Population Dynamics and Habitat Selection of

Resident Urban Canada Geese (*Branta canadensis*)

Scottsdale, AZ

by

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ABSTRACT

Populations of resident Canada geese (*Branta canadensis*) that nest and reside within the contiguous United States have increased at a rate of 7.9% per year to over 3.5 million over the last few decades. Enlarged population levels have resulted in conflicts between geese and humans, including property damage and human health and safety concerns. Noticeable growth of the population of Canada geese in the Indian Bend Wash area of Scottsdale, AZ has been observed in recent years sparking concern that this population will continue to grow at high rates as seen in other urban areas throughout North America. This study was initiated to determine the current population structure, distribution, and productivity of this population of resident geese. During the 2009 to 2010 post-breeding molt, 255 geese were captured and affixed with neck collars allowing individual identification. I conducted surveys from October 2008 to September 2010 and calculated weekly population estimates from mark recapture survey data using the Lincoln-Peterson method. Productivity was also investigated. Nesting was largely limited to one island within the study area, suggesting geese preferentially nest in insular areas to avoid human disturbance. Despite limited nesting opportunities, there was a significant population increase of 15 to 25% from 2009 to 2010 based on population estimates. Goose movement patterns indicate this population has a high level of site fidelity to nesting and molting areas, as has been found in other studies of resident Canada geese. I suggest that management should be implemented to 1) reduce the current population of

resident geese through adult removal and 2) limit future recruitment into the population through control of reproduction and habitat modification.

DEDICATION

I would like to dedicate this in loving memory of Jane Elaine.

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CHAPTER 1

INTRODUCTION

During the 1950s to 1980s wildlife management agencies throughout North America implemented a number of restoration efforts in response to declining Canada geese (*Branta canadensis*), resulting from overharvesting and extensive loss of wetland habitats during the early 1900s (Smith et al. 1999). These efforts led to a considerable increase in distribution and numbers of Canada geese during the past several decades (U.S. Department of Interior (USDI) 2005, Holevinski et al. 2007). In recent years, populations of resident Canada geese that nest and reside for most or all of their life within the contiguous United States have increased dramatically (USDI 2005, Holevinski et al. 2007). Resident populations of Canada geese in the United States have increased at a rate of 7.9% per year , increasing from 1 million to over 3.5 million from 1990 to 2005 (Cleary et al. 2006).

Resident Canada goose populations have become established in many urban/suburban areas where they have thrived. Present year-round throughout these areas and easily recognized, they provide a valuable, close-up wildlife viewing opportunity for people (Atlantic Flyway Council 1999). The public enjoys viewing and feeding geese and their presence increases the aesthetic value of urban areas (McCoy 2000). Unfortunately, in many cases their numbers have increased to the point that they are viewed as nuisances as enlarged population levels result in increased conflict between geese and humans (Conover and Kania 1991, Christens et al. 1995, USDI 2005). Many of these conflicts arise in urban communities where geese congregate on manicured lawns of parks, golf courses, airports and backyards (Coluccy et al. 2001). Frequent conflicts between geese and humans arise from property damage resulting from overgrazing of lawns and the accumulation of feces and feathers (Conover and Kania 1991). Both the aesthetic value and recreation use of areas with overabundant geese are reduced.

Additional conflicts arise over human health and safety concerns. The accumulation of goose feces creates a disease concern and contributes to eutrophication of small ponds and reservoirs (Coluccy et al. 2001). High concentrations of geese also increase the likelihood of avian disease transmission and outbreaks (Smith et al. 1999).

Resident Canada geese have become common bird species involved in aircraft strikes creating additional safety concerns (York et al. 2000). Bird strikes are a growing problem: at least 210 aircraft have been destroyed in the United States resulting from bird strikes and other wildlife strikes in the past 20 years (Dolbeer 2009). The recent crash of US Airways Flight 1549 in the Hudson River after striking a flock of Canada geese at takeoff from New York's LaGuardia airport exemplifies the danger of bird strikes (Dolbeer 2009).

Multiple "races" or subspecies of Canada geese are recognized. The Pacific Flyway western Canada goose (*B. c. moffitti*) is the most common resident subspecies found in urban areas in western regions (Smith et al. 1999). Transplant programs and natural pioneering have resulted in a significant expansion of the distribution of Pacific population of *B .c. moffitti*, many of which are currently nonmigratory (USDI 2005).

Noticeable growth of the population of Canada geese in the Indian Bend Wash area of Scottsdale, AZ has been observed in recent years (M. J. Rabe, Arizona Game and Fish Department, Personal Communication). There is concern that this population will continue to grow at high rates as seen in other urban areas throughout North America. The information gained from this study will be used to guide the development of an urban goose management plan for the City of Scottsdale. The objectives of this study are: 1) determine the size of the resident population of Canada geese within the Indian Bend Wash study area;
2) determine the rate of growth of this population; 3) quantify the natality factors influencing the growth of this population; 4) evaluate those habitat factors influencing how resident geese are using the habitat within the Indian Bend Study area; and 5) develop management recommendations for the resident goose population within the Indian Bend Wash.

CHAPTER 2

BACKGROUND LITERATURE

Damage and Conflicts

Conflicts with overabundant geese in urban/suburban areas are often related to property damage by geese on parks, golf courses, commercial properties and other properties with expanses of well manicured lawns (Conover and Chasko 1985, Atlantic Flyway Council 1999). Damage commonly results from overgrazing and soil compaction as well as the accumulation of body feathers and feces (Conover and Kania 1991, Atlantic Flyway Council 1999).

A goose's digestive system is inefficient necessitating that geese eat large quantities of food, using up to 90% of their day feeding (Ogilvie 1978, USDI 2005). Overgrazing by geese may lead to large bare or dead spots in lawns (Conover 1991). When actively feeding, geese defecate on an average of once very 3 to 4 minutes (Owen 1980). The accumulation of feces is unsightly and detracts from the aesthetic and recreational value of lawns (Conover and Chasko 1985). Accumulation of feces can also lead to eutrophication of small water bodies resulting in excessive algal growth (Smith et al. 1999). Damage can be costly and labor intensive to repair; in some cases it may discourage business resulting in further economic loss (Atlantic Flyway Council 1999). Additionally, public avoidance of parks and golf courses with goose related lawn damage may potentially result in overuse of non-goose populated properties (McCoy 2000).

Further conflicts with overabundant geese in urban areas arise over health concerns. High concentrations of feces create the potential for increased disease transmission for both humans and waterfowl (Atlantic Flyway Council 1999, Preusser et al. 2008). High concentrations of resident Canada geese along with domestics and hybrids found in urban areas increases the chance that avian diseases will be transmitted and create a health risk to migrating waterfowl (Smith et al. 1999, USDI 2005). Warm, stagnant bodies of water can be contaminated by resident Canada goose feces and are a potential source of avian diseases (USDI 2005). One disease concern is duck virus enteritis, a highly contagious disease of waterfowl (Preusser et al. 2008). The contact between resident and migrant waterfowl plays a role in the epidemiology of viruses such as influenza virus and West Nile virus which infect both waterfowl and humans (Hess and Pare 2004).

Feare et al. (1999) screened Canada goose droppings in London for a number of bacteria that could be pathogenic in humans. They detected *Escherichia coli*, *Enterobacter cloacae*, *Salmonella sp.*, *Aeromonas hydrophila* and *Providencia alcalifaciens* in goose feces. Kassa et al. (2004) found *Cryptosporidium*, a protozoan parasite, in Canada goose feces at greater than 80% of study sites in Ohio. Both Feare et al. (1999) and Kassa et al. (2004) emphasized that while other waterfowl feces contain a similar range of pathogens, geese forage further from water's edge than other waterfowl increasing the distribution of their feces and increasing the potential of human exposure to their feces.

Kullas et al. (2002) determined that prevalence of virulent strains of *E. coli* present in Canada goose feces collected in Fort Collins, CO was correlated to seasonal weather and not to goose numbers or fecal load. Virulent *E. coli* in goose feces ranged from 2% in the coldest part of the year up to 94% during the warmest months (Kullas et al. 2002). Warm conditions are ideal for bacterial growth and during the spring and summer resident geese have limited movement, concentrating bacterial contamination over small urban lakes and lawns (Kullas et al. 2002).

One of the largest safety concerns resulting from overabundant geese in urban areas is the risk of bird strikes to aircraft (McCoy 2000). High numbers of Canada geese on and near airports creates a considerable risk. Bird-aircraft strikes are a growing problem; at least 210 aircraft have been destroyed in the United States by wildlife strikes in the past 20 years (Dolbeer 2009). The Federal Aviation Administration (FAA), U.S. Department of Agriculture (USDA), and U.S. Air Force expect the risk and frequency of wildlife-aircraft collisions to continue to increase over the next decade (Cleary et al. 2006).

Due to their large size and flocking behavior Canada geese are considered a very hazardous species for aviation (Atlantic Flyway Council 1999, Dolbeer et al. 2000, Cleary et al. 2006). Waterfowl comprise 35% of all bird-aircraft strikes (USDI 2005). Geese were ranked the third most hazardous species to aviation out of 21 wildlife species/species group which were involved in strike reports from 1991 to 1998 (Dolbeer et al. 2000). Between 1986 and 1990, 11 collisions with Canada geese at Reno-Cannon International airport caused approximately $250,000 damage (Fairaizl 1992). In 1995 at Elmendorf Air Force base in Anchorage, Alaska, an E-3 Sentry Airborne Warning and Control System aircraft struck several Canada geese at take off causing the plane to crash killing all 24 people aboard (York et al. 2000). The 2009 high profile collision of US Airways Flight 1549 with a flock of Canada geese in New York reaffirmed the risk posed by bird strikes (Dolbeer 2009).

Several additional threats to human safety have been raised. Resident geese nesting at locations such as public parks may injure humans by aggressively defending their nests and goslings (Atlantic Flyway Council 1999, Smith et al. 1999). Goose attacks during nesting season have been reported to Wildlife Services resulting in falls or bites (USDI 2005). Human safety concerns also arise from traffic problems caused by resident Canada geese crossing roads in urban areas (Atlantic Flyway Council 1999, USDI 2005). While this problem is more prevalent during the summer molt when geese are flightless, flocks of geese will walk across roads year round.

Characteristics of Urban Goose Habitat Selection

Resident Canada geese remain in urban areas year round and use urban habitats for nesting, feeding, roosting and loafing. Looking at overall habitat selection, Canada geese prefer large open lawn areas associated with water (Feare et al. 1999, Smith et al. 1999). Urban/suburban green spaces with artificial water bodies such as parks, golf courses and residential complexes provide the ideal environment for geese (Smith et al. 1999). Additionally, human presence provides protection from many natural predators making urban areas safe for geese (McCoy 2000). The public often enjoy feeding geese, further enhancing the attractiveness of urban areas (Conover 1999, McCoy 2000).

Canada geese select nesting sites that are in close proximity to or surrounded by water, usually nesting within 50 m of water (Bellrose 1976). In urban/suburban areas, nest site selection is variable; geese may nest in patches of vegetation or at the base of large trees where the nest is less noticeable (Ogilvie 1978, Smith et al. 1999). Nest locations are consistently selected based on safety concerns with geese selecting nests with a good view of the surrounding area (Smith et al. 1999). Islands and banks are often preferred nesting sites, as they provide security from potential predators and are removed from frequent human use (Ogilvie 1978, Smith et al. 1999).

Canada geese are grazers and select lawn areas in urban areas as their primary food source (Conover and Kania 1991, Smith et al. 1999). A major factor in selecting a foraging site is safety (Conover and Kania 1991, Conover 1992). Conover and Kania (1991) found that Canada geese select foraging sites that are open lawns with few obstructions providing high detection of any approaching predators. Geese also select lawns close to or abutting open water providing easy access to immediate refuge from potential danger (Conover and Kania 1991, Smith et al. 1999).

Food quality also plays a role in goose foraging site selection (Conover 1992). Canada geese prefer to feed on grass, especially young actively growing shoots (Smith et al. 1999, USDI 2005). The growing tips of grass are the parts containing the most protein and nitrogen, and are thus more nutritious and palatable (Ogilvie 1978, USDI 2005). Young, short grass is also easier for shortbilled geese to graze (Ogilvie 1978). Urban/suburban mowed lawns supply short grass in abundance (Smith et al. 1999).

Management Strategies

When selecting an effective management strategy to address and alleviate nuisance Canada goose problems there is no one size fits all approach. Each situation is unique requiring directed management approaches (Smith et al. 1999, USDI 2005). No quick or easy solution to goose problems in urban/suburban areas has been discovered, nor is it likely to be due to the complexities of urban goose issues (Gosser et al. 1997, Smith et al. 1999, Swift 2000).

Public attitudes must be considered when implementing management alternatives, especially in urban/suburban areas (Coluccy et al. 2001). Other factors to consider include time of year, cost-effectiveness and laws and regulations (USDI 2005). Canada geese are protected by the Migratory Bird Treaty Act so adult geese, their nests, eggs, or young cannot be harmed out of the legal hunting season without the proper permits (Gosser et al. 1997). Consideration must also be given to the scale of the problem. Canada goose problems may occur at a “lawn” level or at a larger “community” or even “regional” level (McCoy 2000). Before implementing a management strategy it is also crucial to identify what characteristics of a site or area are attracting geese so that management can be directed at reducing those characteristics (Gosser et al. 1997, Smith et al. 1999).

A variety of management strategies have been explored since as early as the 1970s (Atlantic Flyway Council 1999), including lethal and non-lethal techniques (Gosser et al. 1997, USDI 2005, Preusser et al. 2008). Nevertheless, nuisance goose problems have proven difficult to alleviate (Conover 1992, Conover and Kania 1991). Smith et al. (1999) identified the following categories of techniques for addressing resident Canada goose problems: 1) Discontinuance of feeding; 2) Habitat Modification; 3) Hazing and Scaring Techniques; 4) Chemical Repellents; 5) Control of Reproduction; and 6) Removal.

Discontinuance of Feeding. – Many people enjoy feeding geese (Conover 1999, McCoy 2000). Canada geese are grazers and in urban areas feed primarily on lawns; they do not need supplemental feeding to thrive in these areas (Smith et al. 1999) yet many geese become habituated to humans and seek food from them (Conover 1999). Continuance of feeding makes it more difficult to limit the number of geese utilizing a site (Gosser et al. 1997) and exacerbates existing conflicts (Conover 1999, Smith et al. 1999, USDI 2005). It encourages geese and other waterfowl to congregate in an area and potentially makes geese more aggressive toward people (Smith et al. 1999). The risk of disease transmission between geese and both humans and other waterfowl also increases with concentrated groups of waterfowl in close contact with humans (Conover 1999, Smith et al. 1999).

