha in size as long as there were no strong ambient lightings round about, but their effectiveness was short (< 5 days) and produced no long-term or large-scale changes in goose distribution (Sherman & Barras 2004). Loud scaring devices, especially screamer shells, may be successful in flushing birds and causing them to move to other locations (Aguilera *et al.* 1991). Effective devices include automatic propane gas cannons, air horns, screamer shells, shell crackers and other manually operated machines to create noise, all of which can be effective at scaring geese away from the immediate area. Propane gas canons should be set to fire irregularly every 10–20 min and moved every 2–3 days to avoid goose habituation. Manually operated explosive devices are most effective if fired up into the air above the heads of feeding geese. Goose alarm and pre-flight calls apparently can be extremely effective (Steen *et al.* 2015). One study of on-demand use of alarm/alert call playback showed long-term displacement from emerging crops and sewage treatment facilities by brood-rearing and moulting resident geese, with geese displaced in ≤ 4 days when these measures were coupled with screamer or banger shell reinforcement. There was no evidence of habituation within the 90 days of the study

(Whitford 2008). Successful application by an 83-year-old farmer, investing < 2 h of his time over the study reduced crop loss over 30–40 ha by 99.5% on using only 2 call units. However, this technique is only effective when applied persistently and used in combination with other devices (*e.g.* Mott & Timbrook 1988; Aguilera *et al.* 1991). Geese will habituate eventually to any stimulus which they realise ultimately offers no real threat, but these methods are generally highly effective if used in combination with other approaches and switched on a regular basis to avoid habituation. However, most of these methods, and the need for their constant modification, requires investment of substantial human labour which may tip the cost-benefit analysis of such applications. Furthermore, their efficacy can be limited in built-up areas where their disturbance effect may be as unpopular with human populations as with the geese themselves.

More effective at creating goose displacement is to employ methods that actively scare geese, although such stimuli again need to be persistent and focused to be effective and can be extremely labour intensive and thus economically expensive (Simonsen *et al.* 2016). The use of motorised vehicles, pursuit by radio-controlled aircraft, drones or trained birds of prey can be highly effective around airports, where teams of specialist workers coordinate a concentrated campaign (Bradbeer *et al.* 2017), but are totally uneconomical and less feasible for application in built-up residential areas. Geese also may habituate to such stimuli, so application of these techniques need to involve sophisticated coordination of operations to work consistently. Year-round, day-round harassment of Canada Geese by border collies proved effective at eliminating the geese from a 44 ha urban area of buildings, parking lots, a helipad and extensive areas of lawn surrounding a 1.7 ha pond (Castelli & Sleggs 2000). However, such approaches are only effective if geese are permanently moved away from the immediate area, rather than resorting unhelpfully to adjacent water. Combined use of border collies and remote-controlled boats was effective in removing more than 90% of geese in 97% of events in New York State, but radio tracking revealed that individuals showed very high affinities to hazing sites and were displaced relatively short distances, less than required to displace them into adjacent rural areas subject to hunting (Holevinski *et al.* 2007).

Non-lethal chemical repellents

Application of repellents to grass swards (*e.g.* methyl anthranilate or anthraquinone) has proved effective and relatively inexpensive at displacing geese at small spatial scales, but the technique requires frequent re-applications (*e.g.* Mason & Clark 1995; van Liere *et al.* 2009; Ayers *et al.* 2010). Inoculation of grasses with alkaloid-producing endophytic fungi has been successful in reducing non-native Canada Geese at New Zealand airports (Pennell & Rolston 2013) and perhaps holds promise for the future (Bradbeer *et al.* 2017), but as with all repellents, the method remains labour intensive to be effective.

Trapping for relocation

Live capture and translocation tend to be more publicly acceptable techniques for

dealing with excess numbers of urban geese than, for example, lethal methods of control, not least because such control often takes place within public view and needs tacit acceptance by the local community (Adams *et al.* 1987; Cooper 1987, 1991). Such procedures are also labour intensive and expensive, and become self-limiting as populations establish in other areas. Geese are most effectively captured during the approximate 3-week period in summer when they grow new primary feathers, are unable to fly and can be herded (with varying degrees of difficulty) on the water and on land, ultimately into corral traps. Translocation of adult and juvenile geese in family groups may alleviate nuisance problems at conflict sites and is most beneficial and cost effective when geese are translocated > 150 km from the capture site to areas with high hunting pressure in consecutive years (Holevinski *et al.* 2006). Current United States guidelines recommend moving free-flying nuisance Canada Geese > 320 km from their capture site to prevent them from returning (USDA 2016), although studies in Georgia showed distances half of this were effective in combination with local hunting at inhibiting return to conflict areas (Powell *et al.* 2004a). Adult birds are more likely to return to sites from which they have been relocated than are juveniles (Flockhart & Clark 2017).

Trapping for euthanasia

Hunting is rarely feasible in urban and suburban areas, with safety issues too great to permit implementation of such measures. Nevertheless, the physical removal of geese from an area where this is acceptable to the local community does represent a means of removing birds that have adapted to exploiting a specific mosaic of feeding opportunities, at least until further birds discover the same possibilities for survival and reproduction. Local population reduction may be achieved through a "welfare harvest" involving the discrete trapping of geese to be humanely and discretely killed, with the meat sent to a processing plant for distribution to qualifying institutions and welfare agencies, but such procedures are inevitably politically sensitive.

