UNIVERSITY OF CAPE TOWN

An experimental assessment of the efficacy of falconry to mitigate a human-wildlife conflict: Egyptian Geese *Alpochen aegyptiaca* on golf courses.

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Abstract

Human-wildlife conflicts are increasing globally and are believed to be one of the most prevalent and intractable issues that face conservation biologists today. One such conflict is found on golf courses, where high numbers of geese can come into conflict with residents and members. In South Africa, the indigenous Egyptian Goose *Alopochen aegyptiaca* population has increased dramatically over recent years and as a result they are often seen as nuisance animals whose population requires active management. Most non-lethal methods of goose control have had little success due to habituation to their presence, whilst the use of lethal methods are often deemed socially unacceptable. In this study we experimentally investigated the efficacy of falconry as a management tool to mitigate human-wildlife conflict. We hypothesised that the use of falconry would re-establish a landscape of fear, whereby habitat choice is influenced by the perceived fear of predation, resulting in the local departure of geese to a safer habitat, thereby reducing the population of geese to a tolerable level. Absolute counts of geese and analysis of vigilance levels were conducted at three golf courses in the Western Cape which included two control sites and a treatment site. The results of the experiment indicate that goose abundance declined by 73% at the treatment site after falconry was initiated, and that this was well over the losses due to direct predation. Vigilance levels increased by 76% during the treatment period, with no such changes observed at either control site. Additionally, vigilance was higher when filmed from a golf buggy compared to when filmed on foot, which may suggest the geese also learned to associate the golf buggy with the threat of predation, enhancing the overall efficacy of the falconry. While there is a relatively small lethal aspect to falconry, the results of this study confirm that a reduction in the population of geese can be achieved by simulating the naturally occurring non-lethal effects of predation that have been lost in some habitats, as a result of anthropogenic changes to the landscape. To our knowledge, this is the first truly experimental test of the efficacy of falconry to reduce nuisance birds and these important ecological findings have relevance for techniques that people deploy for dealing with human wildlife conflict, particularly where lethal options are unfavourable.

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Introduction

While the global human population is increasing and urban areas are rapidly expanding, natural areas available for native wildlife are decreasing (Chace & Walsh 2006; McKinney 2006; Elmqvist *et al.* 2013). These factors together with anthropogenic changes in the landscape are increasingly bringing wildlife into conflict with people (Conover 2002; Woodroffe, Thirgood & Rabinowitz 2005; Messmer 2009; Redpath *et al.* 2013). These conflicts, referred to as human-wildlife conflicts, are increasingly common (Conover & Decker 1991; Conover 2002), having recently been described as one of the most widespread and intractable issues facing conservation biologists (Treves & Karanth 2003; Dickman 2010; Redpath *et al.* 2013). Human-wildlife conflicts occur when humans or wildlife have an adverse effect on one or each other (Conover 2002; Woodroffe, Thirgood & Rabinowitz 2005;). These conflicts can be real or perceived (Messmer 2009) and can take many forms, from crop damage (Pimentel, Zuniga & Morrison 2005), to man-eating lions (Packer *et al.* 2005), crocodiles (Chomba *et al.* 2012) and tigers (Goodrich 2010). Their impacts can have detrimental economic, political or social consequences (Messmer 2009). How people perceive a human wildlife conflict is contingent upon their perspective of the natural world and their personal belief systems (Conover 2002; Messmer 2009).

Increasingly conservationists and wildlife managers are faced with difficult choices regarding effective ways to manage biodiversity, whilst simultaneously being conscious of the often legitimate needs and livelihoods of those involved in the conflict (Treves & Naughton-Treves 2005; Treves *et al.* 2006; Redpath *et al.* 2013). Optimizing the balance between the positive value of wildlife and potential negative perceptions that can sometimes arise is integral to wildlife damage management which is made profoundly difficult because the advantages and disadvantages of living with wildlife do not fall evenly upon everyone in society (Conover 2002). Additionally, the way in which a human-wildlife conflict and its impacts are managed can result in human-human conflicts known as conservation conflicts (White & Ward, Alastair 2010; Redpath *et al.* 2013). Conservation conflicts occur as a result of differences in stakeholder values and perceptions, and can often create barriers to the effective management of human-wildlife conflicts (Redpath *et al.* 2013). To reduce the impact of conservation conflicts, one needs to know how effective the different management approaches are for mitigating human-wildlife conflict, as well as how effective the process is for reducing human-human conflict and developing long term solutions (Redpath *et al.* 2013).

The conflict between Egyptian Geese (Alopochen aegyptiaca) and golf course managers in South Africa

Urban areas contain high densities of people, and many contemporary urban environments are also home to larger populations of wildlife which have been successful at exploiting the different resources that are provided by such environments (Messmer 2009). Some of these species may create a nuisance situation which affect human activities, or create perceived or real threats to human health and safety (Dickman 2010). The world is rapidly becoming increasingly urbanized, where almost half the world's population lives in urban areas, compared to just 13% at the beginning of the 20th Century (Cohen 2006). The rapidly expanding global population and the tendency towards urbanisation, as opposed to rural living, means that 60% of the land that will be urbanised by 2030 has yet to be built (Elmqvist *et al.* 2013). As a result of the movement of people into cities over the recent and coming decades, urban conservation conflicts are likely to increase (Redpath *et al.* 2013).

In South Africa, one such conflict exists between indigenous Egyptian Geese *Alopochen aegyptiaca* and the managers and users of golf courses (Little & Sutton 2013). The species is widespread throughout sub-Saharan Africa (Davies & Allan 2005) and whilst their range has remained the same in South Africa (McLachlan & Liversidge 1957; Hockey, Dean & Ryan 2005), the population has increased substantially in some areas, including the Western Cape, since the 1960s (Mangnall & Crowe 2001, 2002). These increases have largely been attributed to anthropomorphic alterations to the landscape, such as the expansion of cereal production and dam construction (Froneman *et al.* 2001; Mangnall & Crowe 2001).

In North America and Europe, problems associated with 'nuisance geese' are well documented (Hunt & Bell 1973; Conover & Chasko 1985; Madsen 1991; Vickery & Gill 1999). In South Africa, Egyptian Geese cause damage to crops and farmland, resulting in substantial economic losses (Mangnall & Crowe 2002). Their rapid population growth has led to an increase in the number of conflicts with people and human related activities, especially within urban and sub-urban landscapes (Mangnall & Crowe 2002; Stephen 2008; Cunningham & Hockey 2010). They are also increasingly perceived as nuisances on golf courses and in public parks (Stephen 2008; Cunningham & Hockey 2010; Little & Sutton 2013; Mackay *et al.* 2014). On golfing estates, the most commonly cited problems are the fouling and damage to greens, fairways and tee-boxes, harassment of native bird life and noise pollution (Cunningham & Hockey 2010; Little & Sutton 2013). These issues are similar to those cited as problems on golf courses in Europe (Sutherland & Allport 1991) and North America (Conover & Chasko 1985; Conover 2011; Washburn & Seamans 2012), where the most common problem species is the greater Canada goose *Branta Canadensis*.

Golf courses provide habitat features preferred by Egyptian Geese, including artificial water bodies with open shorelines and unobstructed views (Davies & Allan 2005), large expanses of irrigated grazing lawns and large trees (Froneman *et al.* 2001; Little & Sutton 2013). Additionally, golf courses provide a safer environment with a general lack of natural predators (Little & Sutton 2013); a phenomenon known to influence many native bird species in urban areas (Gering & Blair 1999; Anderies, Katti & Shochat 2007). As human development and pressure continues to alter and degrade natural wetlands, the safer, artificial wetland areas provided by golf courses have become increasingly attractive to water birds (White & Main 2005). In the Western Cape, Egyptian Geese are often found in excess of 100 individuals on any one golf course (Cunningham & Hockey 2010; Mackay *et al.* 2014), and on some golf courses as many as 800 individuals are common (pers comms Clemo 2014), increasing the likelihood they may become a nuisance.

Little and Sutton (2013) empirically assessed the perceptions towards Egyptian Geese by users and residents of a golf estate in the Western Cape. They concluded that geese were viewed as a nuisance by the majority of respondents with 84% of the respondents considering geese to be a problem and 87% felt that the population required active management with a reduction of at least 50% considered necessary.

Alternative goose control methods

In South Africa, and internationally, goose populations are actively controlled by the use of both lethal and non-lethal management practices which vary in their efficacy. Lethal measures include culling by shooting, destroying eggs and nests and poisoning. Non-lethal methods include the use of imitation owls or chemical repellents, relocating geese, or by hazing the geese. Hazing is the persistent harassment of geese, by chasing with dogs or motor vehicles, the use of pyrotechnics, remote controlled boats, strobe lights or distress calls (Conover & Chasko 1985; Aguilera, Knight & Cummings 1991; Cummings *et al.* 1991; Castelli & Sleggs 2000; Holevinski *et al.* 2006; Holevinski, Curtis & Malecki 2007; Stephen 2008).

Culling, relocating the geese and chasing with dogs have been cited as the most successful control measures on golf courses in the Western Cape (Cunningham & Hockey 2010). Although hazing/scaring techniques are often deemed more acceptable due to their non-lethality (Castelli & Sleggs 2000; Coluccy *et al.* 2001; Stephen 2008), habituation to hazing methods has been cited as a major inadequacy of such techniques (Aguilera, Knight & Cummings 1991; Holevinski, Curtis & Malecki 2007). Moreover, it has been suggested that hazing techniques are unlikely to reduce goose populations in urban and sub-urban communities because there will simply be a local redistribution effect (Holevinski, Curtis & Malecki 2007). Furthermore, due to the opportunistic behaviour of Egyptian Geese, they are likely to return following the cessation of any hazing efforts due to the favourable conditions presented by golf courses (Cunningham & Hockey 2010; Little & Sutton 2013). A summary of control techniques was published by Smith *et al.* (1999), who concluded that while population management by lethal means may be required for long term solutions, stakeholders and communities often find non-lethal methods more acceptable. They also concluded that due to the low mortality rate of adult birds and the increasingly favourable habitat conditions, geese populations are able to grow very large. As flock sizes increase the geese become more accustomed to human activity, reducing the efficacy of scaring devices (Smith *et al.* 1999).

Egyptian Geese on golf courses in Cape Town, South Africa, prefer areas on a golf course (so called hot spots) that are within 100 meters of the nearest water body and where open patches of lawn are greater than 1.5 ha in extent, allowing for an unobstructed field of view (Mackay *et al.* 2014). This habitat preference was believed to be because geese feel safer from potential predators in these more open habitats. This was supported by a vigilance experiment, where birds forced into non-hotspots were more vigilant than those within hotspots. Thus, fear of predation seems to play a role in the distribution of birds on a golf course. Based on these findings, one suggested approach, which may offer a long term solution is to redesign golf courses to make them less attractive to geese (Little & Sutton 2013; Mackay *et al.* 2014), by decreasing the amount and size of open space, and increasing the distance to water, whilst simultaneously using vegetation and structures that are attractive to other local bird species (Fox & Hockey 2007; Mackay *et al.* 2014).