The discontinuance of feeding of waterfowl is recommended by Wildlife Services and State wildlife agencies (USDI 2005). Education and regulations have been implemented to help decrease human feeding of waterfowl, but antifeeding policies are often ignored or poorly enforced (Smith et al. 1999, USDI 2005). Conover (1999) suggested that given the difficulty of convincing people to stop feeding wildlife it may prove easier to teach waterfowl to avoid handouts.

Habitat Modification. – Habitat modification techniques include eliminating, modifying, reducing access to areas that attract geese, or making a site appear less safe for geese (Gosser et al. 1997, Smith et al. 1999). Conover (1991) found that Canada goose numbers can be reduced if urban lawns are replaced by unpalatable ground cover or tough-leaf grasses such as tall fescue. Captive feeding tests have shown geese avoid grasses with high ash content or tough leaves and refuse to eat ground covers such as common periwinkle, Japanese pachysandra, and English Ivy even when denied any alternate foods (Conover 1991). Simply reducing or eliminating mowing would also make nuisance sites less attractive to geese (Conover 1992, Smith et al. 1999). While replacing lawns with less attractive ground covers can reduce goose numbers at nuisance sites, it is often either not a feasible option in urban/suburban areas nor an option property owners are willing to implement (Conover 1991, USDI 2005).

Reducing the perceived safety of a lawn will make a site less attractive to geese (Conover and Kania 1991, Gosser et al. 1997). Conover and Kania (1991) found that urban/suburban Canada geese in Connecticut selected foraging sites based primarily on safety considerations. Planting more bushes and hedges around lawns and water bodies to reduce the goose's ability to see approaching predators is a less drastic habitat alteration option available to landowners than replacing lawns (Conover and Kania 1991, Gosser et al. 1997). Planting tall trees around the lawn and body of water may also make a site less attractive to geese. Geese prefer easy flight access in and out of an area, selecting sites with a flight clearance angle less than 13° (Conover and Kania 1991, Gosser et al. 1997).

Another form of habitat alteration available for use in controlling goose damage is to exclude goose access to small water bodies (Gosser et al. 1997, Smith et al. 1999). A grid of high tensile wire, Kevlar, stainless-steel line, UV-resistant polypropylene line, twine, cotton rope, fishing line, or Mylar tape stretched or strung across a water body deters geese from using it by restricting goose landing and takeoff (Gosser et al. 1997, Smith et al. 1999). Combining this with a perimeter fence effectively prevents geese from walking into the area under the grid (Smith et al. 1999). Drawbacks of this method include restriction of water access to humans as well as visual degradation of the area (Gosser et al. 1997, Smith et al. 1999). Grid method variations are available to reduce its visibility and detract less from a site's aesthetic value (Smith et al. 1999).

This method was used as part of an integrated management approach for urban Canada geese in the Reno-Sparks metropolitan area (Fairaizl 1992). In an attempt to prevent geese from roosting on a lake near Reno-Cannon International airport, biologists constructed an experimental wire grid over the lake, attaching it to the existing perimeter fence (Fairaizl 1992). Following construction of the grid geese never used the lake to roost again (Fairaizl 1992).

Hazing and Scaring Techniques. – Hazing is the continuous harassment or frightening of birds until they leave a location and is frequently suggested as an option for urban/suburban goose management (Smith et al. 1999, Holevinski et al.

2007). These techniques are nonlethal and thus more readily accepted by the public than lethal alternatives (Smith et al. 1999, Holevinski et al. 2007). There are a wide variety of hazing techniques available including use of audio and visual stimuli (Smith et al. 1999, Holevinski et al. 2007).

Limitations of hazing include the habituation of geese to the devices and the failure of hazed geese to leave the surrounding area (Smith et al. 1999, Holevinski et al. 2007). In urban/suburban areas, hazing geese from one lawn may just shift the problem to another lawn within the same community (Aguilera et al. 1991, Smith et al. 1999, Castelli and Sleggs 2000, McCoy 2000). Preusser et al. (2008) found that geese usually moved less than 2 km from hazing sites and often returned multiple times after hazing. Geese show a high level of site fidelity to nesting and molting areas (Preusser et al. 2008), contributing to difficulties in long term removal of geese through hazing. Another problem with hazing unique to the urban/suburban environment is that urban geese are accustomed to humans and not as easily scared by some hazing devices as migrant geese (Smith et al. 1999).

The combination of multiple techniques may be necessary to move geese completely out of an area (Smith et al. 1999, Holevinski et al. 2007). A large amount of time and effort may be required for hazing to be successful (Preusser et al. 2008); geese may become habituated to scare tactics and repeatedly return to hazing sites (York et al. 2000). Preusser et al. (2008) found that multiple visits were required per day several days a week and the same flock of geese may have to be hazed up to 21 times.

A wide variety of auditory hazing devices are available including sirens, pyrotechnics (e.g.: screamer shells, bangers, crackers) and goose distress calls (Smith et al. 1999). Effectiveness of these techniques has been variable (USDI 2005). Use of pyrotechnics is inappropriate and prohibited in some urban/suburban areas due to issues such as fire risk and noise complaints (USDI 2005).

Aguilera et al. (1991) found screamer shells were effective in dispersing urban geese in Colorado on both a short term and long term basis. All geese left the site after treatment and geese did not return for up to 15 days after treatment was stopped (Aguilera et al. 1991). Other studies using various pyrotechnics have shown mixed results. In a New York study pyrotechnics alone was successful at removing greater than 90% of geese from a property in only 59% of events; geese often only moved far enough away to avoid the stimulus of the pyrotechnics rather than vacating a site (Holevinski et al. 2007). York et al. (2000) found that approximately 20% of geese returned to airports in Anchorage, AK multiple times after hazing and contributed this to habitual site use rather than habituation to scare tactics. Fairaizl (1992) found the effectiveness of pyrotechnics in hazing geese highly variable: migrant birds responded well while resident birds who were more accustomed to human interactions required more persistence. Response varied on an individual basis as well (Fairaizl 1992).

Success using goose distress calls to scare geese away from an area has been mixed (Smith et al. 1999). Aguilera et al. (1991) found geese responded to taped goose distress calls by becoming alert and sometimes moving up to 100 m away, but calls were ineffective in getting geese to leave a site. Mott and Timbrook (1988) found goose distress calls alone reduced goose numbers by 71% and when calls were used in combination with racket bombs there was a 96% reduction. However, geese only moved a short distance (greater than 100 m) and returned after several weeks (Mott and Timbrook 1988), indicating this method of harassment is only successful on a short term basis (Smith et al. 1999). Conversely, in a rural study in Wisconsin, on-demand distress call playback combined with screamer/banger shells effectively hazed geese from crops on both a short term and long term basis with no sign of habituation (Whitford 2008). The authors assert that they had more success than previous studies (namely Mott and Timbrook 1988, Aguilera et al. 1991) because their calls were unquestionably alarm and alert calls whereas previous studies used questionable calls (Whitford 2008). Additionally, the combination of calls and firing shells was more effective than either technique alone (Whitford 2008).

A variety of visual stimuli have been tried to haze Canada geese from problem areas. Techniques range in complexity from simple visual frightening devices such as plastic flags, Mylar tape and eye-spot balloons to mechanical devices such as remote controlled airplanes and boats (Smith et al. 1999), and more recently lasers (Sherman and Barras 2004). Dogs have also been used to chase geese (Smith et al. 1999). The benefits of using visual frightening devices in urban areas include their low cost (at the low end of complexity), easy implementation and lack of associated noise (as opposed to auditory stimuli) (Smith et al. 1999). Drawbacks include visual detraction (USDI 2005) and necessity of regular maintenance for permanent devices such as flags as well as the high likelihood of goose habituation to these techniques (Gosser et al. 1997, Smith et al. 1999).

Visual deterrents such as flags, eye-spot balloons, kites and tape have had mixed results in repelling Canada geese but are largely ineffective (USDI 2005). These deterrents have the best success when geese first move into an area or when combined with other techniques as geese quickly habituate to these permanent fixtures and ignore them after a few days (Gosser 1997, Smith et al. 1999).

Dogs have been effectively used to chase Canada geese from large properties such as golf courses (Smith et al. 1999) and Wildlife Services has recommended their use in appropriate situations (USDI 2005). Border collies are the dog breed primarily used for harassing geese due to their herding instinct and intelligence (Castelli and Sleggs 2000). Trained dogs can be either purchased or rented as needed (Smith et al. 1999). Castelli and Sleggs (2000) found that a Border collie program successfully removed Canada geese from a corporate complex in New Jersey while the number of geese increased in the surrounding area. The number of geese was immediately reduced after implementation of the program, as was the number of nesting attempts over the next several years (Castelli and Sleggs 2000). With year-round, 24-hour-a-day harassment, nearly 100% control was achieved (Castelli and Sleggs 2000). Border collies were also successful in hazing geese from several urban sites in New York, with regular dog patrols reducing the number of geese by 80 to 100% overall (Swift 2000). While the use of dogs can be quite effective in removing nuisance geese from a property, resident geese require continuous long term harassment or they are likely to return to a site (Swift 2000). Additionally, dogs are only effective on a site-specific basis and their use does not address the larger problem of overabundance of Canada geese on a larger community scale (Castelli and Sleggs 2000).

Radio-controlled aircraft have been used since the early 1980s to haze Canada geese, primarily over airports (Smith et al. 1999). Radio-controlled planes and boats have had high success rates at effectively harassing geese with the drawback that they are expensive in terms of manpower and acquisition cost (Fairaizl 1992). A radio controlled airplane and helicopter were used to harass geese near the Reno, NV airport (Fairaizl 1992). Both devices successfully reduced the number of geese present by 75% after 5 days of hazing (Fairaizl 1992). Geese avoided the hazing site for approximately 10 days before numbers returned to pretreatment levels (Fairaizl 1992).

Remote-controlled boats are often used in combination with Border collies to harass geese. Holevinski et al. (2007) found that remote control boats combined with border collies removed greater than 90% of urban geese in New York in 97% of events. When comparing the efficacy of multiple hazing techniques, they found Border collies alone and Border collies used in combination with remote-controlled boats were most successful hazing techniques during daylight hours (Holevinski et al. 2007). They noted, however, that geese were only temporarily removed from problem sites and returned multiple times (Holevinski et al. 2007).

Preusser et al. (2008) had less success using the combination of remote-controlled boats and border collies over a 3 year study in Orange County, New

York. In their study all geese were successfully hazed from a site from 62% to 92% of the time depending on study year (Preusser et al. 2008). They attributed their limited success in comparison to Holevinski et al. (2007) to the fact that they harassed geese through the molt. (Preusser et al. 2008)

Several captive studies have assessed the efficacy of lasers for visually hazing Canada geese. Blackwell et al. (2002) and Werner and Clark (2006) both found captive geese avoided a laser beam and showed no sign of habituation after up to 20 subsequent nights of hazing. However, they found that effects were temporary with geese returning to treated subplots 3 days after the discontinuance of the laser hazing (Werner and Clark 2006).

Sherman and Barras (2004) had similar results in an urban study in Ohio. They found that laser harassment provided short term success in moving geese short distances (less than 2 km) when used at night (Sherman and Barras 2004). These results indicate that laser harassment will not provide long-term or large-scale control of nuisance geese (Sherman and Barras 2004).

Chemical Repellents. – The efficacy of a number of chemical feeding repellents has been tested for Canada goose damage management yielding mixed results (USDI 2005). The goal of these repellents is to create an aversion to foraging in unwanted areas by spraying the lawn with a chemical that will make grass unpalatable or cause illness but not harm the goose (Conover 1985, Smith et al. 1999). If geese learn to avoid a repellent, it can reduce goose use of an area for extended periods of time after treatment (Belant et al. 1996). Limitations of using chemical repellents include high costs and the need for frequent reapplication (Smith et al. 1999). Additionally, repellents work only to deter geese from foraging at a site with no prevention of other site usage such as loafing and swimming (Smith et al. 1999).

Methiocarb successfully worked as a grazing repellent for Canada geese in both captive and free-range experiments for up to 8 weeks after application (Conover 1985). However, this chemical is not registered by the U.S. Environmental Protection Agency (EPA) as a goose repellent (Smith et al. 1999).

Methyl anthranilate (MA), marketed as ReJeX-iT® and Bird Shield®, is a chemical that makes grass unpalatable to Canada geese and has been registered by the EPA as an avian repellent (Cummings et al. 1995, Belant et al. 1996, Smith et al. 1999, USDI 2005). MA is water soluble so is ineffective after heavy or frequent waters and/or mowing (USDI 2005). Cummings et al. (1995) found MA had limited effectiveness at reducing Canada goose use of treated grass plots for up to 4 days. Belant et al. (1996) found MA was ineffective as a grazing repellent for geese when applied at the manufacturer's recommended rate as well as at triple the recommended rate. Additionally, they found no learned avoidance to MA when geese were pre-exposed (Belant et al. 1996). Both studies used captive geese. Belant et al. (1996) suggests MA may be more effective in repelling free-ranging geese when combined with other forms of harassment, though the high application rates necessary to repel geese would likely be cost prohibitive.

Another potential grazing repellent for Canada goose management is lime. Lime works by producing a caustic effect on mucous linings of the goose's mouth (Belant et al. 1996). A benefit of lime over other grazing repellents is that it is less expensive, easily available and easy to apply, while its major drawback is that it renders grass a gray-white color after application (Belant et al. 1997). Belant et al. (1997) found that lime was an effective repellent at all tested application rates for up to 3 days. After this time period, the growth of grass provided untreated grass at the base of previously treated leaves (Belant et al. 1997).

Anthraquinone (AQ, Flight Control®) is another chemical repellent which shows potential for use in goose management (USDI 2005). AQ has lower toxicity than other avian repellents and causes no odor or grass discoloration (Dolbeer et al. 1998). During a captive study, Flight Control was found effective at repelling foraging for up to 5 days after which geese resumed feeding on treated plots (Dolbeer et al. 1998).

In a slightly different approach to chemical repellent use, Conover (1999) fed urban Canada geese bread treated with chemicals to make the bread distasteful (dimethyl anthranilate or Methiocarb). He hypothesized that waterfowl can be taught to avoid food handouts through conditioned food aversions (Conover 1999). Results indicated that while repellents did work to deter geese from accepting handouts the effect was very short term, lasting only for a few days (Conover 1999).