Population level regulation

Legal or licensed hunting

It may be possible to extend the degree of hunting on specific geese in specific areas, by increasing bag limits, extending the hunting season and relaxing restrictions on hunting methods (*e.g.* by allowing electronic luring devices, extending hunting hours, or resorting to other additional lethal methods of control). There is evidence that hunting and trapping with removal can reduce wildlife populations to levels below their theoretical carrying capacity (*e.g.* Conover 2001). However, in general, passive hunting has been shown to be ineffective under most circumstances, so it is better to implement some form of targeted hunting with population targets set within a meaningful management goal, if this is possible within existing legal frameworks, can be carried out without risk to people and protected wildlife and if the measure is implemented by consensus. However, implementation may be difficult, because in rural areas hunting may not be under the same direct scrutiny as in urban areas, where

many members of the public may consider control unethical or consider the geese part of nature and attractive features of local urban biodiversity. There are also clear issues associated with the safety of managing hunting in even semi-urban areas which are likely to make hunters reticent to undertake such activity. Undisturbed attainment of objectives are likely difficult in urban situations. Dunn & Jacobs (2000) found that liberalisation of the hunting season in urban Pennsylvania was not sufficient to control problems with urban geese, which required additional measures to resolve complaints. Capture and relocation of geese to other sites where hunting occurs may offer a solution (Powell *et al.* 2004b; Holevinski *et al.* 2006) although the jury is still out on this because in some cases relocation makes no difference to survival (*e.g.* Flockhart & Clark 2017). Implementation of September hunts seemed to redistribute the harvest but did not reduce survival for target populations of Canada Geese in Nebraska (Groepper *et al.* 2012). As in the case of trapping for euthanasia, hunting may be politically unacceptable as a means of reducing population size, but is the most effective method for reducing the numbers of individuals with experience of surviving and reproducing within an urban environment (*e.g.* Allan *et al.* 1995; Coluccy *et al.* 2004).

Addling, pricking and painting of eggs under licence

Destruction of goose nests results in females relaying, but coating eggs with white mineral or vegetable oil (Christens *et al.* 1995) is effective in preventing hatching, as is violently shaking eggs to kill embryos and pricking of eggs after which females continue unsuccessfully to incubate. However, all methods of reducing hatching success, no matter the nature of the technique, require disproportionate staff time to locate nests and carry out the necessary effective controls, which requires location of a sufficient proportion of the total nesting population to make them truly effective. These procedures may contribute to local success but are unlikely to be effective on the population scale.

Chemical contraception

Chemical contraception (for example Nicarbazin, see Bynum *et al.* 2005; Yoder *et al.* 2005) provides one publicly acceptable means of reducing overpopulated resident goose flocks (*e.g.* Stout *et al.* 1997), but the options are expensive and often difficult to target effectively to ensure adequate dosage (VerCauteren & Marks 2004).

Summing up

So how should we tackle the issue of urban geese? The simplest response is of course to simply accept them for what they are. Michelfelder (2003) suggested we should not see geese on golf courses as a problem at all, but accept their presence because we ourselves have created an environment highly suited to them. The adoption of the urban landscape by arctic-breeding geese (such as the Cacklers of Oregon and the Snow Geese of British Columbia) has brought these long-distance migratory birds into the hearts of our cities. Their presence is a source of wonder for many local residents and provides a means of communicating the value of nature to even

more people through education. The fact that these geese are making decisions to exploit such habitats (likely based on fitness consequences that accrue) also says much about the quality and the value of elements of the urban environment we have created. However, such pragmatism is unlikely to enjoy wide support across those segments of society upon which such urban geese may have an adverse impact. This is especially the case where increasing numbers of geese and general lack of natural population regulation means that the problem is a growing and expanding source of conflict to multiple sectors.

Any management action that causes mortality to urban geese can be controversial because it involves a diverse set of stakeholders, with differing values and sensitivities with regard to whether the geese constitute a problem and the suite of potential solutions to conflicts. Although a cull is very likely an unpalatable management activity to some stakeholders, it remains the most effective strategy to reduce, for example, overabundant resident Canada Geese in urban North American landscapes, both at the local level (by removing individuals that have a developed capacity to exploit a network of urban sites for food and protection) and at the population level (by reducing overall instantaneous population size and reducing its future reproductive capacity). If culls are not politically unacceptable, modelling has shown for urban Canada Geese that nest treatment would need to increase dramatically to compensate (Beston *et al.* 2016), requiring substantial investment in citizen engagement as well as professionals, to achieve sufficient nest treatment which is, in any case, substantially less effective at reducing population size than elevating current levels of adult morality. Even if such a strategy could be implemented, significant reduction in goose damage based on nest treatment alone would not be realised until several years after the nest treatment began. Additionally, the effectiveness of liberalised harvest regulations in reducing populations will decline as more land is developed and a greater proportion of the goose population is retained within urban areas, rendering them inaccessible to the hunting harvest. It is clear that hunting alone will not contribute to overall reductions in specific goose populations because geese are good at finding areas away from hunting pressure (Beaumont *et al.* 2013), so any attempt to increase hunting mortality will inevitably need to be highly targeted to be effective (Conover *et al.* 2015). In Europe, it is generally the case that urban goose populations are not subject to any hunting.