Another technique that links to the findings of Mackay *et al.* (2013) involves using trained raptors flown at the geese on the golf course, thereby increasing the fear of predation, which should in theory increase vigilance rates and make the golf courses less desirable places for geese to occupy. This technique is still in its infancy but has been used on a few golf courses in both the Western Cape and near Durban, KwaZulu-Natal (B Hoffman pers comm). Thus, using falconry, as a goose hazing technique, could prove to be an effective method suitable for golf courses that require active management of their Egyptian Geese, whilst maintaining a largely non-lethal premise. However, its efficacy in this regard is yet to be evaluated.

Establishing a landscape of fear through falconry

Prey population densities can be reduced through direct consumption by predators and by non-lethal effects (Taylor 1984; Lima & Dill 1990; Lima 1993). Previous studies suggest that the non-consumptive, indirect effects of predation are widespread in the avian world (Lima 1993) and can have as great or greater an influence on populations as lethal effects (Lima & Dill 1990, Lima 1993; Lima 1998a; Cresswell 2008). The flexibility of prey behaviour (anti-predator decision making) in response to a changing risk of predation and the theory of the 'ecology of fear', predicts that the presence of predators in an ecosystem heavily influences prey behaviour and their presence in that system (Lima & Dill 1990; Lima 1998a; Brown 1999; Brown, Laundré & Gurung 1999). The ecology of fear and foraging theory predict that prey select an optimal baseline level of vigilance when there is no evidence of a predators presence and that this baseline level should balance optimal foraging levels, so as not to miss feeding opportunities with the ability to detect a predator to avoid predation (Macarthur & Pianka 1966; Brown 1999). Fear can be measured by levels of vigilance (Welp *et al.* 2004), thus the more fearful an animal is, the more vigilant it should be (Lima and Dill 1990; Brown 1999; Brown, Laundré & Gurung 1999; Laundré, Hernández & Altendorf 2001; Halofsky & Ripple 2008). These behavioural responses have been identified in many studies (Lima & Dill 1990; Lima 1998b; Caro 2005; Cresswell 2008).

In addition to the ecology of fear, the term landscapes of fear (Altendorf *et al.* 2001; Laundré, Hernández & Altendorf 2001; Laundré, Hernández & Ripple 2010) has been used to describe the spatial variation of predation risk in an animals' area of use, reflected in the varying levels of fear of predation (Laundré, Hernández & Altendorf 2001; Laundré, Hernández & Ripple 2010). In addition to predator detection behaviour through vigilance, prey have long been known to distance themselves from predators through predator induced habitat selection by avoiding areas of high predator density (Mech 1977; Edwards 1983; Ripple & Beschta 2003; Mao *et al.* 2005; Valeix *et al.* 2009) and by avoiding areas with high risk of attack by moving to an area deemed safer, even at the cost of good foraging opportunities (Hilton, Ruxton & Cresswell 1999; Walther & Gosler 2001; Whitfield 2003; Cresswell 2008; Cresswell & Whitfield 2008; Sansom *et al.* 2009). A strategy thought to be the most effective anti-predation behaviour (Sansom *et al.* 2009).

Flocking is another effective anti-predation strategy adopted by many species (Caraco 1981; Cresswell 1994; Forsman *et al.* 1998). The benefits of flocking for an individual's survival arise in three main ways: safety in numbers, known as the dilution effect (Hamilton 1971), the confusion effect experienced by an attacking predator as prey flee simultaneously (Neill & Cullen 1974), and the increased likelihood of detecting a predator because of increased group vigilance (Pulliam 1973). The mathematical model developed by Pulliam (1973) predicts a negative relationship between group size and vigilance rates. This relationship, known as the 'group-size effect on vigilance' (Elgar 1989) has been substantiated across a variety of taxa and has also been proven to occur in Egyptian Geese in South Africa (Mackay *et al.* 2014).

These predator-prey interactions are the premise of the management practice of using falconry to control pest animals/birds and it has been applied in a variety of residential and commercial settings globally, stemming from as early as the late 1940s (Wright 1963; Blokpoel & Tessier 1987; Erickson, Marsh & Salmon 1990; Baxter & Robinson 2007; Cook *et al.* 2008). However, the efficacy of falconry as a management tool has rarely been tested. One pseudo-experimental trial assessed a range of methods at multiple UK landfill sites to disperse gulls and corvids (Cook *et al.* 2008). Each trial consisted of a pre-treatment monitoring period of up to four weeks, followed by up to twelve weeks of monitoring during the treatment period, but with no spatially discrete control sites. The study concluded that while there were inter-specific differences in the responses of different bird species to a treatment type, distress calls, falconry (with falcons) and lethal and non-lethal use of ammunition were the most effective at deterring problem species from the landfill sites (Cook *et al.* 2008). Whilst pseudo-experimental studies such as these are more common, it is widely accepted that the strongest inferences come from manipulative experiments that consist of both treatment and control areas, the randomised assignment of treatment and control areas in addition to replication of treatment and control areas (Macnab 1983; Walters & Holling 1990; Johnson 2002; Reddiex & Forsyth 2006).The field of wildlife management has long been criticised for its reliance on descriptive/observational studies rather than experimental designs to examine the effects of management interventions (Walters & Green 1997; Johnson 2002; Reddiex & Forsyth 2006).

In this study, I undertook an experiment to test the efficacy of falconry as a technique to reduce Egyptian Geese numbers on a golf course in Cape Town, South Africa. I monitored geese at three golf courses within 15 km of each other in the Cape Town region before and after the use of falconry at one of these sites, with the two remaining sites acting as controls. I compared the numbers of geese counted at each of the sites, and measured their vigilance before and after the introduction of falconry. I used this experiment to test the hypothesis that the introduction of falconry to the experimental golf course would reduce the number of geese compared to the control sites and that this effect would be due, at least in part, to the non-lethal effect of predation. If this hypothesis is correct I predicted that the introduction of falconry would increase the vigilance of geese at the experimental site compared to vigilance levels at the control sites. Furthermore, because the raptors are flown from golf buggies I also predicted that the increase in vigilance levels would be more pronounced in the presence of a golf buggy, than at the control site where I expected no such change.

Lastly, previous studies have shown that predators can keep gregarious animals ‘healthy’ by reducing prey densities, and removing infected prey thus reducing the transmission of disease and parasites (Packer *et al.* 2003; Ostfeld & Holt 2004; Hatcher, Dick & Dunn 2006; Johnson *et al.* 2006). However, non-lethal effects of predators may alter their prey’s susceptibility to infection through behavioural changes such as feeding activity and movement, thus altering exposure to parasites and stress-induced, immunomodulation (Thiemann & Wassersug 2000; Werner & Peacor 2003; Raffel *et al.* 2010). The non-lethal effects of predators on prey susceptibility to parasite infection remains largely unknown (Raffel, Martin & Rohr 2008). Therefore the study additionally investigated the hypothesis that the immune-suppressive ability of geese may be compromised as a result of increased stress levels after exposure to falconry, resulting in increased susceptibility to infection by cecal worms as well as coccidian ssp at the experimental site.

Methods

Study sites

The study was conducted at three golf courses in the Western Cape (Figure 1). Two golf courses acted as control sites, where no falconry took place. The two control sites were Steenberg Golf Estate (34°04’07” S, 18°25’36” E) and Westlake Golf Club (34°08’0” S, 18°44’13” E). The treatment site[1] at which falconry was conducted was the Rondebosch Golf Club (33°57’25” S, 18°29’44” E). All sites were within 15 km of each other and are located in urban/sub-urban Cape Town, in the Western Cape, South Africa. Westlake and Steenberg golf courses are located within close proximity to the Zandvlei wetland, which acts as an important area of safety for roosting, breeding and moulting (Siegfried 1964; Ndlovu *et al.* 2013). Rondebosch golf course is located in the southern suburbs of Cape Town. It is intersected by the Swartrivier (Black River), and is close to other nearby golf courses including Mowbray, River Club and Royal Cape, as well as the Raapenberg bird sanctuary nature reserve and the decommissioned Athlone coal-fired power station, which all present suitable habitat for Egyptian Geese. The Golf courses occupy 50–60 ha on average (Fox & Hockey 2007). Golf was played daily from sunrise until sunset throughout the year on all of the courses.

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[1] The initial experimental design intended falconry being conducted at the Steenberg Golf Estate whilst Rondeboasch and Westlake Golf Clubs were originally intended to be the control sites. Due to unforeseen animal-rights objections, Raptor Force terminated their contract with Steenberg after only three days of falconry (during which 4 geese were killed) and took on Rondeboach Golf Club as their client. There were no observed changes in geese abundance or vigilance during the three days at Steenberg.

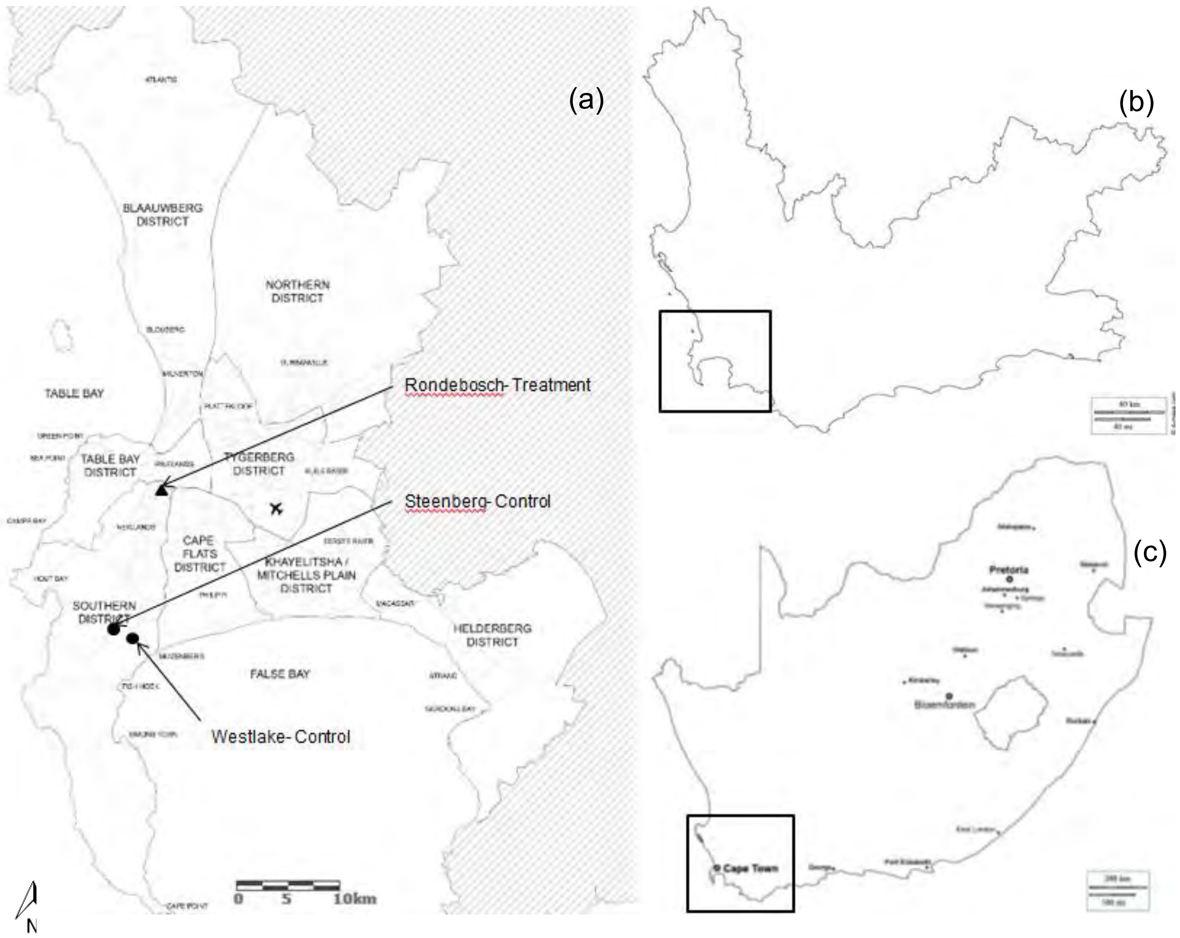

__Figure 1.__Locations of the two control sites (●) Steenberg Golf Estate (1) (34°04'07" S, 18°25'36" E) and Westlake Golf Club (2) (34°08'0" S, 18°44'13" E) and the treatment site at Rondebosch Golf Course (▲) (33°57'25" S, 18°29'44" E). All golf courses are located within 15km of each other in Cape Town (a) in the Western Cape (b). Also shown is the location of Cape Town within the broader context of South Africa (c).