Control of Reproduction. – After surviving their first year, Canada geese have a long life span, potentially living over 20 years (Bellrose 1976, USDI 2005). For long lived species, adult survival has a much larger impact on population growth than does reproduction (Schmutz et al. 1997). Consequently, the most effective means for reducing the size of a Canada goose population is increasing adult mortality (Schmutz et al. 1997, Smith et al. 1999, USDI 2005). This is difficult to attain in urban environments where predation is low to nonexistent and hunting is often impractical or prohibited. While control of reproduction of urban flocks will not effectively reduce the current population it can stabilize the existing flock size, thereby limiting population growth (Smith et al. 1999, USDI 2005).

Several techniques for limiting or preventing reproduction are available including egg destruction, contraception and male sterilization (Smith et al. 1999, USDI 2005). Long-term commitment to a reproduction control program is necessary for it to be effective (Smith et al. 1999). Stabilization of a population requires the regional effort to eliminate nesting on a large scale and needs to be conducted over many years (USDI 2005).

Eggs can be destroyed by oiling, addling, puncturing, freezing or replacing with decoy eggs (USDI 2005). Once eggs are treated they should be replaced so that the female will continue to incubate the non-viable eggs whereas she would likely renest if the eggs were simply removed (Smith et al. 1999). Care must be taken to properly destroy eggs at the right stage in the breeding season. If eggs are destroyed too early, the possibility of renesting increases (USDI 2005)

While egg destruction can be an effective management tool for controlling population growth of resident geese, it has limitations. Many nests cannot be found by resource managers due to the difficulties in gaining access to search private properties where nests may occur (USDI 2005). Additionally, geese which have eggs destroyed in consecutive years may learn to nest away from water in new areas making it more difficult to locate nests (USDI 2005). In 2006, the US Fish and Wildlife Service issued the resident Canada Goose Nest and Egg Depredation Order authorizing landowners and local governments to apply for depredation permits to destroy goose nests and eggs. This order makes it possible for individual landowners to actively manage geese on their own properties with proper permitting.

Forceful addling (shaking) or puncturing can be used to destroy the embryo (Smith et al. 1999). Eggs can be punctured by pushing a thin pin through the shell, introducing bacteria (Smith et al. 1999). In an egg-addling program conducted in Clarkstown, NY, over 6,000 eggs were punctured over 8 years reducing the proportion of goslings by 60% compared to surrounding towns (Swift 2000).

Oiling eggs works by blocking the pores in the eggshell, asphyxiating the developing embryo (Christens et al. 1995). Spraying oil is less labor intensive and equally effective as removing or shaking eggs (Christens and Blokpoel 1991). Eggs should be oiled between the 5th day after the clutch is complete and at least 5 days before hatching is anticipated to ensure all eggs are treated (Smith et al. 1999). Christens et al. (1995) found that 100% of eggs sprayed with white mineral oil during incubation failed to hatch. Females continued to incubate oiled eggs an average of 13.7 days past estimated hatch date (Christens et al. 1995). Preusser et al. (2008) coated Canada goose eggs with corn oil on multiple visits to ensure all eggs were treated; gosling production was greatly reduced at sites where oiling occurred (Preusser et al. 2008).

An alternative to egg destruction for reproductive control of Canada geese is the use of contraceptives. A contraceptive bait can be fed to resident Canada geese at central locations in nesting areas, allowing treatment of many nests spread across multiple properties (Bynum et al. 2007). In 2005, OvoControl G was developed and approved by the EPA for reducing the hatchability of eggs of nuisance Canada geese (Caudell et al. 2010). The active ingredient of OvoControl G is nicarbazin, which has been registered with the Food and Drug Administration since 1955 to treat broiler chickens for coccidiosis (Bynum et al. 2007, Caudell et al. 2010).

In an Oregon study, the use of OvoControl G bait reduced hatchability of resident Canada goose eggs by 36% and increased the number of nests with 0% hatch rate by 93% compared to control sites (Bynum et al. 2007). Caudell et al. (2010) found that as goose densities increase to greater than 35 pairs, this method becomes more cost effective than other methods such as egg oiling or addling. While the use of contraceptive bait requires less effort than locating individual nests to treat eggs, a major drawback of this method for population control is that not all geese will eat high enough doses of bait to inhibit hatchability (Bynum et al. 2007). Bynum et al. (2007) suggest using OvoControl G as part of an integrated management program to help maintain population numbers.

An alternative to female contraception for preventing Canada goose reproduction is vasectomizing males. The main benefit of this approach is that it doesn't require repeat yearly treatment (Hundgen et al. 2000). Drawbacks include difficulties in identifying and capturing all breeding males, especially in large populations, as well as the possibility that a female will pair bond and breed with a different male who has not been vasectomized (USDI 2005).

The use of vasectomies has been successful at reducing gosling production. Converse and Kennelly (1994) found that 84% of reproduction attempts by vasectomized geese were unsuccessful. Hundgen et al. (2000) had similar results, finding that 88% of eggs laid by females paired with vasectomized males were infertile. They emphasize that the implementation of a vasectomy program will be most successful in small resident populations (less than 150 geese) (Hundgen et al. 2000).

Removal. – *Removal* of Canada geese is the most effective way to reduce the size of an urban flock (USDI 2005). As discussed in the *Control of Reproduction* section, due to their long life span the most effective means for reducing the size of a Canada goose population is increasing adult mortality (Schmutz et al. 1997, Smith et al. 1999, USDI 2005). Removal methods include translocation of live individuals or lethal control efforts including shooting several individuals to reinforce hazing techniques, hunting, and capturing with the option to process for human consumption.

Concerns when considering relocation are the potential to spread disease into populations of other waterfowl, impacts on resident species at release sites and the risk that geese will either return or move and create conflicts elsewhere (Craven et al. 1998, USDI 2005). Geese show a high level of site fidelity to nesting and molting areas (Preusser et al. 2008) increasing the possibility they will return to capture sites. Relocating Canada geese has had mixed results but can be effective in reducing overabundant populations and is readily accepted by the public (Fairaizl 1992, USDI 2005). As part of an integrated management program for Canada geese in Reno-Sparks, NV, goslings were relocated to suitable release sites with a return rate of 19% (Fairaizl 1992). Holevinski et al. (2006) found that moving geese as family units decreased the likelihood of return to the original capture site. In their study, 25% of translocated geese returned to capture sites less than 10 months after release (Holevinski et al. 2006).

Although hunting is often impractical or prohibited in many urban areas, it can be used to reduce some populations of resident geese and there are some options for hunting in urban areas (USDI 2005). Special goose hunting seasons can be held at atypical sites such as golf courses using atypical means of take such as archery and entanglement devices (such as snares and nets) that are safe in urban areas (Heusmann 1999). Another option is to translocate geese to areas where traditional hunting is allowed (Holevinski et al. 2006).

Lethal damage management by USDA Animal Plant and Health Services (APHIS) Wildlife Services (Wildlife Services) is the most cost effective management option (USDI 2005). However, lethal techniques are socially controversial and often do not receive public support (Smith et al. 1999, USDI 2005). If geese are captured for removal, it should be done in the summer when no migrants are present in urban areas (USDI 2005). In a study of attitudes of Missouri citizens toward goose management alternatives, Coluccy et al. (2001) found that if it was demonstrated that geese were causing serious damage and that lethal methods were the only means of control, 71% of surveyed citizens would support such measures. If geese were processed and distributed to the homeless for human consumption an additional 13% supported lethal actions (Coluccy et al. 2001). However, a concern with processing urban Canada geese for human consumption is the possibility of contamination with pesticides (Smith et al. 1999).

Management of resident geese remains a management challenge for many urban areas. Nuisance goose problems have proven difficult to alleviate (Conover 1992, Conover and Kania 1991). The combination of multiple techniques as part of an integrated management approach is a more effective approach than solely relying upon one technique (Atlantic Flyway Council 1999, Smith et al. 1999, McCoy 2000, Swift 2000). Multiple nonlethal and lethal methods are available and careful assessment of these options on a case by case basis will assist in development of an effective management plan for communities with overabundant geese.

CHAPTER 3

METHODS

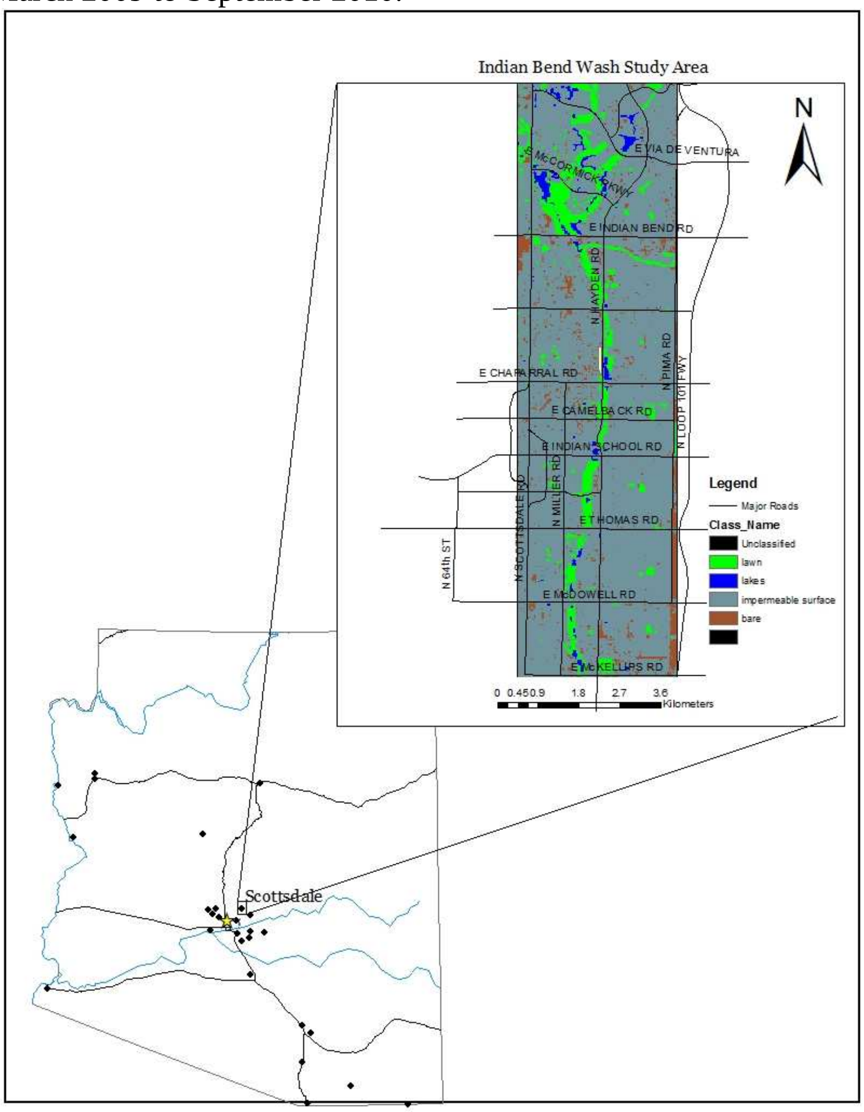
Study Area

The 51.5 km^2 study area is located within the city of Scottsdale, AZ. Scottsdale is part of the Phoenix valley metropolitan area. The study area is centered along Indian Bend Wash and extends 1.6 km in either direction bordered to the west by Scottsdale Rd and to the east by Pima Rd; it extends north/south along Indian Bend Wash from McKellips Rd north to Shea Blvd (Figure 3.1). The Indian Bend Wash area is an extensive corridor of parks and golf courses where geese utilize habitat typified by manicured lawns and numerous artificial bodies of water. I designated sites within the study area based upon park and golf course boundaries and established a site for each body of water.

Data Collection

Capture and Banding. – This study required recognition of individual geese, so adult and gosling resident geese were captured and banded. Observations of marked geese provided individual nesting and movement histories. Geese were captured using drive traps in May to July 2009 and June 2010 corresponding with their annual molt (Costanzo et al. 1995, Holevinski et al. 2006). Geese were herded into the drive traps and then corralled in temporary holding pens (Cooch 1953, Costanzo et al. 1995) at multiple locations throughout the study area corresponding with high goose usage. Geese were marked with both standard aluminum United States Fish and Wildlife Service (USFWS) leg bands and plastic neck collars. Neck collars were supplied by Pro-touch Engraving, Saskatoon, Canada. Neck collars were white with black, 3-digit, unique alpha-numeric codes. The overlap of neck collars was secured using Lomey® Adhesive. Young goslings that were too small to retain neckbands received leg bands only.

Figure 3-1. Map of the Indian Bend Wash study area, Scottsdale, Arizona, from March 2009 to September 2010.



Captured geese were also aged and sexed to determine the population structure. Geese were classified as either adults or goslings based on size and plumage. Sex was determined by examining the everted cloaca (Hanson 1962).

Nesting. – I conducted weekly searches to locate nesting geese from mid-March through early-May of both study years. I located nests by systematically searching suspected nest areas along water shorelines and on islands. Once identified, I checked nests on a weekly basis to determine clutch size and status.

I considered nests successful if at least 1 egg in a nest survived the entire incubation period to hatch (Jehle et al. 2004). I estimated nest success using the apparent method (Johnson 1979). Apparent method nest success estimates can be positively biased because of differences in detection rates for successful and failed nests. However, the apparent method is accurate when nest detectability is high such as when nests are large and conspicuous or located on islands (Brakhage et al. 1987, Gosser and Conover 1999, Jehle et al. 2004). Given that Canada goose nests in this study meet these conditions, I determined that the apparent method was reliable and this method was used to calculate nest success rather than an alternative such as the Mayfield method (Mayfield 1961).

I classified unsuccessful nests as abandoned, depredated, infertile or unknown. Nests were considered abandoned if no goose was present at the nest for 2 consecutive observations (Gosser and Conover 1999). Nests were considered depredated if the entire clutch was destroyed (Bruggink et al. 1994). Nests were considered infertile if the entire clutch was incubated for more than 42 days; average incubation period is 28 days (Bellrose 1976). An unknown outcome was designated if nest outcome could not be determined.

Population Estimates and Growth. – I conducted weekly surveys of adult and juvenile geese throughout the study area from October 2008 to September 2010. Each week, I conducted a predawn count of overnight roosting geese in areas where there was sufficient light. I also performed a daytime survey beginning 2 hours after sunrise, allowing time for all geese to vacate their overnight roost (Ogilvie 1978). For each observation, I recorded the date, time, location, number of geese and neck collar number as well as the primary behavior of the flock (Holevinski et al. 2006). Prior to banding in June 2009, I only conducted daytime surveys.