There are multiple major challenges to finding solutions to the issue of urban geese. Firstly, we know relatively little about the true scale of the problem in Europe, or of the population dynamics and behaviour of the geese, which are unlikely to be similar to equivalent rural populations of the same species (as shown from North American experience), so initiation of such basic studies remains a priority. Secondly, there is often a basic lack of understanding about the biology of geese amongst those charged with finding solutions, many of whom may be employed in park management and biodiversity conservation roles that may not always be appropriate for finding solutions to such

conflict. Thirdly, there remains a basic lack of understanding among biologists about the values and perceptions of urban geese among the wider public, many of whom hold strong (and often opposing) views about such birds. Hence, animal welfare interests tend to advocate what is argued to be more humane population control through egg addling rather than resort to approaches that enhance mortality to resolving conflict, while many wildlife managers would argue non-lethal methods have been tried and failed, especially reducing hatching rates, which neither work quickly nor effectively (Hadidian *et al.* 2000). As well as improving our knowledge of urban goose populations, we therefore also have much to learn about resolving conflict between humans with a legitimate stake in urban goose management, an arena where social scientists are increasingly needed to assist with identification and resolution of such conflicts. We need to begin this discussion and initiate the process soon.

Acknowledgements

Thanks to the many friends and colleagues who have kindly contributed the benefits of their knowledge to this review and to all those who have worked on and published in this research and management area. Thanks to Bradley Bales for his contribution to the 2015 Gram Slot conference that stimulated this analysis, Eileen Rees and the two very kind and helpful referees who provided suggestions for improvements on an earlier draft.

References

Adams, L.W., Rhodehamel, C.D. & McKegg, J.S. 1987. A strategy for managing urban waterfowl populations. *In* L.W. Adams & D.L. Leedy (eds.), *Integrating Man and Nature in the Metropolitan Environment*, p. 235. National Institute for Urban Wildlife, Columbia, Maryland, USA.

Aguilera, E., Knight, R.L. & Cummings, J.L. 1991. An evaluation of two hazing methods for urban Canada geese. *Wildlife Society Bulletin* 19: 32–35.

Alerstam, T. & Högstedt, G. 1982. Bird migration and reproduction in relation to habitats for survival and breeding. *Ornis Scandinavica* 13: 25–37.

Alerstam, T. & Lindström, Å. 1990. Optimal bird migration: the relative importance of time, energy, and safety. *In* E. Gwinner (ed.), *Bird Migration,* pp. 331–335. Springer, Berlin, Germany.

Allan, J.R., Kirby, J.S. & Feare, C.J. 1995. The biology of Canada Geese *Branta canadensis* in relation to the management of feral populations. *Wildlife Biology* 1: 129–143.

Armitage, D.R., Plummer, R., Berkes, F., Arthur, R.I., Charles, A.T., Davidson-Hunt, I.J., Diduck, A.P., Doubleday, N.C., Johnson, D.S., Marschke, M., McConney, P., Pinkerton, E. & Wollenberg, E.K. 2009. Adaptive co-management for social-ecological complexity. *Frontiers in Ecology and the Environment* 7: 95–102.

Ayers, C.R., Moorman, C.E., Deperno, C.S., Yelverton, F.H. & Wang, H.J. 2010. Effects of mowing on anthraquinone for deterrence of Canada Geese. *Journal of Wildlife Management* 74: 1863–1868.

Baldwin, A.H. 2004. Restoring complex vegetation in urban settings: the case of tidal freshwater marshes. *Urban Ecosystems* 7: 125–137.

Balkcom, G.D. 2010. Demographic parameters of rural and urban adult resident Canada Geese in Georgia. *Journal of Wildlife Management* 74: 120–123.

Beaumont, M., Rodrigue, J. & Giroux, J.F. 2013. Movements and habitat use by temperate-nesting Canada Geese during the postbreeding period in southern Quebec. *Avian Conservation and Ecology* 8(1): 3.

Berkes, F., Folke, C. & Colding, J. 2003. *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change*. Cambridge University Press, Cambridge, UK.

Beston, J.A., Nichols, T.C., Castelli, P.M. & Williams, C.K. 2014. Survival of Atlantic Flyway resident population Canada geese in New Jersey. *Journal of Wildlife Management* 78: 612–619.

Beston, J.A., Williams, C.K., Nichols, T.C. & Castelli, P.M. 2015. Survival and harvest of Atlantic Flyway resident population Canada Geese. *Wildlife Society Bulletin* 39: 583–592.

Beston, J.A., Williams, C.K., Nichols, T.C. & Castelli, P.M. 2016. A population model for management of Atlantic flyway resident population Canada geese. *Wildlife Society Bulletin* 40: 106–111.

Birch, S. & McCaskie, J. 1999. Shallow urban lakes: a challenge for lake management. *Hydrobiologia* 395: 365–378.

Bradbeer, D., Rosenquist, C., Christensen, T.K. & Fox, A.D. 2017. Crowded skies: conflicts between expanding goose populations and aviation safety. *Ambio* 46 (Supplement No. 2): 290–300.

Breault, A.M. & McKelvey, R.W. 1991. *Canada Geese in the Fraser Valley: a Problem Analysis*. Technical Report Series No. 133. Canadian Wildlife Service, Pacific and Yukon Region, Delta, British Columbia, Canada.

Brown, J.L. 2000. The influence of Coyotes on an urban Canada Goose population in the Chicago Metropolitan area. M.Sc. thesis, Ohio State University, Ohio, USA. Accessible at: http://lss.fnal.gov/archive/masters/fermilab-masters-2007-02.pdf (last accessed 1 September 2019).

Buij, R., Melman, T.C.D., Loonen, M.J.J.E. & Fox, A.D. 2017. Balancing ecosystem function, services and disservices resulting from expanding goose populations. *Ambio* 46 (Supplement No. 2): 300–318.