Geese abundance counts

Absolute counts of Egyptian Geese on each course were conducted twice per week before midday, for 29 weeks, between mid-June 2014 and mid-January 2015. Geese were counted from a golf buggy along a pre-mapped route so as to avoid double counting. Groups were counted and their position on each fairway marked on a map of the course. A group was defined as all birds within 30 meters of one another. An effort was made to ensure counts were randomly spread throughout the morning, between 6am and 12pm and that the timing of counts was similar for each golf course (Table1). Total counts performed per golf course were 54 at Steenberg, 56 at Westlake and 60 at Rondebosch. Goslings were recorded but only adults were included in the final count data.

Vigilance behaviour monitoring

We recorded Egyptian Goose vigilance behaviour once per week for 26 weeks, at each golf course between mid-June 2014 and mid-January2015. A similar methodology to Mackay *et al.* (2014) was followed. Vigilance filming was conducted on groups of geese of three or more birds. One filming day took place per week at each golf course. On most occasions, each filming day consisted of five filming bouts (watch bouts), each of 15 minutes (Table 1). Different groups of geese were filmed for each of the five watch bouts so as to minimise pseudo-replication on any given filming day (Hurlbert 1984). Filming took place during the afternoons when the birds forage most actively (Halse 1985). Sleeping geese were not recorded. A Panasonic SDR-S50 video camera (Panasonic Corporation 1006, Oaza Kadoma, Kadoma-shi, Osaka 571-8501, Japan) mounted on a 1.7-m tripod was used to record footage of the geese. Mackay *et al.* (2004) performed preliminary observations of goose behaviour to determine the distance at which geese should optimally be filmed and found that geese did not respond to the presence of a human beyond 10 meters. Therefore the cameras and golf buggies were positioned at least 10 meters from the geese, so that the observer did not influence vigilance behaviour. For each watch bout, the observer filmed the geese either on foot or from the buggy. The filming was divided as evenly as possible between these two methods. The observer recorded the date, time and watch bout (1-5), in addition to the group size and the filming method for each watch bout.

Vigilance behaviour was characterized as visual scanning performed by the geese, which increases the probability of detecting predators (Dimond & Lazarus 1974). Thus, a goose was deemed vigilant if its head was above the level of its back and non-vigilant when its head was below body level, which is a suitable assumption considering the foraging strategy of Egyptian Geese (Barbosa 2002). Each watch-bout was paused at ten second intervals and the proportions of vigilant (heads up) geese and non-vigilant (heads down) geese within the frame were counted. For each watch bout, I calculated the sum of the number of vigilant and non-vigilant geese recorded which was used as our response variable in our subsequent data analyses. Additionally, I recorded the number of geese in the group (which may differ from the numbers being filmed at any one time of the watch bout). During the watch bout any disturbance to geese by golfers and or a golf buggy, lawn mowers and ground keeping staff were excluded. This helped to ensure that the vigilance levels of geese being examined reflected natural behaviour as opposed to vigilance initiated by human presence.

Table 1. Summary of the counts and vigilance data collection at each of the three golf courses during the study period. 'Before' refers to the period prior to any falconry treatment and 'after' refers to the period after the experimental falconry treatment – which occurred only at the Rondebosch site.

	Steenberg			***Westlake***			***Rondebosch***		
Data collection	*Before*	*After*	*Total*	*Before*	*After*	*Total*	*Before*	*After*	*Total*
Abundance									
Total counts	36	18	54	38	18	56	38	22	60
Counts 6 am - 9 am	3	10	13	3	9	12	3	12	15
Counts 9 am - 12pm	33	8	41	35	9	44	35	10	45
Vigilance									
Number of weeks	17	9	26	17	9	26	17	9	26
Number of watch bouts	80	42	122	70	37	107	71	66	137
Average group size filmed	10	13	-	14	20	-	10	6	-
Watch bouts 12 pm - 3 pm	22	73	95	28	59	87	28	59	87
Watch bouts 3 pm - 6pm	7	20	27	10	10	20	12	38	50

Parasite load analysis

According to Seivwright *et al.* (2004), faecal counts are often the only measure available to estimate parasite intensity in free-living animals and found faecal egg counts accurately estimated cecal worm intensities. Therefore, in order to investigate intestinal parasite (nemotodes and coccidia) load and patterns during the study period, 15 faecal samples were collected per golf course, per week. Collection began prior to falconry (mid-August 2014) and continued for the duration of the study. The freshest samples were chosen and where possible they were taken shortly after excretion; all samples were assumed to be no more than a day old (the golf course was 'cleaned' every morning using a lawn mower and drag mats). Psuedo-replication was avoided by sampling from different groups of geese in different areas of the golf course on the same day. Four gram faecal samples were collected in sealed sample jars and stored at four degrees centigrade before analysis. All samples were analysed within a 15 day period (Seivwright *et al.* 2004) for optimal results. Parasitological examinations of faecal samples were performed by the Western Cape Provincial Veterinary Laboratory, Stellenbosch (Helderfontein, Helshoogte Road, Stellenbosch. 7599) for both round worm eggs and coccidian oocysts using standard MacMaster slide methodology. Parasite prevalence was reported as round worm eggs per gram and coccidian oocysts per gram.

Falconry

The raptor used during falconry in this experiment was a Harris Hawk *Parabuteo unicinctus.* As this was intended, as far as possible, to be a non-lethal programme, the aim was not to kill, but to deter geese and the falconers were made aware of this. The falconry exercise was conducted by independent registered falconers (Mr Alan Clemo and Mr Hank Chalmers, from Raptor Force Pty). The experienced falconers and trained birds of prey are used to deter nuisance birds from a range of sites. The falconers undergo an apprenticeship into falconry, culminating in an internationally accepted grading, which is approved by the Cape Falconry Club, under the auspices of the provincial conservation agency (Cape Nature) and the South African Falconry Association.

Falconry was conducted for nine weeks, from 10 November 2014 until 10 January 2015 at the experimental site (Rondebosch Golf Club). The first month necessitated a relatively persistent presence of the hawk at the course. To achieve this, falconry took place for a minimum of one hour a day, five days a week for the first week, and less often thereafter (Figure 2). The hawk was always flown from a golf buggy. The handler and the hawk led in the front buggy, whilst the data recorder followed in a second buggy. The falconer approached the geese in the buggy and released the hawk (referred to hereafter as a slip) onto them from varying distances so as to avoid potential habituation. Target areas within the golf course were chosen according to where geese had been seen during counts, as well as to ensure comprehensive coverage of the entire golf course throughout the study period.

Data analysis

Statistical analyses were completed in the statistical package R version 3.1.2 (R Development Core Team 2014). Means are presented with upper and lower 95% confidence limits. No adjustments for multiple testing were made as the redundant pairwise comparisons were neither examined nor reported on.

Abundance

Count data (absolute counts of Egyptian Goose abundance) were analysed using a Generalised Linear Model (GLM) which was fitted with a poisson error distribution. I tested for significant differences between absolute counts of Egyptian Geese between sites, and for an interaction between site and goose counts before and after treatment, my prediction being that if falconry was effective, reductions in counts would be greater at the treatment site as compared to any background changes found at the control sites. The model therefore included the following fixed effect terms – site, treatment (2 level factor – before or after) and the interaction between site*treatment. Where a significant interaction was found, I used a pairwise comparison to test between sites before and after treatment, using the LSMeans package (Lenth 2015).

Vigilance

In all analyses of vigilance levels, I used a generalised linear mixed-effects (GLMM) model using the lme4 package in R (Bates et al 2014), fitted with a binomial error distribution. In all models, we controlled for the non-independence on records taken on the same day, by including the day on which filming took place at each site as a random effect. My binomial response variable was the sum of the number of vigilant geese and the number of non-vigilant geese for each watch bout. A previous analysis had shown an effect of group size on Egyptian Goose vigilance levels (Mackay *et al.* 2014). Therefore, before examining for an effect of treatment on vigilance levels I controlled for the initial group during each watch bout. As with my previous analysis (examining abundance) I used this GLMM to test whether vigilance differed at each site before or after the commencement of falconry, and the model therefore included the following fixed effect terms – site, treatment (2 level factor – before or after) and the interaction between site*treatment.

Because the hawks were flown at the geese from golf buggies, I predicted that the geese may associate the potential predation and become more vigilant around buggies. I therefore ran an additional analysis to determine if there was a difference between vigilance levels of geese at each site dependent on whether filming was recorded on foot or from a buggy, both before and after treatment. To do this I fitted a three-way interaction between site, treatment (before/after) and filming method (foot/buggy).

To explicitly examine the general relationship between vigilance and group size, data were subset to remove all data from the experimental site after falconry had begun. This was done because the introduction of falconry could, in theory, have an influence on this relationship. The model included the fixed effect term- group size and the same random effect term as above. I also subsequently explored whether falconry influenced the nature of this relationship. To do this I used a model using the full dataset and included the three-way interaction term site*group size* treatment (before/after).

Parasite prevalence

To investigate the prevalence of parasites in the faeces of Egyptian Geese, the results of the McMaster test which were zero-inflated and highly over dispersed, were converted to presence-absence data and analysed using a generalised linear model (glm), with a binomial error distribution. The binary specified response was interpreted as the probability of parasite infection. The model again included the following fixed effect terms – site, treatment (2 level factor – before or after) and the interaction between site*treatment. LS Means were used to generate the mean probability of infection from faecal samples taken both before and after treatment each site.

In all cases, p values < 0.05 are indicative of significance.

Results

Falconry

In total fatalities during the falconry period that contributed to this decline averaged nine geese per week for the first three weeks, and two geese per week for the remaining 7 weeks. There were a total of 41 goose fatalities during the 10 week study period (Figure 2).