Following banding, I calculated population estimates from mark recapture data from survey data. The Lincoln-Peterson method was used as follows:

$$N = \frac{(M+1)(n+1)}{R+1} - 1$$

Where N is the estimated population size calculated from M individuals captured and collared, n is the total number of individuals resighted during a survey (collared and non-collared), and R collared individuals resighted (Brower et al. 1998). Prior to banding, mark recapture population estimates were not possible. To correct count data from these months (October 2008 to May 2009), I used a month to month correction factor based on the resighting probability estimate for collared geese, assuming similar detectability from one year to the next.

Population Movement. – I used ArcGIS® 10 to map the UTM coordinates of collared goose locations by using the center of each site where a goose was observed during surveys. I entered survey data collected and the UTM coordinates of each goose location into Excel spreadsheets and imported data into ArcGIS® 10 to map movements and analyze movement patterns. I analyzed both significant movements out of the study area and smaller movement within the study area.

For movement analysis, I broke the study area into 4 primary home areas: McCormick Ranch area, Chaparral Park area, Continental Golf Course, and South End area (Table 3-1). Geese were assigned to a home area if they spent greater than 50% of their time in that area, regardless of where they were banded. This was determined by analyzing sighting records from survey data. While Continental Golf Course was a common destination for geese within the study area, no geese spent the majority of their time at this location. An additional destination, Scottsdale Pavilions, was also included. This site had minimal use due to construction in the area resulting in the filling in of the 2 lakes in this area. Geese collared in 2009 and 2010 were analyzed independently. I followed geese collared in 2009 from June 2009 through September 2010 (16 months). Geese that were not observed after January 2010 were not included in movement analyses due to insufficient data. I selected this date to correspond with the departure of winter migrants. I followed geese collared in 2010 from June 2010 through September 2010 (4 months). Geese that were not observed through September 2010 were not included in analysis. In addition to data collected by

Table 3-1. Survey sites in the Indian Bend Wash study area, Scottsdale, Arizona from March 2009 to September 2010.

Site Name	Home Area	Site Type	Canada Geese Detected	Domestic/ Hybrid Geese Detected
Continental Villas East II	South End	Private Residential	Yes	Yes
Coronado Golf Course	South End	Public Golf Course	Yes	Yes
Eldorado Park – North	South End	City Park	Yes	Yes
Eldorado Park – South	South End	City Park	Yes	No
Vista del Camino Park – McKellips Lake	South End	City Park	Yes	No
Vista del Camino Park – McKellips Lake – North	South End	City Park	Yes	No
Vista del Camino Park – North	South End	City Park	Yes	Yes
Continental Golf Course – North	Continental Golf Course	Public Golf Course	Yes	No
Continental Golf Course – South	Continental Golf Course	Public Golf Course	Yes	No
Bennetts Manor	Chaparral Park	Private Residential	No	No
Camelback Park	Chaparral Park	City Park	Yes	Yes
Chaparral Park	Chaparral Park	City Park	Yes	Yes
Chaparral Park – North	Chaparral Park	City Park	No	No
Chaparral Park – West	Chaparral Park	Private Residential	Yes	Yes
Indian School Park	Chaparral Park	City Park	Yes	No
Scottsdale Shadows	Chaparral Park	Community Golf Course	Yes	No
Gainey Ranch	McCormick Ranch	Private Golf Course	Yes	No
McCormick Ranch – Camelback Lake	McCormick Ranch	Community Golf Course	Yes	Yes
McCormick Ranch – Camelback Lake – North	McCormick Ranch	Private Residential	Yes	Yes
McCormick Ranch – Indian Bend Lake	McCormick Ranch	Community Golf Course	Yes	No
McCormick Ranch – Lake Angela	McCormick Ranch	Private Residential	Yes	No
McCormick Ranch – Lake Margherite	McCormick Ranch	Private Residential	Yes	No
McCormick Ranch – Lake Nino	McCormick Ranch	Private Residential	No	No
McCormick Ranch – Lake Playa	McCormick Ranch	Community Golf Course	Yes	No
McCormick Ranch – Lake Santa Fe	McCormick Ranch	Community Golf Course	Yes	No
McCormick Ranch – Rancho Lake	McCormick Ranch	Community Golf Course	Yes	No
Scottsdale Silverado Golf Club	McCormick Ranch	Public Golf Course	No	No
Scottsdale Pavilions	Scottsdale Pavilions	Shopping Center	Yes	No

myself, a data collection form was available to the Audubon Society and other interested volunteers to report goose observations outside of the study area (Appendix A).

Habitat Modeling. – For each site, I collected habitat characteristic data. For each site's primary water body, I calculated the water body area (m^2), the lawn area (m^2) associated with each water body and distance to nearest road (m) (from center of each water body) using ArcGIS® 10. From the center of each water body, I calculated the angle a goose would have to fly to clear surrounding obstacles (flight clearance angle or FCA) (Conover and Kania 1991). I measured FCAs for 8 directions for each lake (the 4 cardinal directions and 4 intercardinal directions) using a clinometer. I also collected information on whether a water body had a hard concrete edge and the type of property for each site.

I collected information on flock composition and behavior, allowing identification of specific site use. For each observation I recorded the main activity/behavior of the flock. All activities were pooled into 7 primary behavior categories (Table 3-2) (Traut and Hostetler 2003, Tatu et al. 2007).

Table 3-2. List of Canada geese activity categories recorded within the Indian Bend Wash study area, Scottsdale, Arizona from March 2009 to September 2010.

General category	Activities included in category
	Swimming
Active Transport/Locomotion	Walking
Artificial Feeding	People feeding geese
	Nesting
Breeding	Family group with parents guarding young
	Becoming alert
Disturbance induced	Fleeing (locomotion in response to disturbance)
	Grazing on land
Foraging/Feeding	Feeding on aquatic plants, other non-grass terrestrial plants
	Floating on water (loafing/sleeping)
Resting	Standing/sitting on land
	Bathing
Self-maintenance	Preening

Statistical Analysis

All statistical analyses were performed using R 2.12.0 statistical software. For the habitat modeling portion of this study I used a 3-factor factorial split-plot analysis of variance (ANOVA) to test whether goose numbers at sites within the study area were significantly different ($P < 0.10$). The split was week as each site was surveyed weekly throughout the study period. My independent factors were home area, season and year with weekly estimates of goose numbers from weekly surveys as the dependent variable. Significant differences in goose numbers between sites would indicate that there was goose selection for specific habitat characteristics at different sites. ANOVAs were run for both predawn and daytime datasets.

To determine what habitat characteristics may be influencing goose site selection, I developed a linear regression model for each of the 4 home areas

(Table 3-1) established for geese in the study area. For each home area, a separate model was developed for each season for both the predawn and daytime survey periods. To find the best fit regression model, I conducted a backward stepwise regression analysis beginning with a model including all linear variables, as well as all quadratic and cubic terms and possible interactions. I then evaluated the explanatory power of the model and the significance of the included variables.

CHAPTER 4

GOOSE POPULATION DYNAMICS

INTRODUCTION

Studies of population dynamics are needed for effective wildlife management (Gaillard et al. 1998). Populations of resident Canada geese in urban areas throughout the contiguous United States have been increasing at a substantial rate over the past several decades (USDI 2005, Holevinski et al. 2007). The conflicts resulting from increasing populations has produced a need for an understanding of population dynamics of urban geese. It is important to identify the size and distribution of urban populations, as well as predict the potential population growth rate. It is vital to identify what factors are affecting change in population size including productivity as well as emigration and immigration. In many urban areas there is a population of migratory geese joining resident flocks during winter months (Maccarone and Cope 2004). Knowledge of both populations is necessary when developing management plans for Canada geese in urban areas. As with other urban areas throughout the United States, the population of resident Canada geese in the Indian Bend Wash study area appears to be increasing in recent years. However, there is little information on the dynamics of this population.

A primary objective of this portion of the study was to estimate population size throughout the year as resident geese and migrants move in and out of the study area. In order to do this, geese were captured and affixed with neck collars to allow individual identification. I then conducted weekly surveys of geese, allowing calculation of population estimates and growth rate using mark recapture data from weekly survey data. I also identified factors affecting population growth by documenting productivity of the resident population. To gain a better understanding of the extent of breeding, I documented where nesting was occurring and the characteristics of nesting sites. I also determined emigration and immigration rates. This information was gained from identifying movement patterns of geese both within and outside the study area.

RESULTS

Capture and Banding

During May through July 2009, 201 resident Canada geese were captured and banded (of which 198 received neck collars) at 5 separate sites (Table 4-1). I identified 127 (63.18%) adults and 74 (36.82%) goslings. Of the adults banded, there were 65 (51.18%) males, 61 (48.03%) females and one (0.79%) undetermined sex. Of the goslings banded there were 16 (21.62%) males, 37 (50.00%) females and 21 (28.38%) undetermined sex.

During June 2010, 56 resident geese were captured and banded and collared at 4 separate sites (Table 4-2). I identified 29 (51.79%) adults and 27 (48.21%) goslings. Of the adults banded, there were 8 (27.59%) males, 17 (58.62%) females and 4 (13.79%) undetermined sex. Of the goslings banded, there were 5 (18.52%) males, 14 (51.85%) females and 8 (29.63%) undetermined sex. An additional 15 geese captured had bands/collars replaced from 2009.

Table 4-1. Canada goose banding results within Indian Bend Wash study area, Scottsdale, Arizona during the 2009 capture season.

Banding Date	Banding Site	Total Geese	Adults	Male Female Undetermined	Goslings	Male Female Undetermined
22 May 09	McCormick Ranch – Camelback Lake	28	12	6 5 1	16	2 7 7
22 May 09	McCormick Ranch – Camelback Lake – North	1	1	1 0 0	0	0 0 0
27 May 09	Chaparral Park	61	51	27 24 0	10	0 0 10
12 June 09	Continental Villas East II	30	22	12 10 0	8	4 3 1
19 June 09	McCormick Ranch – Camelback Lake	14	6	2 4 0	8	1 4 3
26 June 09	Chaparral Park	17	7	0 7 0	10	4 6 0
26 June 09	Vista del Camino Park – McKellips Lake – North	39	24	14 10 0	15	3 12 0
13 July 09	Chaparral Park	11	4	1 3 0	7	0 7 0
2009 Total		201	127	63 63 1	74	14 39 21

Table 4-2. Canada goose banding results within Indian Bend Wash study area, Scottsdale, Arizona during the 2010 capture season.

Banding Date	Banding Site	Total Geese	Adults	Male Female Undetermined	Goslings	Male Female Undetermined
12 June 10	Chaparral Park	27	11	3 6 2	16	3 6 7
27 June 10	McCormick Ranch – Camelback Lake – North	15	9	1 7 1	6	1 5 0
27 June 10	Vista del Camino Park – McKellips Lake – North	9	9	4 4 1	0	0 0 0
27 June 10	Vista del Camino Park – North	5	0	0 0 0	5	1 3 1
2010 Total		56	29	8 17 4	27	5 14 8

Nesting

The nesting timeline was very similar in 2009 and 2010. The earliest observation of Canada geese nesting on the island in Chaparral Lake was on 5 March 2009. Nesting began a week earlier in 2010 with the earliest occurrence of nesting on 27 February 2010. For both years, the first brood was estimated to have hatched in the last week of March. The last hatching event was estimated to be 4 May in both 2009 and 2010.

In 2009, observations of goslings suggest nesting attempts occurred at 3 locations: Chaparral Park, Coronado Golf Course and McCormick Ranch – Camelback Lake. However, I only located and monitored nests at Chaparral Park. Chaparral Park was the primary nesting location within the study area in both years of this study; all nesting at this site occurred on the island in Chaparral

Lake. In 2009, I documented and monitored 16 nesting attempts at this location. The mean clutch size for all nests at Chaparral Park was 7.81 ± 0.89 eggs. One of the successful nests belonged to a hybrid pair (Canada goose female nesting with Canada goose-domestic goose hybrid male). Abandonment was the predominant cause of nest failure (66.67% of failed nests) (Table 4-3).

In 2010, I observed nesting attempts at 4 locations within the study area: Chaparral Park, Coronado Golf Course, McCormick Ranch – Camelback Lake – North , and Vista del Camino Park – North. An additional nest belonging to a collared pair was monitored at Agua Caliente Center, located just outside of the study area. Observations of goslings at McCormick Ranch – Camelback Lake suggest nesting also occurred at this location.

At Chaparral Park I documented and monitored 17 nesting attempts. Six of these nests were lost to human disturbance (eggs removed) midway through the nesting season on 10 April 10 2010. Consequently, I only considered the 11 remaining nests for nest calculations. In 2010, mean clutch size was lower than 2009 at 6 ± 0.73 eggs. Nest success rate between 2009 and 2010 was not significantly different ($P < 0.10$) (Table 4-3). Of the 4 nests that failed in 2010, 3 were late nesting attempts after the 10 April 2010 human disturbance event to island nests.

Table 4-3. Results of nesting attempts at Chaparral Park during the 2009 and 2010[a] nesting season

Year	Total Nests	Successful Nests	Number Goslings	Failed due to Abandonment	Failed due to Infertility	Failed due to Unknown Reason	Unknown Outcome
2009	16	9 (56.25%)	35	4	1	1	1
2010	11	7 (63.64%)	35	2	1	1	0

[a] Includes nest of 1 hybrid pair (Canada goose female nesting with Canada goose-domestic goose hybrid male in 2009, 2010).

In addition to the 6 nests lost to human disturbance at Chaparral Park, the nest at Agua Caliente complex and the nest at Coronado Golf Course were also lost to human disturbance. None of these nests were included in analysis. Of the 13 remaining nesting attempts throughout the study area (including Chaparral Park) in 2010, the mean clutch size was 5.46 ± 0.86 eggs (Table 4-4). Eight (61.54%) observed nests were successful (Table 4-4). The nest I located at Vista del Camino Park – North was successful with 100% hatch rate. Of the 56 eggs laid in successful nests, 40 (71.43%) hatched with a mean 5.00 ± 0.68 eggs hatching per successful nest. The nest I located at McCormick Ranch – Camelback Lake – N. was abandoned during building.

Table 4-4. Results of nesting attempts throughout the Indian Bend Study Area , Scottsdale, Arizona (including Chaparral Park) during the 2010 nesting season [a].

Total Nests	Successful Nests	Clutch Size	No. Eggs to Hatch per Successful Nest
13	8 (61.54%)	$\bar{x}$ = 5.46, SE = 0.86	$\bar{x}$ = 5.00, SE = 0.68

In 2009, 4 of the goslings that fledged from successful nests were Canada goose-Domestic goose hybrids. Discounting these hybrids, an estimated 35 Canada goslings fledged from 8 nests with an average of 4.38 ± 0.78 goslings per brood. I observed the first brood of 2 goslings at Camelback Park on 30 March

2009, this brood originated from a nest on the island at Chaparral Park (Camelback and Chaparral Parks are adjacent sites separated by Chaparral Rd). The most goslings I observed on a given date originating from Chaparral Park were 27 Canada goslings and 4 domestic-Canada hybrid goslings (originating from a single nest) on 4 May 2009. There was no significant difference in the number of goslings or number of broods produced between years ($P < 0.10$).