Bynum, K., Yoder, C., Eisemann, J.D., Johnston, J. & Miller, L. 2005. Development of Nicarbazin as a Reproductive Inhibitor for Resident Canada Geese. *In* D.L. Nolte & K.A. Fagerstone (eds.), *Proceedings of the 11th Wildlife Damage Management Conference*, pp. 179–189. Accessible at: https://digitalcommons.unl.edu/icwdm_wdmconfproc/101 (last accessed 1 September 2019).

Castelli, P.M. & Sleggs, S.E. 2000. Efficacy of border collies to control nuisance Canada geese. *Wildlife Society Bulletin*, 385–392.

Christens, E., Blokpoel, H., Rason, G. & Jarvie, S.W. 1995. Spraying white mineral oil on Canada goose eggs to prevent hatching. *Wildlife Society Bulletin* 23: 228–230.

Cline, M.L., Dugger, B.D., Paine, C.R., Thompson, J.D., Montgomery, R.A. & Dugger, K.M. 2004. Factors influencing nest survival of giant Canada geese in northeastern Illinois. *In* T.J. Moser, R.D. Lien, K.C. VerCauteren, K.F. Abraham, D.E. Anderson, J.G. Bruggink, J.M. Collucy, D.A. Graber, J.O. Leafloor, D.R. Luukkonen & R.E. Trost (eds.), *Proceedings of the 2003 International Canada Goose Symposium,* p. 84. Madison, Wisconsin, USA.

Coluccy, J.M., Drobney, R.D., Graber, D.A., Sheriff, S. L. & Witter, D. J. 2001. Attitudes of central Missouri residents toward local giant Canada geese and management alternatives. *Wildlife Society Bulletin* 29: 116–123.

Coluccy, J.M., Graber, D.A. & Drobney, R.D. 2004. Population model for giant Canada geese and implications for management. *In* T.J. Moser, R.D. Lien, K.C. VerCauteren, K.F. Abraham, D.E. Anderson, J.G. Bruggink, J.M. Collucy, D.A. Graber, J.O. Leafloor, D.R.

Luukkonen & R.E. Trost (eds.), *Proceedings of the 2003 International Canada Goose Symposium,* pp. 181–186. Madison, Wisconsin, USA.

Conover, M.R. 1987. The urban-suburban Canada Goose: an example of short-sighted management? *Proceedings of the Eastern Wildlife Damage Containment Conference* 3: 346. Accessible at: https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1010&context=ewdcc3 (last accessed 1 September 2019).

Conover, M.R. 1991. Herbivory by Canada geese: diet selection and effect on lawns. *Ecological Applications* 1: 231–236.

Conover, M.R. 1992. Ecological approach to managing problems caused by urban Canada geese. *In* J.E. Borrecco & R.E. Marsh (eds.), *Proceedings of the 15th Vertebrate Pest Conference*, pp. 110–111. University of California, Davis, California, USA.

Conover, M.R. 1999. Can waterfowl be taught to avoid food handouts through conditioned food aversions? *Wildlife Society Bulletin* 27: 160–166.

Conover, M.R. 2001. Effect of hunting and trapping on wildlife damage. *Wildlife Society Bulletin* 29: 521–532.

Conover, M.R. & Chasko, G.G. 1985. Nuisance Canada Goose problems in the eastern United States. *Wildlife Society Bulletin* 13: 228–233.

Conover, M.R. & Kania, G.S. 1991. Characteristics of feeding sites used by urban-suburban flocks of Canada geese in Connecticut. *Wildlife Society Bulletin* 19: 36–38.

Conover, M.R., Dinkins, J.B. & Ruzicka, R.E. 2015. Consequences of hunter harvest, winter weather, and increasing population size on survival of non migratory Canada geese in Connecticut. *Journal of Wildlife Management* 79: 1239–1245.

Cooper, J.A. 1987. The effectiveness of translocation control of Minneapolis-St. Paul Canada goose populations. *In* L.W. Adams & D.L. Leedy (eds.), *Integrating Man and Nature in the Metropolitan Environment,* pp. 169–171. National Institute for Urban Wildlife, Columbia, Maryland, USA.

Cooper, J.A. 1991. Canada Goose management at the Minneapolis-St. Paul international airport. *In* L.W. Adams & D.L. Leedy (eds.), *Wildlife Conservation in Metropolitan Environments,* pp. 175–183. National Institute for Urban Wildlife, Columbia, Maryland, USA.

Cooper, J.A. 1998. The potential for managing urban Canada geese by modifying habitat. *In* R.O. Baker & A.C. Crabb (eds.), *Proceedings of the 18th Vertebrate Pest Conference*, pp.18–25. University of California, Davis, California, USA. Accessible at: https://cloudfront.escholarship.org/dist/prd/content/qt4wp2s07n/qt4wp2s07n.pdf (last accessed 1 September 2019).

Delany, S. 1993. Introduced and escaped geese in Britain in summer 1991. *British Birds* 86: 591–599.

Dieter, R.A., Dieter, R.S., Dieter, R.A. & Gulliver, G. 2001. Zoonotic diseases: health aspects of Canadian geese. *International Journal of Circumpolar Health* 60: 676–684.

Ditchkoff, S.S., Saalfeld, S.T. & Gibson, C.J. 2006. Animal behavior in urban ecosystems: modifications due to human-induced stress. *Urban Ecosystems* 9: 5–12.

Dolbeer, R.A. 2009. Birds and aircraft-fighting for airspace in ever more crowded skies. *Human-Wildlife Conflicts* 3: 165–166.

Dolbeer, R.A., Wright, S.E. & Cleary, E.C. 2000. Ranking the hazard level of wildlife species to aviation. *Wildlife Society Bulletin* 28: 372–378.