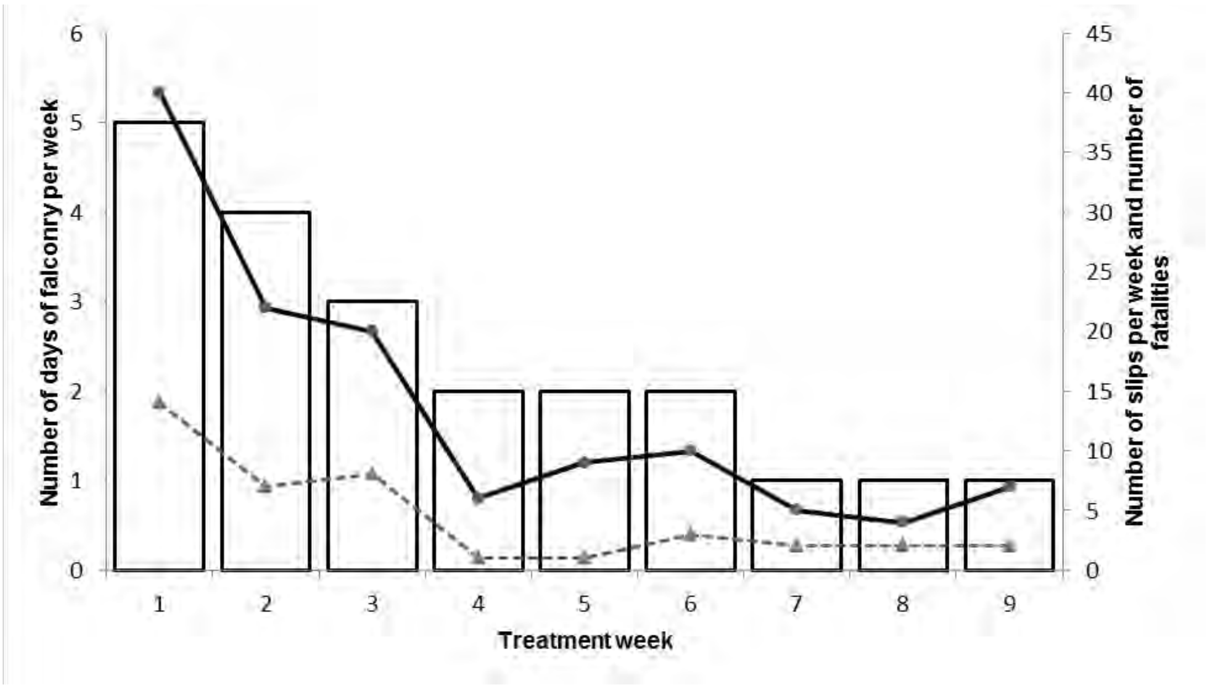

Figure 2. *The number of days per week that a Harris Hawk Parabuteo unicinctus was flown during the nine weeks between 10 November 2014 and 10 January 2015at the Rondebosch Golf Club, Cape Town, South Africa. Additionally, the total number of slips per week (—●—) and total the number of fatalities (- -▲ - -) per week are shown.*

Abundance

Before the implementation of falconry, numbers of geese at the three sites followed similar patterns of fluctuations, with numbers increasing particularly in late October into early November (Figure 3). However, during this pre-treatment period, there were fewer geese at the experimental site (Rondebosch) where numbers were generally around 50% lower than the other two control sites: mean abundance pre-treatment at Steenberg was 208 individuals (95% CL 203-213), at Westlake was 211 individuals (95% CL 207-216) and at Rondebosch 100 individuals (95% CL 97-103).

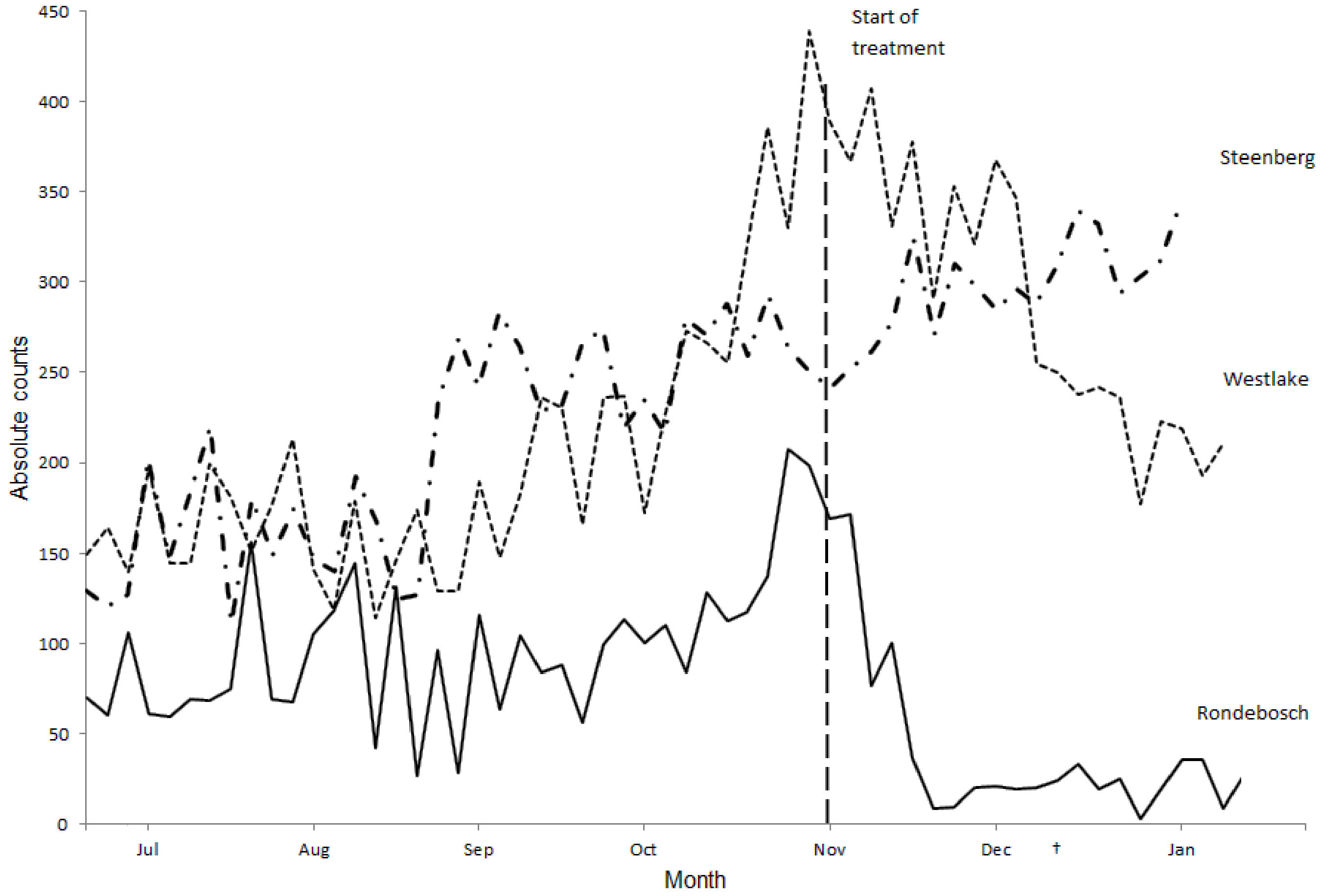

Figure 3. *Twice weekly absolute counts of Egyptian Geese at both control sites (dashed lines) and at the treatment site (solid line). The vertical dashed line depicts the start of the treatment period on the 10 November 2014. Falconry occurred at the treatment site only (solid line). † depicts 10th December, when a fence was built around the main pond at Westlake golf course.*

However following the introduction of falconry at the treatment site the mean abundance of geese for the month preceding the start of falconry fell rapidly from 148 geese to only eight geese within two weeks, and remained below 30 geese with a mean of 27 individuals throughout the experimental period.

Analysis of these count data suggested a significant interaction in the counts between sites before and after treatment, (χ^2 = 1691, $df_{2,164}$, p = <0.01). Further examination of the relationships (Figure 4) revealed a significant increase (Z = 19.7, p = <0.01) in the mean abundance of geese at Steenberg from 208 (95% CL 203-213) before the treatment period to 297 (95% CL 289- 304) after the treatment period, and also in the abundance at Westlake, from 211 (95% CL 207-216) before the treatment period to 280 (95% CL 272-288), after the treatment period (Z= 15.6, p= <0.01). Conversely, at the treatment site there was a significant decrease (Z = -29.7, p = <0.01) in the mean abundance of geese from 100 individuals (95%

CL 97-103) before the treatment period to 27 individuals (95% CL 25-29) after treatment, representing a reduction in the mean abundance of c. 73%.

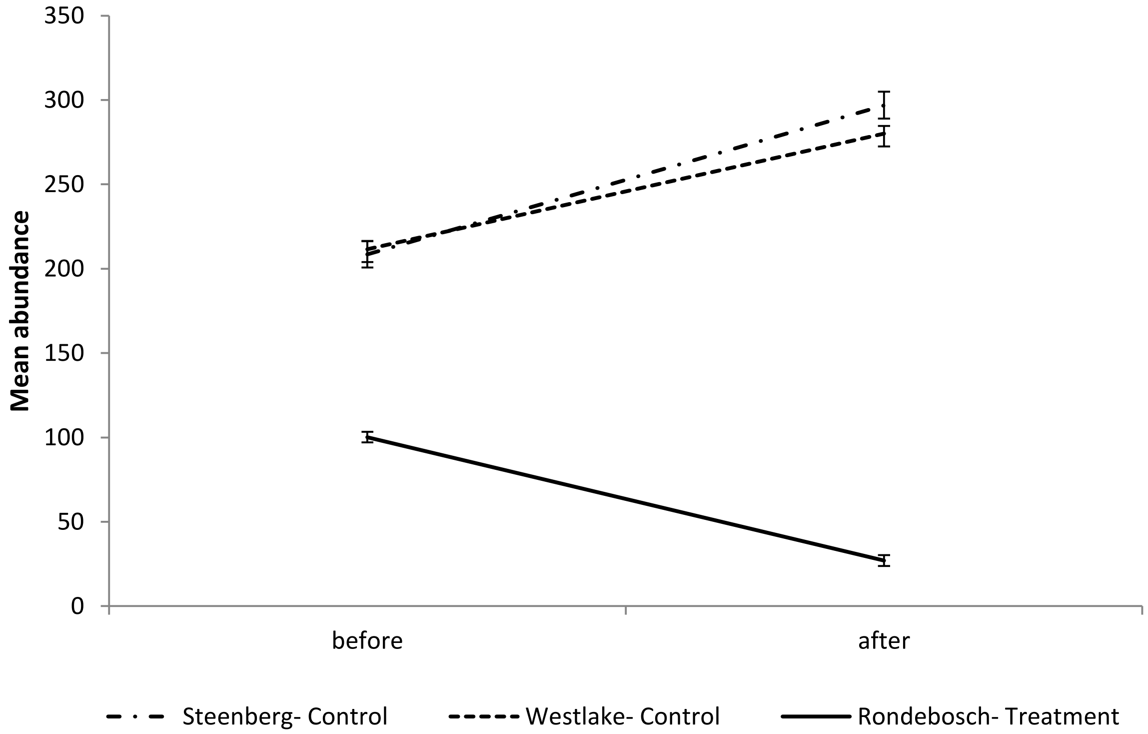

__Figure 4.__ Mean abundance of Egyptian Geese before and after the introduction of falconry (treatment period) at both control sites (dashed lines) and at the treatment site (solid line). The means and their 95% confidence limits depicted are the results of a general linear model. The interaction between site and treatment (before/after) was significant (p = <0.01).