In 2009, 27 goslings were banded at Chaparral Park (Table 4-5). Eight goslings (2 broods), originating from suspected unlocated nests at Coronado Golf Course, were observed and banded at Continental Villas East II. I observed goslings at McCormick Ranch – Camelback Lake in both 2009 and 2010 though I did not locate any successful nests in this area. In 2009 24 goslings were banded at McCormick Ranch – Camelback Lake. Fifteen goslings were banded at Vista del Camino Park on 26 June 2009, though there was no indication breeding occurred here. By this date gosling morphology was similar to that of the adults, thus limiting the ability to determine brood size

Despite the loss of 6 nests in 2010, the same number of goslings fledged from Chaparral Park nests as in 2009 with an estimated 35 goslings fledging from the 7 successful nests. Average brood size in 2010 was 5.00 ± 0.79 goslings. The first brood of 6 goslings was observed at Chaparral Park on 2 April 2010. The most goslings observed on a given date originating from Chaparral Park were 28 Canada goslings and 2 domestic goslings (originating from Canada goose nests) on 8 May 2010. Sixteen goslings were banded here (Table 4-5).

Table 4-5. Gosling production by study site within the Indian Bend Wash study area Scottsdale, Arizona during the 2009 and 2010 breeding seasons.

Study Site	Year	Number of goslings[a]	Number of broods	Mean brood size	Number of goslings banded
Chaparral Park	2009	31[b]	6	5.17	27
	2010	35[c]	7	5	16
Coronado Golf Course	2009	8	2	4	8
	2010	0	0	0	0
McCormick Ranch – Camelback Lake	2009	22	3	7.33	24
	2010	6	1	6	6
Vista del Camino Park[d]	2009	0	0	0	15
	2010	5	1	5	5
All Sites	2009	61	11[e]	5.5[f]	74
	2010	41	8	5.13	27

[a] 2009: Maximum number of goslings observed at each site on a given date; 2010: Total number of goslings observed
[b] Includes 4 goslings of 1 hybrid pair (Canada goose female nesting with Canada goose-domestic goose hybrid male
[c] Includes 2 domestic goslings from Canada goose nests
[d] Includes 2 adjacent sites: Vista del Camino Park – McKellips Lake – North, Vista del Camino Park – North
[e, f] Excludes Vista del Camino Park where data not available

In 2010, 6 goslings (a single brood) originating from an unlocated nest were observed and banded at McCormick Ranch – Camelback Lake. In 2010, one brood of 5 goslings originating from a nest at Vista del Camino Park – North was monitored and banded.

Analysis of variance showed no significant difference ($P < 0.10$) in either the number of goslings or number of broods between years. There was also no significant difference found between sites, though both approached significance ($P = 0.1358$ and $P = 0.1068$, respectively). While there appears to be a difference in the number of goslings and number of broods between sites, there was too much variation in the data to be able to isolate these differences. Analysis of variance did show a significant difference ($P < 0.05$) in the number of goslings banded between years and sites. Banding results more accurately reflect the number of goslings produced in the Indian Bend Wash study area since not all nests and young goslings were located.

Population Estimates and Growth

From October 2008 to September 2010, I surveyed 28 sites throughout the study area (Table 3-1). Daytime surveys were conducted for the entire period of the study while predawn surveys began in June 2009 with the initiation of banding. I detected Canada geese at 24 of the 28 study sites. I made 884 daytime observations and 396 predawn observations of Canada geese.

I calculated resighting probability estimates for collared geese for each survey site beginning in June 2009 and averaged estimates by month. Resighting probabilities were then used to generate adjusted daytime estimates for Canada goose count data prior to banding in June 2009 (Figure 4-1).

Seasonal Variation in Population Numbers. – During the winter months of both years migrant Canada geese joined the resident population in the Indian Bend Wash study area. Migrants began arriving at the end of November and started to depart in the beginning of February. Canada goose numbers reflect the addition of migrants, peaking in January of 2009 and 2010. During the first year of the study (October 2008 to September 2009), population estimates were lowest in June 2009. During the second year of the study (October 2009 – September 2010), population estimates were lowest in March 2010. (Table 4-6, Table 4-7, Fig. 4-1, Fig. 4-2).

Using Analysis of Variance (ANOVA), I determined the number of geese detected varied significantly with season ($P < 0.001$) as well as between predawn and daytime surveys ($P < 0.01$). There was not a significant difference ($P < 0.10$) between years or season:year interactions.

There were 17 known mortalities of collared geese during the study. The highest cause of mortality was removal by Wildlife Services ($n = 8$, 47.06%). Removals took place at various locations outside of the study area. Four geese (23.53%) were found dead from unknown causes. One of these appeared to be due to a possible coyote attack at the Chaparral Park – West site. Two geese (11.76%) were hit by cars in the Chaparral Park area. There was one (5.88%) hunter harvested goose taken near Roosevelt Lake, AZ. Finally, 2 geese (11.76%) sustained injuries and were euthanized at a local rehabilitation center.

Table 4-6. Mean monthly predawn estimates of Canada geese within the Indian Bend Wash study area, Scottsdale, Arizona from June 2009 to September 2010.

	June 2009 to Sept. 2009[a]		Oct. 2009 to Sept. 2010	
Survey month	$\bar{x}$	SE	$\bar{x}$	SE
October			571	110.37
November			530	21.07
December			1260	217.18
January			2420	536.93
February			1746	725.53
March			305	23.85
April			343	27.29
May			406	28.78
June	244	12.09	357	50.10
July	284	28.32	409	53.26
August	404	49.64	591	28.63
September	459	11.15	585	51.02

[a]Predawn surveys began in June 2009 with the initiation of banding

Figure 4-1. Mean monthly predawn estimates of Canada geese within the Indian Bend Wash study area, Scottsdale, Arizona from June 2009 to September 2010.

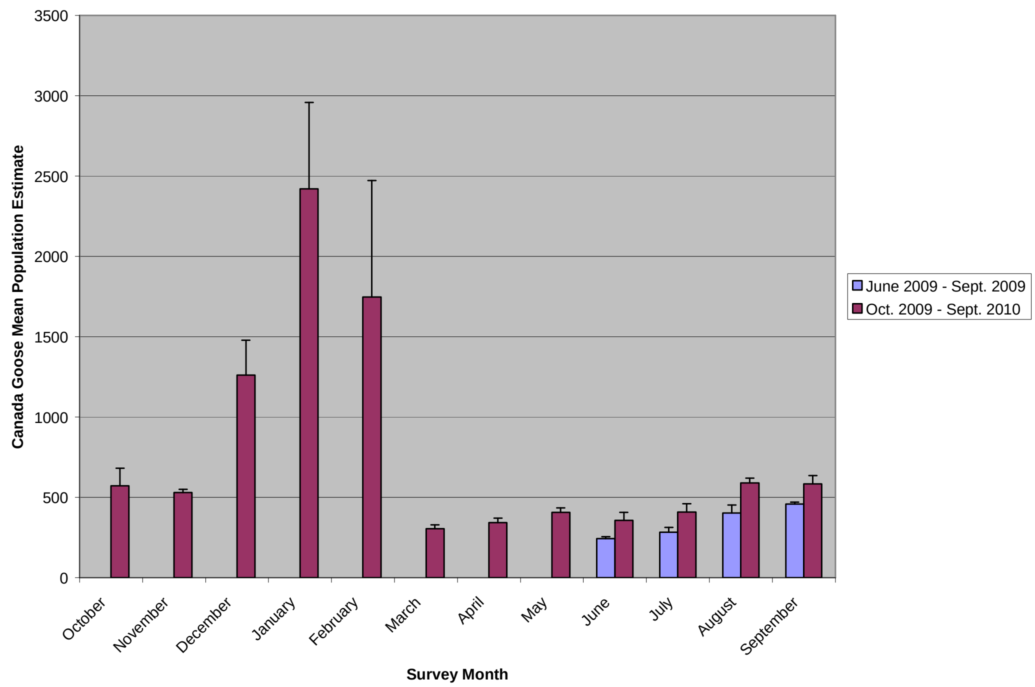
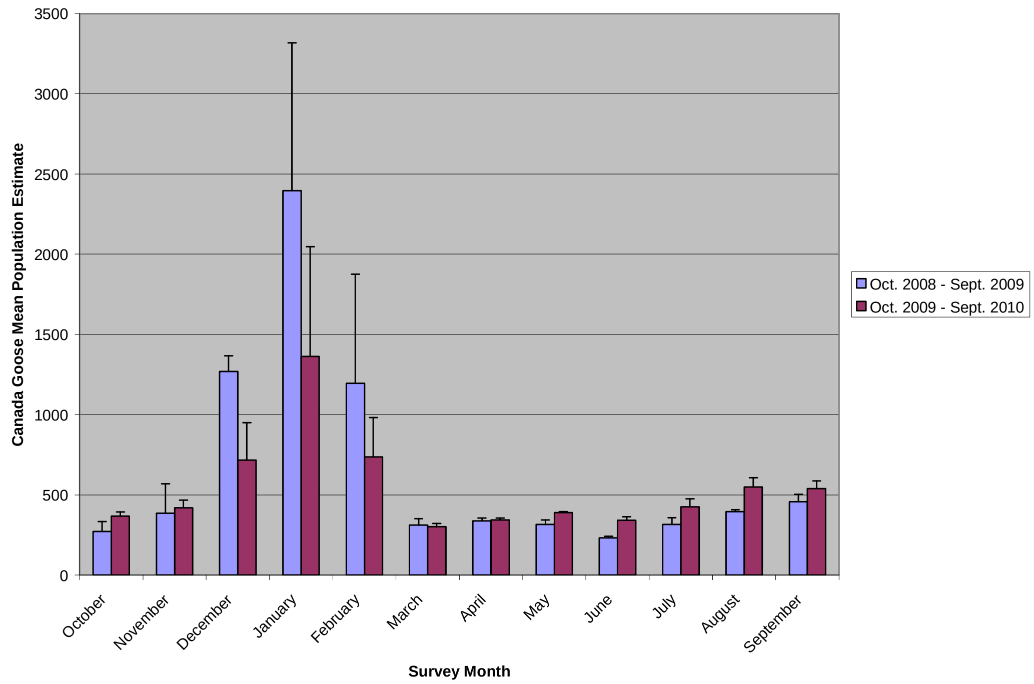


Table 4-7. Mean monthly daytime estimates of Canada geese within the Indian Bend Wash study area, Scottsdale, Arizona from June 2009 to September 2010.

	Oct. 2008 to Sept. 2009		Oct. 2009 to Sept. 2010	
Survey Month	$\bar{x}$	SE	$\bar{x}$	SE
October	272	60.95	367	27.18
November	384	184.73	419	48.18
December	1270	96.74	717	231.73
January	2395	922.18	1363	684.12
February	1196	680.00	737	245.65
March	311	39.62	303	18.37
April	338	16.02	343	12.65
May	315	27.55	390	5.58
June	232	9.48	342	20.15
July	315	42.70	426	48.25
August	395	10.81	549	57.19
September	457	46.62	539	48.86

Figure 4-2. Mean monthly daytime estimates of Canada geese within the Indian Bend Wash study area, Scottsdale, Arizona from October 2008 to September 2010.



I calculated population growth rate from 2009 to 2010 by comparing June 2009 population estimates, which include 2009 goslings, to June 2010 population estimates as calculated using adults only (Table 4-8). Based upon predawn surveys, there was a 24.85% (n = 60) population increase between the 2 study years. Daytime survey results yielded a slightly lower population increase of 15.42% (n = 35). The population growth based on both predawn and daytime surveys was significant at $P < 0.10$ (Table 4-8). I also calculated population growth estimate based upon natality, mortality, immigration and emigration. This method showed no net change. Natality rate using the production of 74 goslings banded in 2009 was 30.29% or 31.78% (depending on predawn or daytime surveys). There were 15 known mortalities from June 2009 to June 2010 resulting in mortality rate of 6.14% or 6.44%, predawn or daytime survey, respectively. The immigration rate was estimated 1.87% or 12.46%, predawn or daytime population estimates, respectively, based on number of new adult geese collared in 2010 (n = 29). Emigration was estimated to be 36.02% or 37.80% (predawn or daytime surveys) based upon number of collared geese not seen in June 2010 (n = 88) excluding known mortalities.

Table 4-8. Population change of resident Canada geese in the Indian Bend Wash study area from June 2009 to June 2010.

	Month/Year			
Survey Period	June 2009	June 2010	Population Change	P-value[a]
Predawn	$\bar{x}$ = 244	$\bar{x}$ = 305	n = 61 (24.92%)	0.0785
Daytime	$\bar{x}$ = 232	$\bar{x}$ = 268	n = 36 (15.52%)	0.0979

[a]Level of significance for population increase

Population Distribution and Movement

For movement analysis, I broke the study area into 4 primary home areas: McCormick Ranch area, Chaparral Park area, Continental Golf Course, and South End area (Table 3-1). Geese were assigned to a home area if they spent greater than 50% of their time in that area, regardless of where they were banded. This was determined by analyzing sighting records from survey data.

ANOVAs showed that the distribution of geese at different sites and home areas within the Indian Bend Wash study area varied significantly across seasons ($P < 0.001$) and between predawn and daytime surveys ($P < 0.01$). Tukey Multiple Range

Tests showed that for each home area the mean estimated number of Canada was significantly different (P < 0.10) from every other home area for each season during both predawn and daytime surveys. The Chaparral Park and McCormick Ranch areas consistently had the highest numbers of geese across all seasons during the 2 year study for both predawn and daytime surveys (Table 4-9, Table 4-10, Appendix B, Figs. B-1 to B-10). McCormick Ranch areas had significantly higher (P < 0.10) numbers of geese during the fall and winter predawn surveys than any other home area indicating high usage by winter migrants (Table 4-9). During the daytime, the highest numbers of geese were consistently located at Chaparral Park with the exception of Fall 2009 (Table 4-10).

Table 4-9. Mean seasonal predawn distribution of Canada geese within the Indian Bend Wash study area Scottsdale, Arizona from Summer 2009 through Summer 2010[a].