Dorak, B.E., Ward, M.P., Eichholz, M.W., Washburn, B.E., Lyons, T.P. & Hagy, H.M. 2017. Survival and habitat selection of Canada Geese during autumn and winter in

metropolitan Chicago, USA. *Condor* 119: 787–799.

Dunn, J.P. & Jacobs, K.L. 2000. Special resident Canada goose hunting seasons in Pennsylvania – management implications for controlling resident Canada geese. *In* M.C. Brittingham, J. Kays & R. McPeake (eds.), *Proceedings of the 9th Wildlife Damage Management Conference,* pp. 322–336. State College, Pennsylvania, USA. http://digitalcommons.unl.edu/icwdm_wdmconfproc/45 (last accessed 22 May 2007).

Elmberg, J., Berg, C., Lerner, H., Waldenström, J. & Hessel, R. 2017. Potential disease transmission from wild geese and swans to livestock, poultry and humans: a review of the scientific literature from a One Health perspective. *Infection Ecology & Epidemiology* 7: 1.

Flockhart, D.T.T. & Clarke, J.B. 2017. Demographic consequences of translocation of overabundant Canada geese breeding in urban areas. *Wildlife Society Bulletin* 41: 231–239.

Folke, C., Hahn, T., Olsson, P. & Norberg, J. 2005. Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources* 30: 441–473.

Forbes, J.E. 1993. *Survey of Nuisance Urban Geese in the United States*. Great Plains Wildlife Damage Control Workshop Proceedings, Paper No. 334. Accessible at http://digitalcommons.unl.edu/gpwdcwp/334 (last accessed 25 May 2017).

Fox, A.D. & Kahlert, J. 1999. Adjustments to nitrogen metabolism during wing moult in greylag geese. *Functional Ecology* 13: 661–669.

Fox, A.D. & Madsen, J. 2017. Threatened species to super-abundance: The unexpected international implications of successful goose conservation. *Ambio* 46 (Supplement No. 2): 179–187.

Fox, A.D. & Abraham, K.F. 2017. Why geese benefit from the transition from natural to agricultural habitats. *Ambio* 46 (Supplement No. 2): 188–197.

Fox, A.D. & Leafloor, J.O. (eds.) 2018. *A Global Audit of the Status and Trends of Arctic and Northern Hemisphere Goose Populations*. Conservation of Arctic Flora and Fauna International Secretariat, Akureyri, Iceland.

Fox, A.D., Elmberg, J., Tombre, I. & Hessel, R. 2017. Agriculture and herbivorous waterfowl: a review of the scientific basis for improved management. *Biological Reviews* 92: 854–877.

Friend, M. (ed.) 1987. *Field Guide to Wildlife Diseases. Volume I: General Field Procedures and Diseases of Migratory Birds*. U.S. Fish and Wildlife Service Research Publication No. 167. U.S. Department of the Interior, Washington DC, USA.

Gomis, S., Didiiuk, A.B., Neufeld, J. & Wobeser, G. 1996. Renal coccidiosis and other parasitologic condition in lesser snow goose goslings at Tha-anne River, west coast Hudson Bay. *Journal of Wildlife Diseases* 32: 498–504.

Gorham, T.J. & Lee, J. 2015. Pathogen loadings from Canada Geese faeces in freshwater: potential risks to human health through recreational water exposure. *Zoonoses and Public Health* 63: 177–190.

Gosser, A. L., Conover, M.R. & Messmer, T.A. 1997. *Managing Problems Caused by Urban Canada Geese*. Berryman Institute Publication No. 13. Utah State University, Logan, USA. Accessible at https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=3309&context=wild_facpub (last accessed 1 September 2019).

Graczyk, T.K., Cranfield, M.R., Fayer, R., Tout, J. & Goodale, H.J. 1997. Infectivity of *Cryptosporidium parvum* oocysts is retained upon intestinal passage through migratory waterfowl species (Canada goose, *Branta canadensis*). *Tropical Medicine and International Health* 2: 342–347.

Green, R.E., Cornell, S.J., Scharlemann, J.P. & Balmford, A. 2005. Farming and the fate of wild nature. *Science* 307: 550–555.

Groepper, S.R., Gabig, P.J., Vrtiska, M.P., Gilsdorf, J.M., Hygnstrom, S.E. & Powell, L.A. 2008. Population and spatial dynamics of resident Canada Geese in southeastern Nebraska. *Human-Wildlife Conflicts* 2: 270–276.

Groepper, S.R., Vrtiska, M.P., Powell, L.A. & Hygnstrom, S.E. 2012. Evaluation of the effects of September hunting seasons on Canada geese in Nebraska. *Wildlife Society Bulletin* 36: 524–530.

Guerena, K.B., Castelli, P.M., Nichols, T.C. & Williams, C.K. 2014. Spatially-explicit land use effects on nesting of Atlantic Flyway resident Canada geese in New Jersey. *Wildlife Biology* 20: 115–122.

Guerena, K.B., Castelli, P.M., Nichols, T.C. & Williams, C.K. 2016. Factors influencing nest survival in resident Canada geese. *Journal of Wildlife Management* 80: 1022–1030.

Guth, B.D., Blankespoor, H.D., Reimink, R.L. & Johnson, W.C. 1979. Prevalence of dermatiti-producing schistosomes in natural bird populations of lower Michigan. *Proceedings of the Helminthological Society of Washington* 46: 58–63.

Hadidian, J., Hodge, G.R. & Grandy, J.W. (eds.) 1997. *Wild Neighbors: the Humane Approach to Living with Wildlife*. The Humane Society of the United States, Washington DC, USA.