During the treatment period a decline was also noticed at Westlake starting in early December, however unlike abundance at our treatment site, this decline did not result in counts being any lower than that found during the pre-treatment period, suggesting numbers stayed within the range of natural variation found at these control sites.

Vigilance

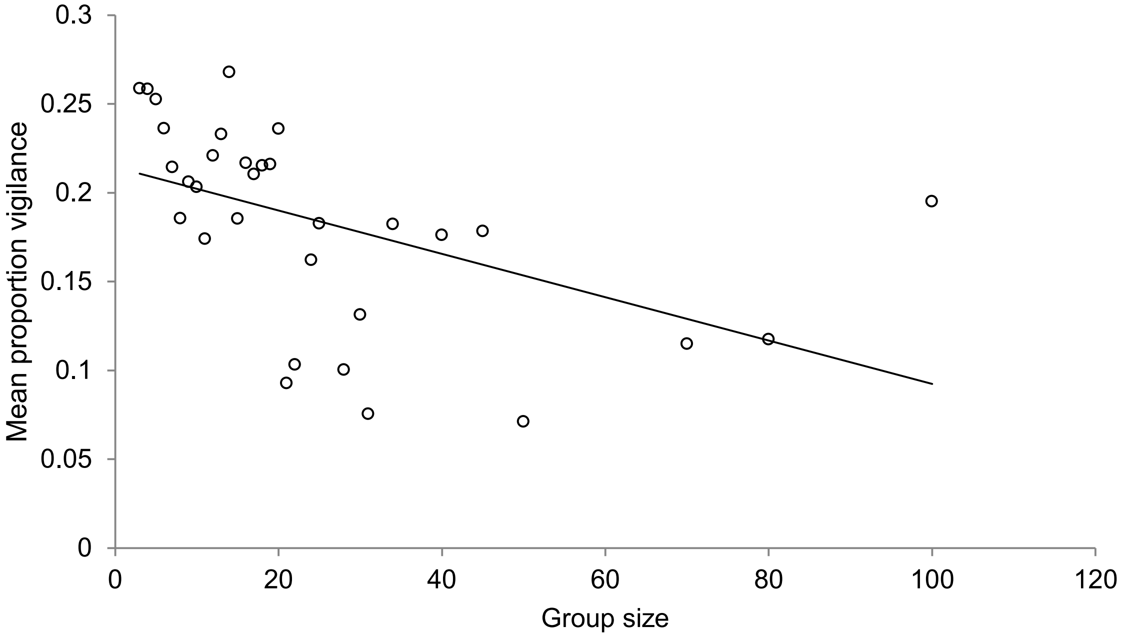

Figure 5. *The group-size effect on vigilance levels. Data points represent average vigilance per group size during the pre-treatment period from each site. The relationship is significant (p=<0.01)*

Previous research demonstrated a negative relationship between vigilance and the group size of Egyptian Geese (Mackay *et al.* 2014). Using only control data, I investigated the relationship with group size for which, as predicted, a significant decrease in vigilance was apparent (χ^2 = 11.8, $df_{1,297}$, *p* = <0.01) (Figure 5). After controlling for the influence of group size, there was a significant interaction between site and treatment (χ^2 = 32.5, $df_{2,358}$, *p* = <0.01) on the mean proportion of vigilant geese (Figure 6). Exploring this further we found that as predicted, there was a significant 76% increase in mean vigilance at Rondebosch (Z = 5.6, *p* = <0.01), from 0.209 (95% CL 0.178-0.244) before the treatment period, to 0.369 (95% CL 0.324-0.416), which is equivalent to a c. 76% increase in mean proportion of vigilant geese. Conversely there was a significant decrease (Z = -2.3, *p* = 0.02) in vigilance at the Steenberg control site from a mean of 0.198 (95% CL 0.170-0.230) to a mean of 0.145 (95% CL 0.116-0.180) and a non-significant decrease in vigilance at Westlake (Z = -0.5, *p* = 0.63) from 0.161 (95% CL 0.135-0.188) to 0.150 (95% CL 0.120-0.188) afterwards.

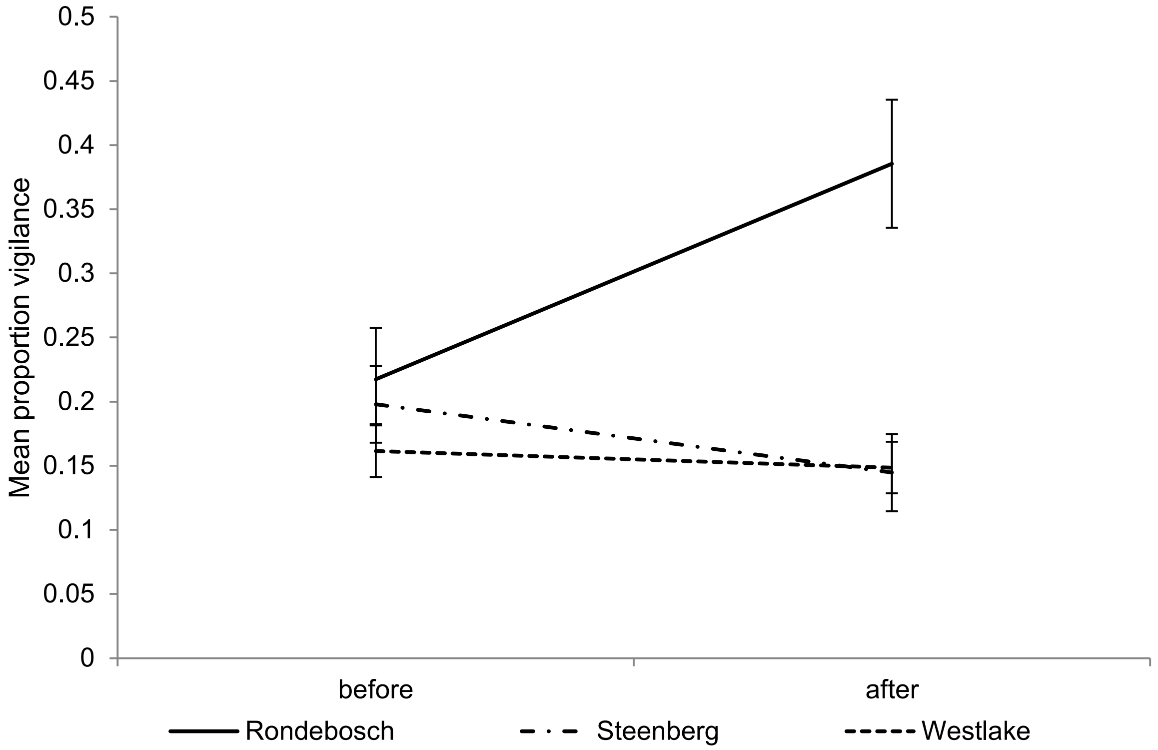

Figure 6. *Mean proportion vigilance for Egyptian Geese before and after the treatment period (introduction of falconry at Rondebosch only) at both control sites (dashed lines) and the treatment site (solid line). The means and their 95% confidence limits depicted are the results of a generalised linear model. The interaction between site and treatment (before and after) was significant (p = <0.01). The effect of group size and for random variations between watch days was controlled for.*

Does falconry increase vigilance around buggies

In addition to increased levels of vigilance exhibited by Egyptian Geese in response to falconry at the treatment site, I tested the hypothesis that Egyptian Geese, would exhibit higher vigilance levels when the recorder filmed from a buggy compared to when filmed on foot, as a result of associating the buggy with a potential threat. The three way interaction between site, treatment period (before/after) and filming method (on foot or by buggy) revealed that there was a significant difference in the relationship between sites ($\chi^2 = 504.3$, df $_{2,353}$, $p = <0.01$).

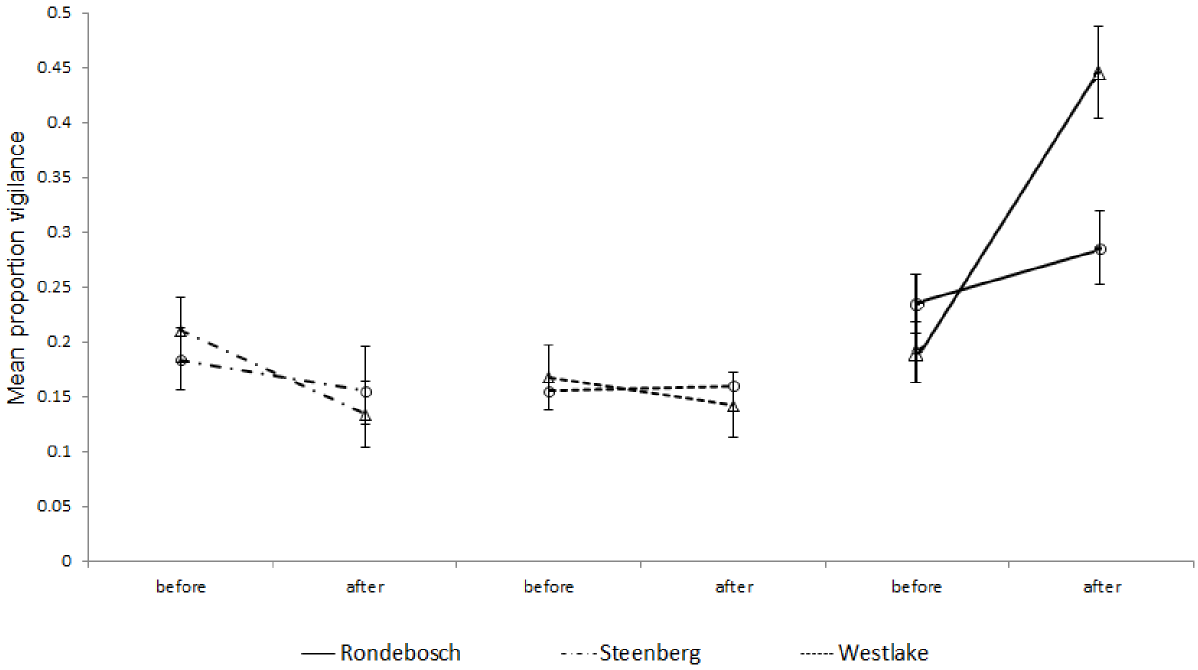

Figure 7. *Mean proportion vigilance for Egyptian Geese before and after the treatment period (introduction of falconry at Rondebosch only) at both control sites (dashed lines) and the treatment site (solid lines). Vigilance levels when filmed on foot (open circles) compared to when filmed by buggy (open triangles) are contrasted for each site. The means and their 95% confidence limits depicted are the results of a generalised linear model. The interaction between site, before/after treatment and by buggy/on foot was significant (p= <0.01). The effect of group size and for random variations between watch days was controlled for.*

Further examination of the effect of the interaction (Figure 7 and Table 2) revealed that at both control sites, there was no significant difference between vigilance before and after treatment when filmed on foot, whereas at the experimental site- Rondebosch, there was an increase in vigilance after treatment, which was near significant (Z = 1.749, *p* = 0.080). There was a significant decrease in vigilance when filmed from the buggy at Steenberg after the treatment period compared to before the treatment period (Z = -3.3, *p* = <0.01). Similarly, there is also a decrease in vigilance after the treatment period at Westlake when filmed from the buggy, though not significant (Z = -1.1, *p* = 0.27). In contrast, there was a pronounced increase in vigilance after the treatment period when filmed from the buggy at the experimental site. Additionally, at the treatment sites prior to the introduction of falconry, vigilance was significantly lower when filmed from a buggy 0.187 (95% CL 0.158-0.220) than from on foot 0.236 (95% CL 0.201-0.270) (Z= -8.7, *p*= <0.01). After treatment however, vigilance 0.452 (95% CL 0.403-0.50) is significantly greater (Z= 24, *p*= <0.01) when filmed by buggy than the mean filmed on foot 0.285 (95% CL 0.245-0.270).