Home Area	Season				
	Summer 2009	Fall 2009	Winter 2009-2010	Spring 2010	Summer 2010
South End	54.18	35.01	31.97	21.74	88.37
Chaparral Park	147.88	144.13	199.16	250.05	202.24
McCormick Ranch	106.93	368.60	1582.75	77.19	171.20

[a]Due to the timing of this study Fall 2010 consisted of one month (September 2010) so it was not included in this analysis.

Table 4-10. Mean seasonal daytime distribution of Canada geese within the Indian Bend Wash study area Scottsdale, Arizona from Summer 2009 through Summer 2010 [a].

Home Area	Season				
	Summer 2009	Fall 2009	Winter 2009-2010	Spring 2010	Summer 2010
South End	58.91	33.46	41.30	18.35	87.05
Continental Golf Course	8.22	57.20	92.30	22.26	29.42
Chaparral Park	143.30	147.72	515.29	230.98	176.15
McCormick Ranch	104.16	167.27	231.14	60.48	137.62

[a]Due to the timing of this study Fall 2010 consisted of one month (September 2010) so it was not included in this analysis.

Significant Movement. – I considered any trips outside of the Indian Bend Wash study area significant movements (Appendix C). All significant movements included in movement analyses were within Arizona. Information on significant movements was based on reported sightings of collared geese outside the study area made by volunteers from the public.

Volunteers from the public reported 123 sightings of collared geese outside of the study area as a result of multiple sightings of the same geese. Of the 2009 collared geese, 70 (42.17%) geese made 78 known trips outside of the study area. No known significant movements were made by geese collared in 2010. Eighteen (48.65%) of the 37 McCormick Ranch area geese collared in 2009 were reported outside of the study area. Three were reported making multiple trips out of the study area, resulting in 21 reported sightings (Table 4-11). Twenty-six (33.77%) of the 77 Chaparral Park area geese collared in were reported outside of the study area. Five of these geese were sighted multiple times within a trip, while one goose made multiple trips, resulting in 27 outside sightings. While there appeared to be variation in the number of movements between seasons and between home areas, an ANOVA showed no significant difference for either ($P < 0.10$).

I examined the demographics of geese making significant movements. Neither the sex nor age (collared as gosling or as adult) of geese moving outside of the study area was found to be statistically significant ($P < 0.10$).

Table 4-11. Frequency and proportion of seasonal movements made outside the Indian Bend Wash study area, Scottsdale, Arizona by collared Canada geese for each home area from June, 2009 to September 2010.

Home Area	Season					
	Summer 2009	Fall 2009	Winter 2009-2010	Spring 2009-2010	Summer 2010	Total
McCormick Ranch	0	6 (28.57%)	2 (9.52%)	13 (61.91%)	0	21
Chaparral Park	1 (2.78%)	18 (50.00%)	9 (25.00%)	6 (16.67%)	2 (5.56%)	36
South End	0	13 (19.70%)	30 (45.46%)	20 (30.31%)	3 (4.55%)	66
Total	1	37	41	39	5	123

I estimated the distance travelled from the individual goose's primary home area to the farthest destination on each trip out of the study area to the nearest km using ArcGIS 10® (Table 4-11). The minimum known distance travelled was 4 km while the maximum known distance travelled was 74 km. The mean distance for all 78 trips was 15 km. Geese travelled to 25 known destinations in all directions; most destinations were to the southeast of the study area (44.00%, n = 11) (Fig. 4-3). The most common destination for all geese was Gilbert Water Ranch (35.90%, n = 28).

There was some variation in the destinations and distances travelled outside the study area between geese from the 3 different home areas (Table 4-12). Taking all trips into consideration, Chaparral Park area geese travelled a significantly greater distance ($P < 0.01$) than South End area geese. There was not a significant difference in the distances travelled between McCormick Ranch area geese and either Chaparral Park or South End area geese at $P < 0.10$. The maximum distance travelled by McCormick Ranch area geese was 30 km to Arrowhead Country Club in Glendale. The minimum distance travelled was 4 km to a location (Agua Caliente) just outside of the study area where a known nesting attempt occurred. Geese leaving the study area travelled in multiple directions from McCormick Ranch, most commonly to the southeast (38.10%, n = 8) (Fig. 4-3). Geese were reported at 9 destinations outside of the study area, of which the most frequent destinations were Agua Caliente to the northwest and Gilbert Water Ranch to the southeast (28.57%, n = 6 for both locations).

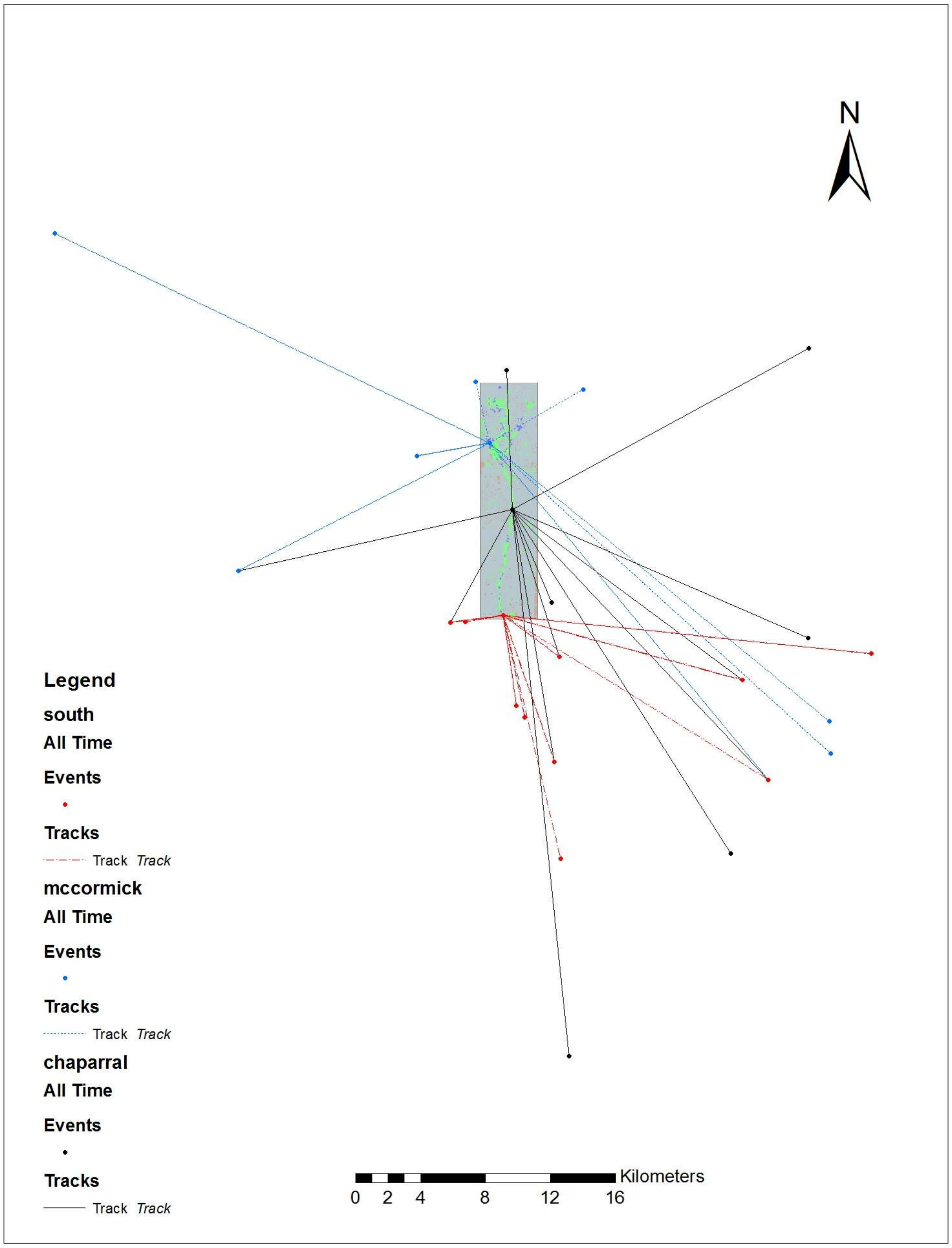
Table 4-12. Distances travelled by resident Canada geese outside of Indian Bend Wash study area, Scottsdale, Arizona.

	McCormick Ranch	Chaparral Park	South End
Min Distance (km)	4	6	3
Max Distance (km)	30	34	74
Mean Distance (km)	15	20	12

The maximum distance travelled by Chaparral Park area geese was 34 km to Sun Lakes Golf Club in Sun Lakes while the minimum distance travelled was 6 km to the Phoenix Zoo (Table 4-12). Geese leaving the study area travelled in multiple directions from Chaparral Park. As seen for McCormick Ranch geese, the most common direction travelled was southeast (81.48%, n = 22) (Fig. 4-3). The Chaparral Park geese were reported at 12 destinations outside of the study area, most commonly Gilbert Water Ranch to the southeast (59.26%, n = 16) (Fig. 4-3).

The maximum distance travelled by South End area geese was 74 km to Roosevelt Lake while the minimum distance travelled was 3 km to the Phoenix Zoo (Table 4-12). Geese leaving the study area travelled in multiple directions from the South End area. As seen for McCormick Ranch and

Figure 4-3. Movements of Canada geese outside the Indian Bend Wash study area, Scottsdale, Arizona from June 2009 to September 2010, originating from each home area[a].



[a]Map only includes destinations within the Phoenix, Arizona metropolitan area.

Chaparral geese, the most common direction travelled was southeast (53.33%, *n* = 16). Geese from this area were observed at 13 destinations outside of the study area, of which the most frequent destination was the Phoenix Zoo to the west (26.67%, *n* = 8).

McCormick Ranch area geese returned to the study area 85.71% (*n* = 18) of the time. Two of the 3 geese that failed to return were confirmed mortalities at their destination. Chaparral Park area geese returned to the study area 96.30% (*n* = 26) of the time. South End area geese had the lowest rate or return to the study area: 30.00% (*n* = 9) failed to return, with 8 of the 9 resulting from mortalities outside of the study area.

Movements within Study Area. – Only 4.22% (*n* = 7) of geese collared in 2009 were never seen outside of their home area. Of these geese, 3 originated from McCormick Ranch area, 3 originated from Chaparral Park area, and one originated from the South End area. All 7 geese were adults: 4 females, 2 males, and one of undetermined sex. Three of the 7 geese nested in 2010. An additional 8 geese (4.82%) were never seen outside of their home area *inside* the study area but were reported *outside* of the study area. Five of these geese originated from McCormick Ranch area while 3 originated from the South End area. There was no significant statistical difference ($P < 0.10$) between sex and age of these geese.

Twenty-seven (52.94%) of geese collared in 2010 were never seen outside of their home area. None of the 11 geese originating from McCormick Ranch area and 91.67% (*n* = 11) of the geese originating from the South End area were ever seen outside of their home areas. Chaparral Park area geese had much more movement than the other areas; only 17.86% (*n* = 5) of these geese never left their home area. As with 2009 geese, there was no significant statistical difference between either sex or age of geese that remained in their home areas.

Table 4-13. Frequency and proportion of monthly movements made inside the Indian Bend Wash study area, Scottsdale, Arizona by collared Canada geese for each home area from June, 2009 to September 2010.

	McCormick Ranch area		Chaparral Park area		South End area		Total	
Month	*n*	%	*n*	%	*n*	%	*n*	%
Jun 2009	11	11.70	2	0.65	2	1.09	15	2.56
July 2009	12	12.77	19	6.15	39	21.31	70	11.95
Aug 2009	7	7.45	5	1.62	16	8.74	28	4.78
Sept 2009	1	1.06	16	5.18	29	15.85	46	7.85
Oct 2009	2	2.13	41	13.27	3	1.64	46	7.85
Nov 2009	3	3.19	20	6.47	20	10.93	43	7.34
Dec 2009	17	18.09	49	15.86	11	6.01	77	13.14
Jan 2010	0	0.00	28	9.06	2	1.09	30	5.12
Feb 2010	10	10.64	12	3.88	1	0.55	23	3.92
March 2010	10	10.64	13	4.21	15	8.20	38	6.48
April 2010	3	3.19	14	4.53	9	4.92	26	4.44
May 2010	2	2.13	8	2.59	4	2.19	14	2.39
June 2010	3	3.19	7	2.27	1	0.55	11	1.88
July 2010	4	4.26	12	3.88	11	6.01	27	4.61
Aug 2010	6	6.38	22	7.12	13	7.10	41	7.00
Sept 2010	3	3.19	41	13.27	7	3.83	51	8.70
Total	94	100.00	309	100.00	183	100.00	586	100.00

A total of 560 inside movements were recorded for 166 geese collared in 2009, occurring during all months of the study (Table 4-13). Most movements occurred in December 2009 closely followed by July 2009. Most inside movements occurred in fall and winter with approximately the same number of movements occurring in these 2 seasons. There were some differences between movement patterns of geese originating from the 3 home areas (Table 4-14).

McCormick Ranch area geese and Chaparral Park area geese had the most movements during December 2009, as was seen for all geese combined. South End area geese moved the most during July 2009.

Table 4-14. Frequency, proportion and distance of movements made by Canada geese collared in 2009 to destinations inside the Indian Bend Wash study area, Scottsdale, Arizona for each home area from June 2009 to September 2010.

Home Area	Destination	*n*	%	Distance (km)
McCormick Ranch	Chaparral Park	54	57.45	4
	Continental Golf Course	10	10.64	7
	South End	20	21.28	10
	Scottsdale Pavilions	10	10.64	3
	Total	94	100.00	
Chaparral Park	Continental Golf Course	207	65.85	2
	South End	57	18.66	6
	McCormick Ranch	44	15.14	4
	Scottsdale Pavilions	1	0.35	3
	Total	309	100.00	
South End	McCormick Ranch	34	18.68	10
	Chaparral Park	71	38.46	6
	Continental Golf Course	78	42.86	3
	Scottsdale Pavilions	0	0.00	9
	Total	183	100.00	

Geese collared in 2009 primarily moved to neighboring areas (Table 4-14). McCormick Ranch area geese had the most movements to the Chaparral Park area, a 4 km trip. Trips to Chaparral Park accounted for 57.45% (n = 54) of McCormick Ranch area geese’s within study area movements. Similarly, Chaparral Park area geese were most often seen at Continental Golf Course, a 2 km trip (85%, n = 187). South End area geese moved to 2 areas on a frequent basis: Continental Golf Course (3 km away) and Chaparral Park (6 km away).

Movements to these 2 locations accounted for 42.86% (*n* = 78) and 38.46% (*n* = 70) of all South End area goose movements, respectively.