Hadidian, J., Childs, M., Perry, N. & Lane, P. 2000. Resolving conflicts with Canada geese: an animal welfare perspective. *In* M.C. Brittingham, J. Kays & R. McPeake (eds.), *Proceedings of The Ninth Wildlife Damage Management Conference Proceedings,* pp. 293–299. Penn State University, Pennsylvania, USA.

Harrington, E.R. 2016. A comparative study of foraging behavior and disturbance regimes in urban versus agricultural habitats used by Cackling Geese wintering in the Willamette Valley, Oregon. M.Sc. thesis, Oregon State University, USA. Accessible at https://ir.library.oregonstate.edu/concern/graduate_thesis_or_dissertations/f4752m138 (last accessed 1 September 2019).

Hill, G.A. & Grimes, D.J. 1984. Seasonal study of a freshwater lake and migratory waterfowl for *Campylobacter jejuni* from migratory waterfowl. *Canadian Journal of Microbiology* 30: 845–849.

Holevinski, R.A., Malecki, R.A. & Curtis, P.D. 2006. Can hunting of translocated nuisance Canada geese reduce local conflicts? *Wildlife Society Bulletin* 34: 845–849.

Holevinski, R.A., Curtis, P.D. & Malecki, R.A. 2007. Hazing of Canada geese is unlikely to reduce nuisance populations in urban and suburban communities. *Human-Wildlife Conflicts* 1: 257–264.

Hsu, T.T.D., Mitsch, W.J., Martin, J.F. & Lee, J. 2017. Towards sustainable protection of public health: The role of an urban wetland as a frontline safeguard of pathogen and antibiotic resistance spread. *Ecological Engineering* 108: 547–555.

Hygnstrom, S.E., Timm, R.M. & Larsson, G.E. (eds.) 1994. *Prevention and Control of Wildlife Damage*. University of Nebraska Cooperative Extension Service, Lincoln, Nebraska, USA.

Jellison, K.L., Lynch, A.E. & Ziemann, J.M. 2009. Source tracking identifies deer and geese as vectors of human-infectious *Cryptosporidium* genotypes in an urban/suburban watershed. *Environmental Science and Technology* 43: 4267–4272.

Johnson, F.A., Alhainen, M., Fox, A.D. & Madsen, J. 2016. Development of an adaptive harvest management program for Taiga Bean Geese. African Eurasian Waterbird Agreement Technical Progress Summary, Ref. No. AEWA/EGM IWG

1.8. AEWA Secretariat, Bonn, Germany. Accessible at https://www.unep-aewa.org/sites/default/files/document/aewa_egm_iwg_1_8_tbg_ahmp.pdf (last accessed 1 September 2019).

Kassa, H., Harrington, B. & Bisesi, M.S. 2001. Risk of occupational exposure to Cryptosporidium, Giardia, and Campylobacter associated with the feces of Giant Canada Geese. *Applied Occupational and Environmental Hygiene* 16: 905–909.

Kassa, H., Harrington, B.J. & Bisesi, M.S. 2004. Cryptosporidiosis: A Brief Literature Review and Update Regarding Cryptosporidium in Feces of Canada Geese (*Branta canadensis*). *Journal of Environmental Health* 66: 34–40.

Kistler, W.M., Stallknecht, D.E., Deliberto, T.J., Swafford, S., Pedersen, K., van Why, K., Wolf, P.C., Hill, J.A., Bruning, D.L., Cumbee, J.C., Mickley, R.M., Betsill, C.W., Randall, A.R., Berghaus, R.D. & Yabsley, M.J. 2012. Antibodies to avian influenza viruses in Canada Geese (*Branta canadensis*): a potential surveillance tool? *Journal of Wildlife Diseases* 48: 1097–1101.

Kleinhenz, A. & Koenig, A. 2018. Home ranges and movements of resident graylag geese (*Anser anser*) in breeding and winter habitats in Bavaria, South Germany. *PLoS ONE* 13: e0202443.

Kokko H. 1999. Competition for early arrival in migratory birds. *Journal of Animal Ecology* 68: 940–950.

Kullas, H., Coles, M., Rhyan, J. & Clark, L. 2002. Prevalence of *Escherichia coli* serogroups and human virulence factors in faeces of urban Canada Geese (*Branta canadensis*). *International Journal of Environmental Health Research* 12: 153–162.

Luechtefeld, N.W., Blaser, M.J., Reller, L.B. & Wang, W.L.L. 1980. Isolation of *Campylobacter fetus* ssp. *jejuni* from migratory waterfowl. *Journal of Clinical Microbiology* 12: 406–408.

Luukkonen, D.R., Prince, H.H. & Mykut, R.C. 2008. Movements and survival of molt migrant Canada geese from southern Michigan. *Journal of Wildlife Management* 72: 449–462.

Madsen, J. & Andersson, A. 1990. Status and management of the Canada Goose *Branta canadensis* in Europe. *In* G.V.T. Matthews (ed.), *Managing Waterfowl Populations. Proceedings of the International Symposium on the Management Waterfowl Populations, Astrakhan 1989,* pp. 66–69. IWRB Special Publication No. 12. IWRB, Slimbridge, UK.

Madsen, J. & Williams, J.H. 2012. International species management plan for the Svalbard population of the Pink-footed Goose *Anser brachyrhynchus*. AWEA Technical Report No. 48. African-Eurasian Waterbird Agreement, Bonn, Germany.