Table 2. Comparison of the mean proportion vigilance of Egyptian Geese for both filming methods (on foot and by buggy), at each of the three golf courses during the study period. Confidence intervals (95%) are presented, as are the parameter estimates and significance values of pairwise contrasts. 'Before' refers to the period prior to any falconry treatment and 'after' refers to the period after the experimental falconry treatment – which occurred only at the Rondebosch site.

			On Foot			
	before		after		before - after	
Site	**Mean vig**	**95%CI**	**Mean vig**	**95%CI**	**Z ratio**	***p* Value**
Steenberg	0.184	0.157-0.210	0.156	0.124-0.190	-1.2	0.22
Westlake	0.155	0.130-0.180	0.161	0.123-0.200	0.2	0.83
Rondebosch	0.236	0.201-0.270	0.285	0.245-0.330	1.8	0.08
			By Buggy			
	before		**after**		**before - after**	
Site	**Mean vig**	**95%CI**	**Mean vig**	**95%CI**	**Z ratio**	***p* Value**
Steenberg	0.211	0.181-0.240	0.135	0.107-0.170	-3.3	<0.01
Westlake	0.168	0.141-0.200	0.142	0.111-0.180	-1.1	0.27
Rondebosch	0.187	0.156-0.220	0.452	0.403-0.500	8.8	<.01

The group size effect on vigilance

I tested whether falconry had any influence on the observed group size effect on vigilance (Figure 8), using data subset by site I included the interaction term- group size*treatment (before/after). There was a significant interaction only for the treatment site (χ^2 = 310.2, $df_{1,132}$, p = <0.01) (Figure 8 (a)). Investigating this further revealed that there was a significant change in the relationship with group size from a negative to a positive relationship (Z = 8.1, p = <0.01). Thus, during the treatment period, vigilance increased with increasing group size. Conversely at Steenberg (Figure 8 (b)), whilst the relationship differs, the interaction was not significant (χ^2 = 3.5, $df_{1,117}$, p = 0.06), indicating the values are largely within the same range. At Westlake (figure 8 (c)), while the relationship was significant, vigilance decreases with increasing group size during both the pre-treatment and the treatment period (χ^2 = 3.9, df $_{1,100}$, p = 0.05).

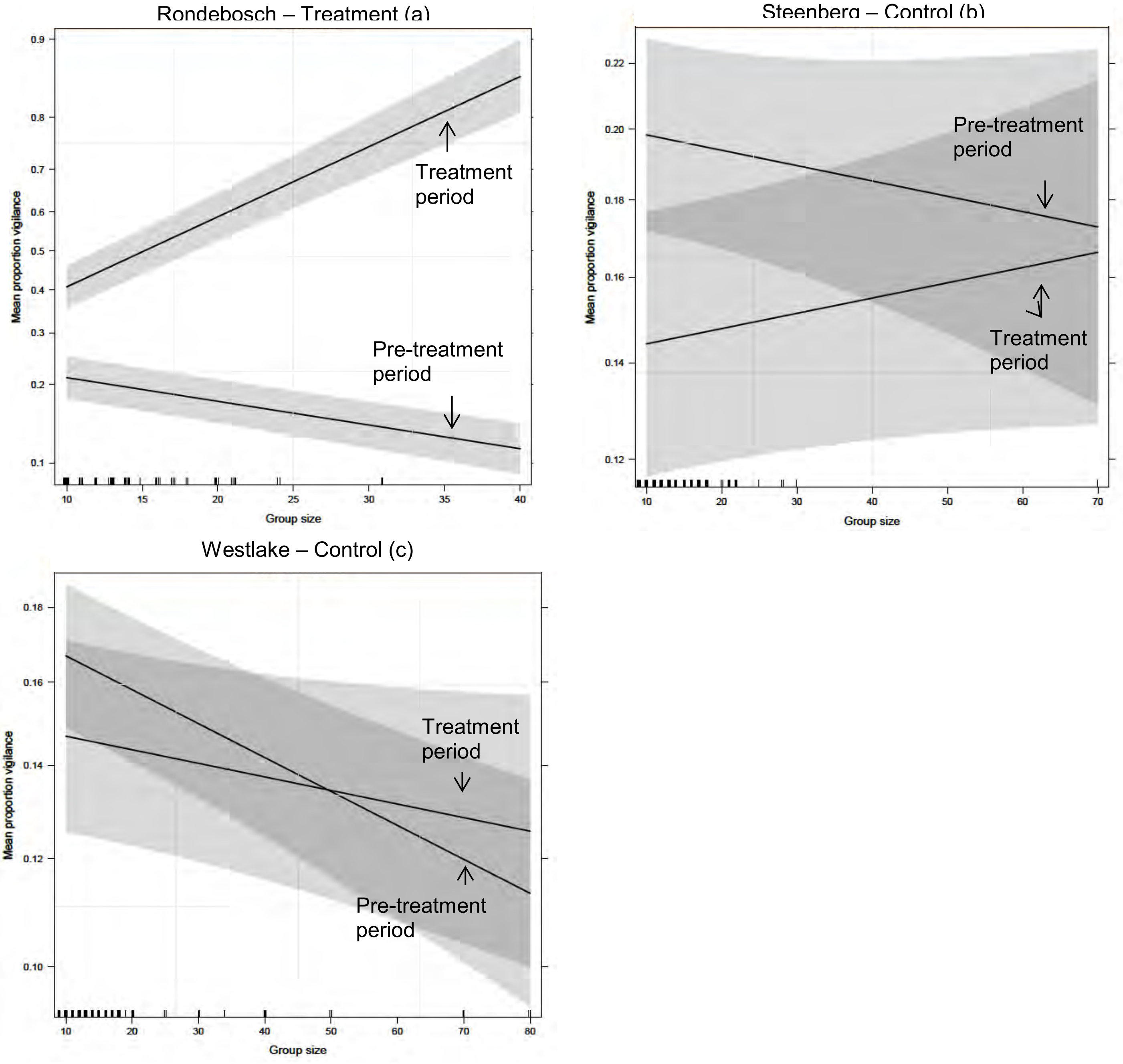

Figure 8. *Interaction effect of treatment period on the group size effect on vigilance levels at Rondebosch-Treatment (a), Steenberg- Control (b) and Westlake- Contol (c). Results are based on a generalised linear mixed model with the interaction term group size*treatment period (before or after) at each site, controlling for random variations between watch days. The slopes of the relationships are presented with their 95% Confidence Intervals.*

Parasite prevalence

Of the total number of samples collected and analysed for parasites (Table 3) only c. 5% and c. 6% of the Rondebosch samples contained parasites before and after treatment respectively. At Steenberg, c. 12% of the samples contained parasites before and only c. 4% after treatment. The fewest samples that were found to contain parasites were from Westlake with only c. 3% before and after treatment.

Table 3. The total number of faecal samples collected from each golf course during the before and after treatment phases and the number of samples that were found to contain parasites.

	Rondebosch		Steenberg		Westlake	
	before	after	before	after	before	after
Samples containing round worm eggs	2	1	6	4	3	1
Samples containing coccidia oocysts	6	7	14	1	1	3
Total faecal samples analysed	150	130	165	130	135	130

I tested whether falconry had any influence on the prevalence of parasites, using data subset by round worm infection and coccidian infection. I included the fixed effect terms – site, treatment (2 level factor – before or after) and the interaction between site*treatment. There was no significant difference detected in the mean probability of infection by round worm eggs in the geese faeces before treatment compared to after treatment at any of the golf courses ($\chi^2 = 0.5$, df $_{2,834}$, $p = 0.78$) (Figure 9).

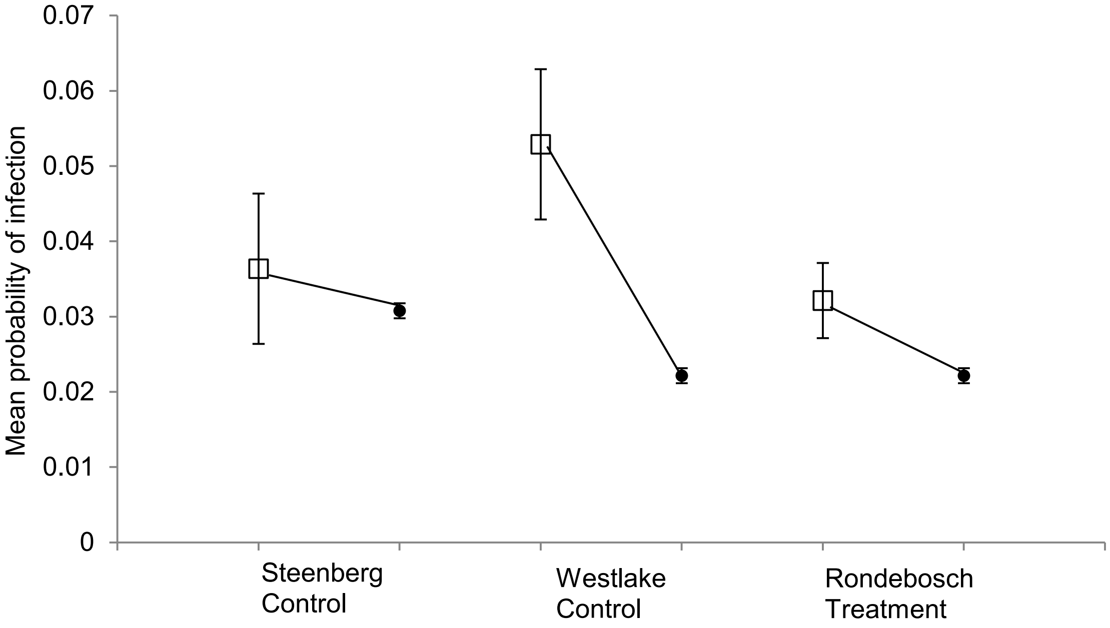

Figure 9.*Mean probability of infection by round worm eggs at each site before (□) and after (●) treatment. Results are based on a generalised linear model with the interaction term group size*treatment period (before or after) at each site with a binary specified response.*

There was a significant difference detected in the mean probability of infection by coccidian oocysts for the interaction between site and treatment ($\chi^2 = 10.7$, df $_{2,834}$, p = <0.01) (Figure 10). However, further examination of the result revealed no significant difference in the probability of infection at the treatment site ($Z = 0.5$, $p = 0.58$), nor at Westlake (control) ($Z = 0.9$, $p = 0.32$). There was a significantly lower probability of infection by coccidian oocysts after treatment at Steenberg (control) than before treatment ($Z = -2.4$, $p = 0.01$).