Geese collared in 2010 made very few known movements out of their home areas (Table 4-15). Overall, there were 26 inside the Indian Bend Wash study area movements recorded for the 51 geese included in movement analyses. None of the geese originating from McCormick Ranch left their home area, and only one goose left the South End area with a destination of the Chaparral Park area, a distance of 6 km. Geese originating from Chaparral Park made substantially more movements (n = 25) inside the study area. The most frequent destination of the Chaparral Park area geese was the Continental Golf Course (80%, *n* = 20), a distance of 6 km (Table 4-15).

Table 4-15. Frequency, proportion and distance of movements made by Canada geese collared in 2010 to destinations inside the Indian Bend Wash study area, Scottsdale, Arizona for each home area from June 2010 to September 2010.

Home Area	Destination	*n*	%	Distance (km)
McCormick Ranch	Chaparral Park	0	0.00	4
	Continental Golf Course	0	0.00	7
	South End	0	0.00	10
	Scottsdale Pavilions	0	0.00	3
	Total	0	0.00	
Chaparral Park	Continental Golf Course	20	80.00	2
	South End	4	16.00	6
	McCormick Ranch	1	4.00	4
	Scottsdale Pavilions	0	0.00	3
	Total	25	100.00	
South End	McCormick Ranch	0	0.00	10
	Chaparral Park	1	100.00	6
	Continental Golf Course	0	0.00	3
	Scottsdale Pavilions	0	0.00	9
	Total	1	100.00	

DISCUSSION

Nesting

Nesting primarily occurred at Chaparral Park in both study years. All observed nesting attempts at this site occurred on a small (2207 m^2) island. Other studies have found Canada geese prefer to nest on islands rather than on mainland (Bruggink et al. 1994; Gosser and Conover 1999; Raveling 1981). Islands provide safety from mammalian predators, and in urban settings provide refuge from humans and dogs.

Gosser and Conover (1999) found that availability of insular nesting sites did not limit reproduction of an urban Canada goose population in Connecticut as a result of low predation rates on mainland nests. There was no indication in this study of nest predation and there was limited evidence of mammalian predation on adults, indicating that predation pressure was low within the Indian Bend Wash study area. This suggests Canada geese may preferentially nest on Chaparral Island to avoid human disturbance. Eight nests throughout the study area were lost to human disturbance and not included in nest success calculations, further supporting the hypothesis that geese nested in insular sites to avoid humans. The Indian Bend Wash study area likely has a much higher level of human use than Gosser and Conover's (1999) study sites. I observed a very low proportion of adults nesting, which may further indicate that the availability of safe, primarily insular, nesting sites may be limiting reproduction of this population.

Chaparral island nests had a mean clutch size of 7.81 ± 0.89 in 2009 and 6.00 ± 0.73 in 2010 compared to the average clutch for Canada geese of just over 5 eggs (Smith et al. 1999, Ogilvie 1978). A possible explanation for the increased clutch size is 'dump' nesting. Egg-dumping is known to occur in Canada geese, especially in southern breeding populations (Mowbray et al. 2002). In colonial nesting situations with limited nest site availability, crowded conditions may cause greater amount of territorial disputes and females may be forced to lay eggs wherever she can, including in another nest (Ogilvie 1978). On Chaparral Island, nest density was high and included both Canada goose and domestic goose nests. There were also many additional eggs scattered around the island unassociated with a nest which could further indicate the occurrence of egg-dumping. However, it is unknown to what extent these dumped eggs belonged to Canada geese versus domestic geese as both were nesting on the island.

Abandonment was the predominant cause of nest failure (66.67%) further indicating that over crowding on the island caused conflicts between nesting pairs leading to the abandonment of nests (Ogilvie 1978). There was no sign of predation on nests though it is possible that it went undetected. Island nests are protected from mammalian predators and there was no indication of any adults killed while incubating eggs.

Overall nest success rate averaged 59.94% ± 3.70% for 2009 and 2010. Other studies of both urban and wild Canada geese populations have reported similar nest success rates. Gosser and Conover (1991) reported 55% success for mainland nests and 65% for island nests of an urban population. Bruggink et al. (1994) reported 58.3 ± 9.9% nest success across years for a wild population.

I was unable to locate several nests within the study area in both 2009 and 2010 due to accessibility issues on large golf courses. As a result, gosling counts give a more accurate indication of recruitment into the population than does nest monitoring results. Additionally, despite the potential limitation of nesting sites within the study area, there is evidence that resident geese are nesting in areas outside of the study area. In 2009, there was a 17.57% increase in goslings identified in the study area post-nesting season. Reports of collared geese outside the study area included multiple observations of breeding at 5 locations around the Phoenix metropolitan area, including the Phoenix Zoo in Phoenix, AZ and Gilbert Water Ranch in Gilbert, AZ. Consequently, population growth rate cannot be purely attributed to recruitment from nests within the study area.

Population Estimates and Growth

During the first year of the study (October 2008 to September 2009), the month with the lowest estimated number of Canada geese (244 predawn, 232 daytime) within the study area was June 2009. At this time of the year, geese were finishing nesting and undergoing their annual molt. June to August 2009 also had the highest resight probabilities. During the second year of the study, the month with the lowest estimated number of Canada geese (305 predawn, 303 daytime) within the study area was March 2010. At this time of the year, geese were beginning to nest and beginning their molt. Data suggests that during the nesting/molting season (approximately March to July) many resident geese moved to other areas within the Phoenix metropolitan area outside of the Indian Bend study area to undergo molt and/or breed. This is supported by a number of reports of collared geese detected outside of the study area during this time period including reports of breeding at other locations. March 2010 had one of the highest numbers of reports of collared geese outside the study area. The remaining geese represent the core population of the Indian Bend Wash area, with many residents distributing to surrounding areas valley wide to molt. Population estimates gradually increased throughout the late summer/early fall months prior to the arrival of migrants as geese moved back into the study area.

The plastic neck collars used during this study were known to crack and in some cases fall off. During the 2010 banding season, 15 geese captured had bands/collars replaced from 2009. This problem with neck collar retention was likely caused by the high summer temperatures experienced in the Scottsdale study area. Potential error in population estimates and resight probability may be attributed to this issue.

During both years of the study the number of Canada geese detected within the study area peaked in January. The high number of geese during this month can be attributed to the presence of migrants and their movements in and out of the study area. There is indication that some residents departed with winter migrants. Thirty-two (16.16%) collared geese were never observed after January 2010. One goose collared as a juvenile in 2009 at McCormick Ranch was reported out of state at Johnson Lake, Banner Marsh in Illinois. The mother of this goose as well as 4 identified brood mates were also never observed after January 2010. Following the departure of the migrants, population estimates dropped substantially to core population levels of approximately 300 resident geese.

Despite limited nesting attempts within the Indian Bend Wash study area, population growth from 2009 to 2010 was estimated between 15.42% and 24.85% based on survey data. No net population change was found based on estimates using natality, mortality, and the dispersal of individuals. This may be attributed to an overestimation of emigration. As previously discussed, many geese frequently moved in and out of the study area while remaining in the greater Phoenix valley metropolitan area. Due to this pattern of intra-valley movement of geese it is very difficult to accurately estimate the magnitude of the emigration factor.

Though there is little data available in the literature on growth rate for individual urban populations, the overall resident population of Canada geese in the United States and Canada is estimated to have increased at a rate of 7.9% per year from 1980 to 2005 (Cleary et al. 2006). Other estimates of the growth rate of resident geese include 15% per year from 1990 to 1999 for the Atlantic Flyway (Atlantic Flyway Council 1999). Geese in the Indian Bend Wash population as well as other urban populations face very low mortality pressure with limited predation and the absence of hunter harvest. This is a main contributing factor to high levels of population growth for resident geese. Balkcom (2010) found that urban Canada geese have considerably higher survival rates than their rural counterparts due to lack of hunting pressure, estimating the survival rate for Canada geese in Georgia at 0.958 for an urban population compared to 0.682 for a rural population. Sheaffer et al. (2004) reported mean annual survival rates of Eastern Prairie Population Canada geese increased when hunter harvest was restricted.

Spatial Dynamics

Significant Movement – Data on outside movements was obtained from public reports alone, limiting the breadth of information and is a potential source of error. Forty-two percent of 2009 collared geese made known trips outside of the Indian Bend Wash study area, while no geese collared in 2010 were known to leave. As with limited inside movement of 2010 geese, this is most likely attributed to the fact that approximately 50% of geese collared that year were goslings and family groups were not moving during their first summer. The month during which the highest number of sightings was reported was November 2009. However it is not clear whether this reflects an actual increase in outside movements during this month or simply more birders reporting sightings at this time of year. The lowest number of outside sightings occurred in summer 2009 and 2010, corresponding with the breeding season and annual molt when fewer geese were moving from their home areas.

While geese were reported in locations throughout the Phoenix metropolitan area, the most common direction travelled by geese was southeast. The most commonly reported destination overall was Gilbert Water Ranch in the southeast valley (27 km from McCormick Ranch), a riparian reserve which attracts many water birds and bird watchers. It is clear that Indian Bend Wash geese are moving throughout the greater Phoenix area on a frequent basis and likely that geese from surrounding areas are moving in and out of the study area as well. Most reports received were of geese within the Phoenix area. However, there is indication that Indian Bend Wash geese are moving further afield. A goose collared in the South End area was hunter harvested near Roosevelt Lake, a distance of approximately 74 km to the northeast.

Indian Bend Wash geese that moved outside the study area had a high rate of return, ranging from 70.00% for South End area geese to 96.30% for Chaparral Park area geese. This indicates that this population of geese exhibits a high level of site fidelity. Geese originating from the South End area had the highest rate of movement outside of the study area and the lowest rate of return. Their high rate of movement can be attributed to their movement to the Phoenix Zoo, 3 km to the west of this area. This was the most frequent destination outside of the study area for this group of geese. The low rate of return is due to mortalities at the Phoenix Zoo. Six of 9 geese whom failed to return to the study area were removed by Wildlife Services at this location.

Inside Movement – The Chaparral Park and McCormick Ranch areas consistently had the highest numbers of geese across all seasons during the 2 year study (Appendices B-K). I typically detected winter migrants in the McCormick Ranch area. This is especially apparent in fall and winter predawn numbers as migrants roosted overnight in this area, primarily on Camelback Lake. Migrants routinely left McCormick Ranch at dawn and typically flew several km east of the study area to feed on alfalfa fields on the Salt River Pima-Maricopa Indian Community reservation. Inside the study area, I also detected large numbers of winter migrants at Camelback Park during midday, which is reflected in daytime winter distribution. During the remainder of the year, the highest numbers of residents were consistently located at Chaparral Park. This is also the site where most nesting occurred.

Geese moved throughout the study area on a regular basis year round. Geese collared in 2010 moved less than those collared in 2009; 52.94% of geese collared in 2010 were never detected outside of their home area. The limited summer movement of 2010 geese may be attributed to the high percentage of goslings collared that year. Most inside movements occurred in fall and winter. During spring and summer, geese were nesting and undergoing their annual molt, restricting their movements.

All geese included in movement analysis had an easily identifiable home area where they spent more than 50% of their time. The 3 identified home areas included sites where nesting occurred. Geese originating from all 3 home areas within the study area primarily made short movements (less than 6 km) to neighboring areas. Geese from both Chaparral Park area and South End area frequently visited Continental Golf Course which is a site located between these 2 home areas. However, no geese spent greater than 50% of their time at Continental Golf Course and no nesting occurred at this site. This pattern of movement further indicates this population has a high level of site fidelity to nesting and molting areas, as has been found in other studies of resident Canada geese. Preusser et al. (2008) found that geese usually moved less than 2 km from hazing sites and often returned multiple times after hazing. York et al. (2000) found that 20% of hazed geese returned to airports in multiple times and contributed this to habitual site use.

CHAPTER 5

HABITAT MODELING

INTRODUCTION

Though a number of management strategies have been explored, managing nuisance geese has proven difficult (see Chapter 2). Much attention has been focused on hazing techniques. However, another possible management approach is habitat modification. Habitat modification techniques include eliminating, modifying, reducing access to areas that attract geese, or making a site appear less safe for geese (Gosser et al. 1997, Smith et al. 1999). In order to identify what types of modification should be made, it is necessary to identify what specific characteristics geese are attracted to so that management can be directed at reducing those characteristics (Gosser et al. 1997, Smith et al. 1999). In broad terms, Canada geese prefer large open lawn areas associated with water (Feare et al. 1999, Smith et al. 1999). Conover and Kania (1991) examined characteristics of goose nuisance sites in Connecticut and were able to identify more specific factors affecting goose selection.

The objective of this section of the study was to develop statistical models to describe which habitat characteristics are attracting geese to specific sites within the Indian Bend Wash area. Resident geese utilize this area year round for multiple purposes including nesting, roosting and feeding. I developed models to explain goose site selection for each of 4 home areas within the study area (each home area encompasses multiple adjacent sites) for both predawn and daytime survey periods. I identified primary behaviors at each site to determine how geese are using specific sites allowing better understanding of why specific habitat characteristics are attracting or detracting from individual sites.

RESULTS

Habitat Characteristic Selection

Using analysis of variance (ANOVA), I determined that there was a significant difference ($P < 0.001$) in Canada goose usage of individual sites within the study area for both the predawn and daytime survey periods. Once this was established, I developed a total of 28 linear regression models to explain goose selection criteria. I considered 8 habitat characteristics (Table 5-1) to develop a habitat model for the 4 home areas within the study area. Refer to Table 3-1 for a list of which sites were included in each home area. All models were significant, as were all independent variables included in the 28 models ($P < 0.10$).

Table 5-1. List of habitat measurements taken in the Indian Bend Wash study area, Scottsdale, Arizona used for habitat modeling.

Measurement	Description
Min FCA	Minimum flight clearance angle measured from center of lake in 8 cardinal directions
Max FCA	Maximum flight clearance angle measured from center of lake in 8 cardinal directions
Avg FCA	Average of all flight clearance angles measured from center of lake in 8 cardinal directions
Lake	Area of lake
Land Use	Type of property: city park, community golf course, private residential property or public golf course
Edge	Presence or absence of hard concrete edge around lake
Distance to Road	Distance to nearest road from center of lake
Lawn	Area of lawn associated with lake (lawn area may encompass multiple lakes)

All predawn habitat models developed for the South End area were highly significant ($P < 0.001$) but had limited explanatory power. The winter model had the highest adjusted R^2 (0.453) suggesting this model explained 45.33% of variation in goose numbers. The spring model explained the least amount of variation (Adjusted $R^2 = 0.107$). During the predawn survey period, lake area was found to influence goose site selection during all 4 seasons for the South End area (Table 5-2). In 3 of the 4 season models, property type and average FCA had a significant effect on goose numbers.