Madsen, J., Williams, J.H., Johnson, F.A., Tombre, I.M., Dereliev, S. & Kuijken, E. 2017. Implementation of the first adaptive management plan for a European migratory waterbird population: The case of the Svalbard pink-footed goose *Anser brachyrhynchus*. *Ambio* 46 (Supplement No. 2): 275–289.

Mason, J.R. & Clark, L. 1995. Evaluation of methyl anthranilate and activated charcoal as Snow Goose grazing deterrents. *Crop Protection* 14: 467–469.

Michelfelder, D.P. 2003. Valuing wildlife populations in urban environments. *Journal of Social Philosophy* 34: 79–90.

Mini, A. E. 2012. The role of body size in the foraging strategies and management of avian herbivores: a comparison of Dusky Canada (*Branta canadensis occidentalis*) and Cackling Geese (*B. hutchinsii minima*) wintering in the Willamette Valley of Oregon. Unpublished Ph.D. thesis, Oregon State University, USA.

Moore, M.V., Zakova, P., Shaeffer, K.A. & Burton, R.P. 1998. Potential effects of

Canada geese and climate change on phosphorus inputs to suburban lakes of the northeastern USA. *Lake and Reservoir Management* 14: 52–59.

Mott, D.F. & Timbrook, S.K. 1988. Alleviating nuisance Canada goose problems with acoustical stimuli. *Vertebrate Pest Conference Proceedings* 13: 301–304.

Moul, I.E. & Elliott, J.E. 1994. The bird community found on golf courses in British Columbia. *Northwestern Naturalist* 75: 88–96

Nichols, J.D., Runge, M.C., Johnson, F.A. & Williams, B.K. 2007. Adaptive harvest management of North American waterfowl populations: A brief history and future prospects. *Journal of Ornithology* 148: 343–349.

Nürnberg, G.K. & LaZerte, B.D. 2016. Trophic state decrease after lanthanum-modified bentonite (Phoslock) application to a hyper-eutrophic polymictic urban lake frequented by Canada geese (*Branta canadensis*). *Lake and Reservoir Management* 32: 74–88.

Owen, M. 1971. The selection of feeding sites by white-fronted geese in winter. *Journal of Applied Ecology* 8: 905–917.

Pacha, R.E., Clark, G.W., Williams, E.A. & Carter, A.M. 1988. Migratory birds of central Washington as a reservoir for *Campylobacter jejuni*. *Canadian Journal of Microbiology* 34: 80–82.

Paulin, J.B. & Drake, D. 2003. *Positive Benefits and Negative Impacts of Canada Geese*. New Jersey Agricultural Experimental Station Rutgers Cooperative Research and Extension Fact Sheet No. FS1027. Rutgers, State University of New Jersey, New Brunswick, USA. Accessible at https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs141p2_018050.pdf (last accessed 1 September 2019).

Pennell, C.G.L. & Rolston, M.P. 2013. Avanex™ unique endophyte technology – Bird deterrent endophytic grass for amenity turf and airports. *In* D. Michalik, G. Millar, W. Badgery & K. Broadfoot (eds.), *Proceedings of the 22nd International Grassland Congress*, pp. 454–459. New South Wales Department of Primary Industries, Orange, Australia. Available at http://www.grassland.org.nz/publications/nzgrassland_publication_2590.pdf (last accessed 1 September 2019).

Powell, L.A., Vrtiska, M.P. & Lyman, N. 2004a. Survival rates and recovery distributions of Canada geese banded in Nebraska. *In* T.J. Moser, R.D. Lien, K.C. VerCauteren, K.F. Abraham, D.E. Andersen, J.G. Bruggink, J.M. Coluccy, D.A. Graber, J.O. Leafloor, D.R. Luukkonen & R.E. Trost (eds.), *Proceedings of the 2003 International Canada Goose Symposium,* pp. 60–65. Madison, Wisconsin, USA.

Powell, L.A., Conroy, M.J., Balkcom, K.S. & Caudell, J. 2004b Urban Canada Geese in Georgia: assessing a golf course survey and a nuisance relocation program. *In* T.J. Moser, R.D. Lien, K.C. VerCauteren, K.F. Abraham, D.E. Andersen, J.G. Bruggink, J.M. Coluccy, D.A. Graber, J.O. Leafloor, D.R. Luukkonen & R.E. Trost (eds.). *Proceedings of the 2003 International Canada Goose Symposium,* pp. 145–149. Madison, Wisconsin, USA.

Ray, J.D. & Miller, H.W. 1997. A concentration of small Canada geese in an urban setting at Lubbock, Texas. *The Southwestern Naturalist* 42: 68–73.

Reed, M.S. 2008. Stakeholder participation for environmental management: A literature review. *Biological Conservation* 141: 2417–2431.

Rosin, Z. M., Skórka, P., Wylegała, P., Krąkowski, B., Tobolka, M., Myczko, Ł., Spark, T.M. & Tryjanowski, P. 2012. Landscape structure, human disturbance and crop management affect foraging ground selection by migrating geese. *Journal of Ornithology* 153: 747–759.

Rutledge, M.E., Siletzky, R.M., Gu, W., Degernes, L.A., Moorman, C.E., DePerno, C.S. & Kathariou, S. 2013. Characterization of *Campylobacter* from resident Canada geese in

an urban environment. *Journal of Wildlife Diseases* 49: 1–9.

Rutledge, M.E., Moorman, C.E., Washburn, B.E. & Deperno, C.S. 2015. Evaluation of resident Canada goose movements to reduce the risk of goose-aircraft collisions at suburban airports. *Journal of Wildlife Management* 79: 1185–1191.