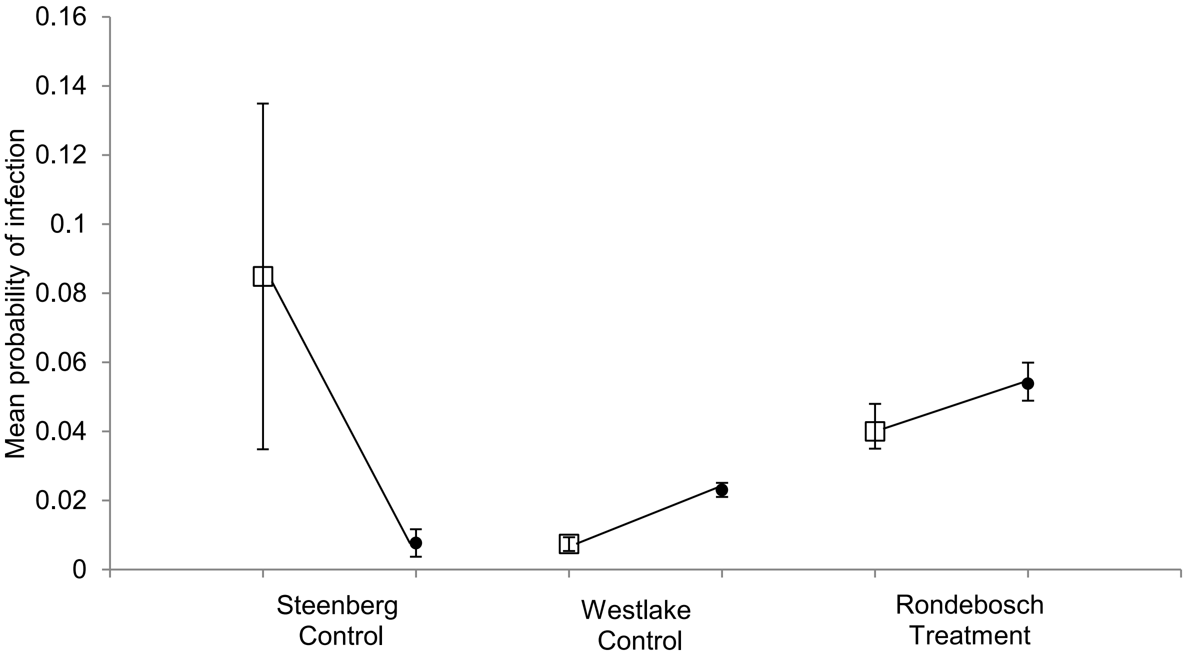

Figure 10. *Mean probability of infection by coccidian oocysts at each site before (□) and after (●) treatment. Results are based on a generalised linear model with the interaction term group size*treatment period (before or after) at each site with a binary specified response.*

Discussion

This study experimentally investigated the efficacy of falconry as a management tool to control nuisance populations of Egyptian Geese on golf courses by reducing the goose population on the golf course to a tolerable number. The intention was not to eradicate the geese from the golf course entirely. The hypothesis that the introduction of falconry would result in a decrease in the abundance of geese at the experimental golf course and not at the control sites was supported by the study. The results confirm a marked reduction in the abundance of geese at the treatment site after the onset of falconry while an overall increase in mean abundance was observed at both of the control sites. There was no indication that the decrease in abundance at the treatment site was mirrored by increases at the two control sites, as the majority of this increase had occurred prior to the treatment period, suggesting that these increases were unlikely to be as a consequence of birds moving from the treatment site. It was further hypothesised that the decrease in Egyptian Goose abundance would be over and above the effect of lethal predation and that this could be attributed to the non-lethal effects of predation. The results of the support this prediction as the reduction of on average 73 birds is almost double the numbers killed by the hawks alone (n=41). The hypothesis that the introduction of falconry would increase the vigilance of geese at the experimental site compared to vigilance levels at the control sites as a result of increased fear of predation and the prediction that increases in vigilance would be more pronounced in the presence of a golf buggy were also supported by the study. The results of the experiment additionally show that while the group size effect on vigilance is apparent during the control period, the opposite relationship is detected for the geese exposed to falconry, with vigilance increasing with group size. Lastly, the results of the study did not support the hypothesis that an increased level of fear and thus stress in Egyptian Geese would result in an increase in susceptibility to parasite infection as there was no observed increase in parasite load at any of the study sites.

Abundance

Predator avoidance behaviour, whereby individuals prefer to forage in areas with low predator presence, results in an overall redistribution of the population to less risky areas (Brown 1999; Brown, Laundré & Gurung 1999) and has been documented in a number of studies (Mech 1977; Edwards 1983; Ripple & Beschta 2003; Mao *et al.* 2005; Valeix *et al.* 2009). This occurs even if it means giving up a profitable foraging area in favour of a less profitable foraging habitat with a lower risk of predation (Cresswell 1994; Whitfield 2003;

Cresswell & Whitfield 2008). Predator avoidance behaviour effectively reduces predation risk, greatly increasing the chance of survival and is thus likely to have a strong selection pressure. It is therefore believed to be the most important anti-predation strategy (Sansom *et al.* 2009).

In a recent study, Egyptian Geese were found to avoid areas of their habitat that were perceived to be less safe (Mackay *et al.* 2014). Similarly, the results of this study suggest that the use of falconry changed the perceived quality of the habitat for the geese since even though food availability was high, the geese chose to leave otherwise favourable parts of the golf course in order to find safer feeding grounds.

Comparisons of the mean abundance of geese before and after the treatment at each site, reveals falconry had a pronounced effect on the numbers of geese at the experimental site. During the month preceding the start of the falconry experiment, the mean abundance of geese at the Rondebosch golf course was 148 individuals. After two weeks of falconry, during which time 21 geese were killed (14% of the mean abundance for the month preceding falconry), the numbers of geese on the golf course decreased substantially and for the seven weeks that followed the mean number of geese observed was 21 individuals (just c. 14% of the mean number of geese during the month preceding falconry). Additionally, the mean abundance of geese during the entire treatment period, including the first two weeks was 27 (95% CL 25-29), which represents an overall reduction of 73% when compared to the entire non-treatment period and c. 82% when compared to the mean abundance of geese during the month preceding falconry. This decrease in the abundance of geese can therefore largely be attributed to the non-lethal effects of predation pressure since the initial lethal impact represents just 14% of the initial reduction. Thereafter, there were on average, only two goose fatalities per week, which can be regarded as a form of reinforcement to ensure that no habituation to non-lethal falconry occurred.

Predator avoidance by habitat selection is widespread in the animal kingdom and has been demonstrated to occur in a variety of taxa from aquatic and marine species (Turner & Mittelbach 1990) to mammals and birds (Cresswell 1994; Whitfield 2003; Ripple & Beschta 2004; Mao *et al.* 2005; Cresswell & Whitfield 2008). This experiment demonstrates that by taking advantage of this naturally occurring phenomenon, falconry can be effectively used as a management tool to mitigate human-wildlife conflicts caused by high population numbers of geese on golf courses.

Vigilance

The landscape of fear phenomenon describes the variability of an animal's area of use in terms of how safe that animal perceives it to be (Altendorf *et al.* 2001; Laundré, Hernández & Altendorf 2001; Laundré, Hernández & Ripple 2010). Fearful individuals are usually more vigilant (Welp *et al.* 2004), thus those that inhabit areas deemed less safe, tend to exhibit higher levels of vigilance (Brown 1999; Brown, Laundré & Gurung 1999; Laundré, Hernández & Altendorf 2001). Urbanization and artificially created landscapes such as golf courses provide open areas, with large water bodies and fewer large natural predators, affording geese safer conditions than in natural landscapes (Chace & Walsh 2006; McKinney 2006). To further test that the mechanism reducing the abundance of geese after the treatment period was as a result of increased fear from the introduction of falconry, vigilance levels of the geese were measured both before and after the falconry treatment period. Potential prey species would in most cases select an optimal baseline level of vigilance that balances perceived safe foraging with predator detection (Macarthur & Pianka 1966; Brown 1999). Before the treatment period, geese that inhabited the control sites exhibited similar baseline vigilance levels to geese found at the experimental site. However, during the treatment period, vigilance levels markedly increased by c. 76% at the experimental site, yet geese at both control sites exhibited no change in their vigilance levels. The results therefore provide support for the hypothesis that falconry results in an increase in vigilance by re-establishing a landscape of fear in an otherwise relatively safe environment.

The buggy effect on vigilance

It was predicted that the geese may learn to associate golf buggies with the threat of an attack since during falconry raptors were flown from a golf buggy. If this proved to be the case, geese would be more fearful of buggies at the experimental site during the treatment period than during the non-treatment period and thus exhibit increased vigilance, enhancing the effect of the landscape of fear. It was predicted there would be no such response at the control sites. Underpinning this is the assumption that the geese are capable of learning. Research has demonstrated that learning is a widespread phenomenon in the animal kingdom, and that many species store environmental information and consequently alter their behaviour (Dukas 1998). It is also true that anti-predator behaviour can be improved upon with experience (Griffin, Blumstein & Evans 2000; Griffin 2004). Learning to respond to the buggy as a potential threat is a form of association learning, traditionally referred to as classical conditioning, whereby a biologically insignificant event or object (the conditional stimulus), in this case the buggy, is paired with a biologically significant event (Pavlov 1927), in this case an attack by a predator. Conditioned fear responses have been observed in a number of studies of fish (Chivers *et al.* 1995), mammals (Herzog & Hopf 1984) and birds (Curio 1988; McLean, Hölzer & Studholme 1999).

To test the hypothesis, vigilance levels of the Egyptian Geese were monitored using two filming methods, either on foot or from a buggy. Egyptian Geese at both control sites exhibited similar levels of vigilance during the pre-treatment period and the treatment period for both filming methods. In contrast, while vigilance levels at the experimental site increased during the treatment period for both filming methods, there was a markedly greater increase in vigilance when the geese were filmed from the buggy during the treatment period compared to when filmed on foot. This relationship was reversed during the pre-treatment period, where geese were more vigilant in the presence of the observer on foot than when the observer was in a buggy.

The results of the study therefore suggest that geese at the experimental site became more fearful during the treatment period, which was reflected in an increase in vigilance levels. This result therefore further supports the hypothesis that the mechanism behind the decrease in abundance of geese at the experimental site is attributable to the non-lethal effect of predation, since geese probably felt more at risk during the treatment period and the majority chose to find a safer habitat elsewhere. It is likely that by releasing the raptor from within a buggy, the efficacy of falconry can be enhanced because the geese are conditioned to be wary of the buggies. Golf buggies are in constant use on the golf course by golfers, thus geese will be more vigilant every time they are in close proximity of a buggy and are able to devote less time to foraging.

The neighbour effect on vigilance

The group size effect on vigilance is a well documented anti-predation phenomenon for many animals (Caraco 1981; Cresswell 1994; Forsman *et al.* 1998). A benefit to animals that live in groups is that the collective vigilance of the group allows an individual to be less vigilant, and thus able to dedicate more time to foraging (Pulliam 1973). In a recent study, Egyptian Geese were demonstrated to exhibit lower vigilance levels when they were part of larger groups (Mackay *et al.* 2014). The results of this study confirm the existence of the group size effect on vigilance during the non-treatment period at all three study sites. During the treatment period however, the geese have higher levels of vigilance, yet this high level of vigilance is not dissipated by there being many birds in the group, instead vigilance increases with increasing group size. Thus the comfort of being in a group is lost when there is a novel predator in the system.

This finding supports the theory known as the neighbour effect on vigilance (Sirot 2006). The theory argues that whilst vigilance is shared in a flock, certain predators preferentially attack the least vigilant individual (Bednekoff & Lima 1998), therefore detectors of predators are more likely to escape attack than are ‘non-detectors’ (Hilton, Cresswell & Ruxton 1999). In an attempt to avoid becoming the non-detector within a group, individuals also monitor each others’ vigilance, thus their perception of predation risk is influenced by their neighbour’s level of vigilance, and the chance of an individual being vigilant is higher when in the presence of a greater number of vigilant neighbours (Sirot 2006; Sirot & Touzalin 2009). When predation risk is low, the neighbour effect on vigilance can therefore result in low levels of vigilance within a group. When the risk of predation is high however, synchronization of vigilance levels can precipitate high levels of collective vigilance as each individual attempts to avoid being the straggler (Sirot 2006; Sirot & Touzalin 2009).

This study provides empirical evidence to support the model predictions of Sirot and Touzalin (2009), which suggests that vigilance levels of an individual will initially decrease as a result of collective detection, and thereafter will increase when the number of vigilant neighbours becomes higher as a result of a perceived increase in the risk of predation. Similar results of studies on birds (Fernández-Juricic & Kacelnik 2004; Fernández-Juricic, Smith & Kacelnik 2005), and mammals (Pays *et al.* 2009) confirm that some species are receptive to the levels of vigilance exhibited by their neighbours and modify their behaviour accordingly.

If an individual is part of a larger group that are taking social cues from one another, then it makes evolutionary sense to not ignore these signals, otherwise it would always be the last to detect the attacking predator and risk capture (Sirot 2006). However, high levels of vigilance due to high disturbance are known to reduce survival, since birds can lose feeding time, which has been demonstrated for wildfowl (Owens 1977; Gill, Sutherland & Watkinson 2007). Therefore, in order to avoid these consequences on fitness, animals are likely to choose to move to a habitat where they feel less at risk of predation, and can spend more time foraging, even if those foraging grounds are less profitable (Whitfield 2003; Cresswell & Whitfield 2008). Therefore, the neighbour effect on vigilance adds to the effect of falconry and likely further improves its efficacy, because geese in the presence of a novel predator are more likely to choose to find new foraging grounds than to stay on the disturbed golf course and risk having to devote less time to feeding.

Parasite load

Parasite eggs/oocysts can be passed with the faeces of their host and subsequently ingested by another grazing bird, spreading the infection. Infection tends to be higher in birds living in crowded conditions, young birds and stressed birds (Ballweber 2004). Initially we predicted that in the presence of a predator due to falconry, increased fear levels in geese may be enough of a stressor to result in an increased parasite infection. The results of this study do not support the hypothesis. The results indicate that the geese at all three sites had low levels of parasite infection throughout the study. It is possible that the initial low levels of infection may have been the reason there were no significant increases in the probability of infection during the treatment period. Additionally, it is likely that if increased stress levels were to lead to a greater probability of infection, a longer study period would be required in order to detect these changes.

Limitations and future research

The strongest inferences can be made from experimental designs that consist of replicated treatment and control areas (Hurlbert 1984; Reddiex & Forsyth 2006; Prosser 2010). The results of this study, while they appear to be convincing, are based on one replicate. Due to the logistical problems of having more than one replicate site for this study the control site was instead replicated. By replicating the control site with one treatment site, we obtain n-1 degrees of freedom for testing the statistical hypothesis that the treatment effect arises by chance (Oksanen 2001). If the treatment site becomes a statistical outlier after the onset of the experiment, then the experiment can be said to have had a statistically significant effect at the treatment site (Oksanen 2001). In the case of this study, it would be difficult to conceive how these results could be interpreted differently as they are additionally backed up by changes in the levels of vigilance.

Whilst the control sites remained free from the use of falconry throughout the study period, both sites engaged in some form of Egyptian Goose management at some point during the study period. According to the General Manager at Westlake Golf Club, their greenkeeper regularly (five to six days a week) harasses the geese using a dog. This practice has however, been ongoing for six years (pers comms Gleeson 2015). However, the high Egyptian Goose abundance recorded at Westlake, and the similar levels of vigilance compared to geese at both Steenberg Golf Estate and Rondebosch Golf club during the pre-treatment period, suggests that this approach is relatively ineffective or that the geese here have become habituated to the presence of the dog. On 10 December 2014, Westlake Golf Club had begun erecting a fence around their largest pond. The reduction in the numbers of geese after this date at this one control site may have been due to the combination of harassment by the dog and this newly erected fence. Unlike the reduced abundance at our treatment site however, the decline at Westlake did not result in counts being any lower than that found during the pre-treatment period, suggesting numbers stayed within the range of natural variation found at this site. The management at Steenberg Golf Estate similarly built fences around their main pond, which were completed at the end of December (pers comms Cowell 2015). Additionally, Steenberg initiated use of a goose hazing method known as the "Goosenator" a remote controlled device designed to scare away geese (pers comms Claussen 2014) however, this only took place in early January. Neither action seemed to have any effect on goose abundance or vigilance during the short period of the study they were in use.

An interesting question that was impossible to answer during this study, thus presenting a limitation of the study and a possible future research area, relates to who the remaining individuals are on the golf course after the onset of falconry. Once a landscape of fear has been re-established, and many of the Egyptian Geese chose to move to an alternative site, the remaining individuals could be those that choose to stay rather than find safer foraging opportunities, or naïve geese opportunistically colonising a seemingly ideal habitat where there is ample undefended habitat with abundant resources. If the remaining geese were naïve individuals, then it would be expected that vigilance levels would increase as when naïve individuals appear in a landscape that they know little about the more vigilant geese are likely to learn of potential threats of predation quicker than non-vigilant geese. Therefore it is possible that the increased levels of vigilance during the treatment period are not as a result of falconry itself, but due to the landscape of fear associated with an unknown habitat. The design of this study makes it difficult to answer this question since to explore this it would be necessary to have a marked population of geese. The contrasting relationship of vigilance levels with the buggy that has been observed however, provides the argument against this being the case. While it could be argued that naïve geese are more fearful of buggies as it is the first time they have experienced them, the relationship does suggest that there is some familiarity with falconry from buggies, because if anything, it would be expected that geese would be more scared of people on foot than people in buggies, which was the case before treatment at the experimental site. It is therefore likely that at least some of the geese were the same individuals that were exposed to falconry. Future studies would benefit from having a marked population.

Conclusion

Human-wildlife conflicts are widespread (Dickman 2010; Redpath *et al.* 2013) and conservation managers are faced with difficult choices regarding the most effective ways to manage biodiversity (Redpath *et al.* 2013). Balancing the positive value of wildlife with potential negative perceptions that can sometimes arise is often made difficult because the advantages and disadvantages of living with wildlife do not fall evenly upon everyone in society (Conover 2002). How a human-wildlife conflict is therefore perceived is dependent upon how the perspectives and belief systems of individuals differ (Conover 2002; Messmer 2009). Whilst the Egyptian Goose is indigenous to South Africa, and not an invasive species, it has some of the characteristics of one (e.g. flexible breeding/ foraging behaviour, rapid population growth and speedy geographic spread) (Chapple, Simmonds & Wong 2012). In the human-wildlife conflict presented here, the geese are viewed as a nuisance by a variety of stakeholders from golf course users (Little & Sutton 2013) to agricultural farmers (Mangnall & Crowe 2002), whereas in other areas of society, the geese are enjoyed and viewed as a benefit to society.

The way in which a human-wildlife conflict and its impacts are managed is often the subject of debate and can result in human-human conflicts known as conservation conflicts, which can cause barriers to effective management of human-wildlife conflicts (Young *et al.* 2010; Redpath *et al.* 2013). There are a number of key factors that underlie any conservation conflict. These include the different value systems of stakeholders and their perceptions of the impact, the economic gains or losses that result from the human-wildlife conflict, the sensationalistic representation of the conflict in the media, as well as the appropriateness of relevant legislation (Redpath *et al.* 2013). Whilst it is vitally important to acknowledge and understand the different perspectives and viewpoints held by the stakeholders involved (Young *et al.* 2010) it is equally important to acknowledge the role that science plays in

understanding the causes of conflicts, assessing human-wildlife impacts and suggesting and testing alternative mitigation techniques (Young *et al.* 2010; Redpath *et al.* 2013).
Falconry is a relatively commonly used practice to control pests and nuisance animals and is used in a variety of residential and commercial settings globally (Blokpoel & Tessier 1987; Erickson, Marsh & Salmon 1990; Baxter & Robinson 2007; Cook *et al.* 2008), indicating that it is considered to work. While there have been a number of studies that investigate the efficacy of different lethal and non-lethal methods to control goose populations on golf courses (Smith *et al.* 1999), the failures of most control methods are due to their short-term efficacy often as a result of habituation, their high cost, or ethical unacceptability (Smith *et al.* 1999; Stephen 2008). To my knowledge, this is the first truly experimental test of the efficacy of falconry to reduce nuisance birds. This study suggests the perception that falconry is effective is well founded and furthermore, gives a strong indication of the mechanisms involved. The results of this study add to the literature aimed at mitigating the existing human-wildlife conflict between geese and golf courses, whilst also suggesting that there may be many other situations where the deployment of trained predators may be successful at reducing numbers of nuisance animals. Whatever approach is taken to mitigate human-wildlife conflicts ultimately there will need to be flexibility and compromises made by the stakeholders involved (Young *et al.* 2010).

Here I present the results of an experimental assessment of the efficacy of falconry as a management tool for reducing the population size of Egyptian Geese on golf courses, thereby reducing the likelihood they may become a nuisance animal. While there is a relatively small lethal aspect to falconry, I use sound behavioural ecology concepts and theories to confirm that a reduction in the population of geese can be achieved by simulating the naturally occurring non-lethal effects of predation that have been lost in some habitats, as a result of anthropogenic changes to the landscape. This important ecological finding has relevance for techniques that people deploy for dealing with human wildlife conflict. While not tested here, it is likely that the use of falconry in conjunction with habitat alterations that create a less safe environment would enhance the efficacy of the human-wildlife conflict management further.

Ethics statement

The methods used in this study were approved by the University of Cape Town Science Faculty Animal Research Ethics Committee (protocol number 2014/V22/AA).

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