Saltoun, C.A., Harris, K.E., Mathisen, T.L. & Patterson, R. 2000. Hypersensitivity pneumonitis resulting from community exposure to Canada Goose droppings: When an external environment antigen becomes an indoor environmental antigen. *Annals of Allergy, Asthma and Immunology* 84: 84–86.

Scherer, N.M., Gibbons, H.L., Stoops, K.B. & Muller, M. 1995. Phosphorus loading of an urban lake by bird droppings. *Lake and Reservoir Management* 11: 317–327.

Sherman, D.E. & Barras, A.E. 2004. Efficacy of a laser device for hazing Canada Geese from urban areas of Northeast Ohio. *The Ohio Journal of Science* 104: 38–42.

Simonsen, C.E., Madsen, J., Tombre, I.M. & Nabe-Nielsen, J. 2016. Is it worthwhile scaring geese to alleviate damage to crops? – An experimental study. *Journal of Applied Ecology* 53: 916–924.

Skene, R.C., Remmler, O. & Fernando, M.A. 1981. Coccidia of Canada geese at Korthright Waterfowl Park, Guelph, Ontario, Canada, with a description of *Isopora anseris* n.sp. *Canadian Journal of Zoology* 59: 493–497.

Smith, A.E., Craven, S.R. & Curtis, P.D. 1999. *Managing Canada Geese in Urban Environments*. Jack Berryman Institute Publication No. 16. Cornell University Cooperative Extension, Ithaca, New York, USA.

Steen, K.A., Therkildsen, O.R., Karstoft, H. & Green, O. 2015. An adaptive scaring device. *International Journal of Sustainable Agricultural, Management and Informatics* 1: 130–141.

Stevick, P.F. 2017. Migration routes and stopovers of North Puget Sound Snow Geese. M.Sc. thesis, Evergreen State College, Olympia, Washington, USA. Accessible at http://archives.evergreen.edu/masterstheses/Accession86-10MES/Stevick_PFMESthesis2017.pdf (last accessed 1 September 2019).

Stout, R.J., Knuth, B.A. & Curtis, P.D. 1997. Preferences of suburban landowners for deer management techniques: A step towards better communication. *Wildlife Society Bulletin* 25: 348–359.

Stringer, L.C., Dougill, A.J., Fraser, E., Hubacek, K., Prell, C. & Reed, M.S. 2006. Unpacking "participation" in the adaptive management of social-ecological systems: A critical review. *Ecology and Society* 11: 39.

Tombre, I.M., Eythórsson, E. & Madsen, J. 2013. Stakeholder involvement in adaptive goose management; case studies and experiences from Norway. *Ornis Norvegica* 36: 17–24.

United States Department of Agriculture (USDA). 2016. *Wildlife Services Preventing and Managing Waterfowl Damage*. USDA/Animal and Plant Health Inspection Service (APHIS) Wildlife Services Factsheet. USDA, Washington DC, USA. Accessible at: https://www.aphis.usda.gov/publications/wildlife_damage/content/printable_version/fs_waterfowl.pdf (last accessed on 1 September 2019).

Väänänen, V.M., Nummi, P., Lehtiniemi, T., Luostarinen, V.M. & Mikkola-Roos, M. 2011. Habitat complementation in urban barnacle geese: from safe nesting islands to productive foraging lawns. *Boreal Environment Research* 16 (Supplement B): 26–34.

Van Liere, D.W., Van Eekeren, N.J.M. & Loonen, M.J.J.E. 2009. Feeding preferences in greylag geese and the effect of activated charcoal. *Journal of Wildlife Management* 73: 924–931.

VerCauteren, K.C. & Marks, D.R. 2004. Movements of urban Canada Geese:

implications for Nicarbazin treatment programs. *In* T.J. Moser, R.D. Lien, K.C. VerCauteren, K.F. Abraham, D.E. Andersen, J.G. Bruggink, J.M. Coluccy, D.A. Graber, J.O. Leafloor, D.R. Luukkonen & R.E. Trost (eds.), *Proceedings of the 2003 International Canada Goose Symposium*, pp. 151–156. Madison, Wisconsin, USA.

Washburn, B.E. & Seamans, T.W. 2012. Foraging preferences of Canada geese among turfgrasses: implications for reducing human-goose conflicts. *Journal of Wildlife Management* 76: 600–607.

Whitford, P.C. 2008. Successful use of alarm and alert calls to reduce emerging crop damage by resident Canada Geese near Horicon Marsh, Wisconsin. *In* R.M. Timm & M.B. Madon (eds.), *Proceedings of the 23rd Vertebrate Pest Conference*, pp. 74–79. University of California, Davis, California, USA.

Williams, B.K. & Brown, E.D. 2012. *Adaptive Management. The U.S. Department of the Interior Applications Guide.* U.S. Department of the Interior, Washington DC, USA.

Wobeser, G. & Brand, C.J. 1982. Chlamydiosis in two biologists investigating disease occurrence in wild waterfowl. *Wildlife Society Bulletin* 10: 170–172.

Yoder, C.A., Miller, L.A. & Bynum, K.S. 2005. Comparison of nicarbazin absorption in chickens, mallards, and Canada geese. *Poultry Science* 84: 1491–1494.

Zhang, Y., Fox, A.D., Cao, L., Jia, Q., Lu, C., Prins, H.H.T. & de Boer, W.F. 2019 Effects of ecological and anthropogenic factors on waterbird abundance at a Ramsar site in the Yangtze River floodplain. *Ambio* 48: 293–303.

Photograph: Greylag Geese grazing in front of the Landtag paraliament building in Stuttgart, Germany, by Friederike Woog.