Table 5-2. Habitat selection models by season and survey time for Canada geese using the South End home area of the Indian Bend Wash study area from October 2008 to September 2010.

Spring	Predawn	Ŷ=7.666 + 2.985e-04(Lake) - 3.433(Land Use) df = 74, SE = 8.233, Adj R^2 = 0.107, P = 5.790e-03
	Daytime	Ŷ = -6.014e+01 - 6.245e-01(Max FCA) + 3.582(Avg FCA) + 7.917e-04(Lake) + 5.252(Land Use) + 8.692(Edge) df = 78, SE = 8.064, Adj R^2 = 0.142,P = 4.280e-03
Summer	Predawn	Ŷ = 1.518e+02 - 3.775(Min FCA) -5.802(Avg FCA) -1.563e-03(Lake) – 1.642e+01(Land Use) df = 163, SE = 21.79, Adj R^2 = 0.187, P = 1.155e-07
	Daytime	Ŷ = 11.069 + 3.125(Min FCA) + 1.016(Max FCA) - 5.118(Avg FCA) + 7.529(Land Use) df = 171, SE = 21.59, Adj R^2 = 0.100, P = 1.921e-04
Fall	Predawn	Ŷ = 72.53 - 4.903(Avg FCA) - 7.274e-04(Lake) df = 109, SE = 17.2, Adj R^2 = 0.250 P = 5.91e-08
	Daytime	Ŷ = -16.477 + 3.968e-01(Max FCA) + 5.402(Land Use) df = 109, SE = 21.12, Adj R^2 = 0.035, P = 0.054
Winter	Predawn	Ŷ = 1.204e+01 + 5.811(Min FCA) + 1.394(Max FCA) - 6.346(Avg FCA) + 1.042e-03(Lake) + 7.458(Land Use) - 1.413e+01(Edge) df = 77, SE = 8.591, Adj R^2 = 0.453 P = 9.122e-10
	Daytime	Ŷ = -1.245e+02 + 1.164e+01(Min FCA) + 4.641e-01(Max FCA) + 2.167e-03(Lake) + 1.990e+01 df = 79, SE = 11.43, Adj R^2 = 0.507 P = 2.262e-12

Consistent with predawn models for the South End area, all daytime models were significant ($P < 0.10$). The fall model had the lowest significance of all South End models ($P = 0.054$). It also had the lowest explanatory power, only explaining 3.47% of variation in goose numbers. As seen with predawn models, the winter model explained the most variation (adjusted $R^2 = 0.507$). During the daytime survey period, maximum FCA had a significant effect on goose numbers during all 4 seasons for the South End area (Table 5-2). As with predawn models, property type was included in 3 of the 4 season models.

The Continental Golf Course area was only surveyed during the daytime so no predawn models were developed for this area. For the fall survey period, none of the considered habitat characteristics were found to influence goose selection so no model was developed. The 3 models that were developed for this area were all significant ($P < 0.05$) (Table 5-3). However, of the 4 home areas, the Continental Golf Course area habitat models had the lowest explanatory power. The spring and summer models explained less than 10% of variation in goose numbers for this area. Maximum FCA had a significant negative effect on goose numbers for the 3 models developed.

All predawn habitat models developed for the Chaparral Park area were highly significant ($P < 0.001$) and had high explanatory power (Table 5-4). The adjusted R^2 values ranged from 0.695 for the fall model to 0.954 for spring. Both the spring and winter models explained over 90% of variation in goose numbers. Minimum and maximum FCA had a significant negative effect on goose numbers for all seasons.

Table 5-3. Habitat selection models by season and survey time for Canada geese using the Continental Golf Course home area of the Indian Bend Wash study area from October 2008 to September 2010.

Spring	Daytime	$\hat{Y}$ = 32.3359 - 1.231(Max FCA) df = 22, SE = 12.16, Adj R^2 = 3.888e-02 P = 1.786e-01
Summer	Daytime	$\hat{Y}$ = 54.976 - 2.658(Max FCA) df = 48, SE = 25.82, Adj R^2 = 6.052e-02 P = 0.047
Fall	Daytime	$\hat{Y}$ = 24.039 df = 31, SE = 39.06
Winter	Daytime	$\hat{Y}$ = 212.920 - 9.685(Max FCA) df = 22, SE = 51.41, Adj R^2 = 0.198 P = 1.693e-02

[a] This area not surveyed during predawn period

Daytime habitat models for the Chaparral Park area were also all highly significant ($P < 0.001$). However, the adjusted R^2 values were lower. The spring model had the highest adjusted R^2 value, while the winter model had the lowest adjusted R^2 value. In all 4 season models, average FCA, lake area, and land use had a significant effect on goose numbers.

All predawn habitat models developed for the McCormick Ranch area were highly significant ($P < 0.001$) (Table 5-5). The predawn models had adjusted R^2 values ranging from 0.566 for winter to 0.730 for spring. This suggested that the spring model had the greatest explanatory power of the 4 predawn models. As seen for the Chaparral Park area, all predawn models consisted of the same independent variables: minimum FCA, maximum FCA, average FCA, lake area, and land use. All variables had a positive effect on goose numbers.

Daytime habitat models for the McCormick Ranch area were also all highly significant ($P < 0.001$) with the exception of the winter model. While the winter model had a lower level of significance, it was still significant at $P > 0.05$.

Table 5-4. Habitat selection models by season and survey time for Canada geese using the Chaparral Park home area of the Indian Bend Wash study area from October 2008 to September 2010.

Spring	Predawn	$\hat{Y}$ = 1196.479 - 17.651(Min FCA) - 51.052(Max FCA) df = 30, SE = 26.12, Adj R^2 = 0.954, P < 2.2e-16
	Daytime	$\hat{Y}$ = 375.027 + 4.663(Min FCA) - 32.255(Avg FCA) + 3.799e-03(Lake) – 41.052 (Land Use) df = 67, SE = 24.42, Adj R^2 = 0.906, P < 2.2e-16
Summer	Predawn	$\hat{Y}$ = 826.820 - 12.198(Min FCA) - 35.279(Max FCA) df = 69, SE = 43.45, Adj R^2 = 0.780, P < 2.2e-16
	Daytime	$\hat{Y}$ = 2.080e+02 + 8.154(Min FCA) - 1.885e+01(Avg FCA) + 2.607e-03(Lake) - 2.558e+01(Land Use) df = 145, SE = 31.61, Adj R^2 = 0.702, P < 2.2e-16
Fall	Predawn	$\hat{Y}$ = 859.134 - 12.674(Min FCA) - 36.658(Max FCA) df = 45, SE = 56.1, Adj R^2 = 0.695 P = 9.138e-13
	Daytime	$\hat{Y}$ = 2.039e+02 + 1.143e+01(Min FCA) - 1.897e+01(Avg FCA) + 2.785e-03(Lake) - 2.682e+01(Land Use) df = 91, SE = 45.35, Adj R^2 = 0.556 P = 3.515e-16
Winter	Predawn	$\hat{Y}$ = 952.998 - 14.059(Min FCA) - 40.663(Max FCA) df = 33, SE = 22.78, Adj R^2 = 0.946, P < 2.2e-16
	Daytime	$\hat{Y}$ = 2.936e+03 - 4.533e+01(Max FCA) - 1.543e+02(Avg FCA) - 1.525e-02(Lake) - 1.035e+02(Land Use) df = 67, SE = 196.10, Adj R^2 = 0.222 P = 3.183e-04

The adjusted R^2 values were not as high as was seen for predawn models. The fall model had the highest explanatory power of the daytime models with an adjusted R^2 value (0.6482) similar to that seen for the predawn fall model. The adjusted R^2 value for the winter model suggests this model only explained 7.219% of variation in goose numbers. While the winter model for both predawn and daytime had the lowest explanatory power, the daytime model was much weaker compared to the predawn model.

Table 5-5. Habitat selection models by season and survey time for Canada geese using the McCormick Ranch home area of the Indian Bend Wash study area from October 2008 to September 2010.

Spring	Predawn	$\hat{Y}$ = -4.668e+03 + 6.608e+02(Min FCA) + 5.706(Max FCA) + 1.294e+02(Avg FCA) + 1.117e-02(Lake) + 5.773e+02(Land Use) df = 60, SE = 16.12, Adj R^2 = 0.730, P < 2.2e-16
	Daytime	$\hat{Y}$ = 903.8e+02 - 6.985e+01(Min FCA) - 1.479(Max FCA) - 1.332e+01(Avg FCA) - 8.466e-04(Lake) -1.481e+02(Land Use) - 6.134e+01(Edge) + 3.908e-01(Distance to Rd) - 6.839e-02(Lawn Area) + 1.712e-02(Land Use:Lawn Area) df = 110, SE = 11.72, Adj R^2 = 0.475 P = 6.516e-14
Summer	Predawn	$\hat{Y}$ = -8.355e+03 + 1.183e+03(Min FCA) + 1.036e+01(Max FCA) + 2.312e+02(Avg FCA) + 2.001e-02(Lake) +1.033e+03(Land Use) df = 138, SE = 39.29, Adj R^2 = 0.603, P <2.2e-16
	Daytime	$\hat{Y}$ = -4.704e+01 + 8.571(Min FCA) - 3.878e+01(Use) + 6.101e+01(Edge) + 9.915e-05(Lawn Area) + 9.907e-05(Land Use:Lake) df = 245, SE = 30.12, Adj R^2 = 0.366, P < 2.2e-16
Fall	Predawn	$\hat{Y}$ = -2.139e+04 + 3.031e+03(Min FCA) + 2.734e+01(Max FC) + 5.904e+02(Avg FCA) + 5.108e-02(Lake) + 2.645e+03(Land Use) df = 90, SE = 77.35, Adj R^2 = 0.699, P < 2.2e-16
	Daytime	$\hat{Y}$ = -1.748e+02 + 2.007e+01(Min FCA) - 3.241(Max FCA) + 1.078e+01(Avg FCA) + 4.986e-04(Lake) - 1.908e+01(Land Use) + 9.022e+01(Edge) df = 152, SE = 26.77, Adj R^2 = 0.648, P < 2.2e-16
Winter	Predawn	$\hat{Y}$ = -6.342e+04 + 8.904e+03(Min FCA) + 1.173e+02(Max FCA) + 1.727e+03(Avg FCA) + 1.516e-01(Lake) + 7.796e+03(Land Use) df = 66, SE = 298.9, Adj R^2 = 0.566 P = 6.884e-12
	Daytime	$\hat{Y}$ = -5.065e+01 + 7.716e-04(Lake) - 7.043e+01(Land Use) +8.794e+01(Edge) + 2.531e-04(Lawn) df = 115, SE = 105.6, Adj R^2 = 0.072 P = 0.013

Behavioral Factors Influencing Habitat Selection

During predawn surveys I made 396 observations; geese were primarily roosting: thus, the most common activity observed during these surveys was resting (*n* = 225, 56.82%) (Table 5-6). The next most frequent behavior observed during predawn was active transport (*n* = 82, 20.71%), specifically swimming. Mean flock size for each activity category varied widely with the largest flocks observed in self-maintenance and the smallest flocks exhibiting breeding behavior (Table 5-6).

Table 5-6. Frequency, proportion and mean number of individuals involved by activity for Canada geese during predawn surveys within the Indian Bend Wash study area, Scottsdale, Arizona from June 2009 to September 2010.

Activity Category	*n*	%	Flock Size
Active Transport	82	20.71	$\bar{x}$ = 66.29, SE = 8.21
Artificial Feeding	11	2.78	$\bar{x}$ = 64.09, SE = 16.71
Breeding	16	4.04	$\bar{x}$ = 8.75, SE = 2.16
Disturbance	1	0.25	$\bar{x}$ = 10.00, SE = 0.00
Foraging/Feeding	35	8.84	$\bar{x}$ = 42.71, SE = 6.60
Resting	225	56.82	$\bar{x}$ = 45.44, SE = 5.11
Self-maintenance	26	6.57	$\bar{x}$ = 75.23, SE = 10.63
Total	396	100.00	$\bar{x}$ = 44.64, SE = 10.09

Looking at site specific behavior observations, resting was the primary predawn behavior for most sites with several exceptions (Appendix D) At McCormick Ranch – Camelback Lake the most commonly observed behavior was active transport (*n* = 40, 32.79%). This was also the behavior exhibited by the largest flocks (97.33 ± 18.10 geese). While geese at Chaparral Park were most often observed resting (*n* = 100, 59.88%), the activity pursued by the largest flocks was artificial feeding ($\bar{x}$ = 71, SE = 17.10).

I made 880 observations during daytime surveys and observed several common activities (Table 5-7). Overall, foraging/feeding was the most commonly observed behavior (*n* = 281, 31.93%). This was also the activity exhibited by the largest flocks ($\bar{x}$ = 21.55, SE = 1.45 geese). Foraging/feeding was closely followed by both resting (*n* = 228, 25.91%) and active transport (*n* = 206, 23.41%). The smallest flocks were observed exhibiting breeding behavior (9.82 ± 1.49).

Table 5-7. Frequency and proportion and mean number of individuals involved by activity for Canada geese during daytime surveys within the Indian Bend Wash study area, Scottsdale, Arizona from October 2008 to September 2010.

Activity Category	*n*	%	Flock Size
Active Transport	206	23.41	$\bar{x}$ = 20.16, SE = 4.14
Artificial Feeding	33	3.75	$\bar{x}$ = 18.85, SE = 4.11
Breeding	28	3.18	$\bar{x}$ = 9.82, SE = 1.49
Disturbance	17	1.93	$\bar{x}$ = 18.94, SE = 5.82
Foraging/Feeding	281	31.93	$\bar{x}$ = 21.55, SE = 1.45
Resting	228	25.91	$\bar{x}$ = 15.55, SE = 1.32
Self-maintenance	87	9.89	$\bar{x}$ = 15.53, SE = 2.01
Total	880	100.00	

Looking at site specific behavior observations, at most sites either foraging, resting, or active transport behaviors were the primary activities I observed, consistent with overall daytime observations combined (Appendix E). However, there were several exceptions to this.

At Vista del Camino Park – North, the most commonly observed behavior was breeding (*n* = 8, 50%). For all daytime survey observations, breeding behavior only accounted for 3.18% (*n* = 28) of observations (Table 5-7). There were 5 sites where breeding behavior was observed during surveys.

At Eldorado Park – North, while active transport was the most commonly observed behavior (*n* = 8, 38.10%), artificial feeding tied with foraging/feeding as the second most common behavior (Appendix N). Artificial feeding accounted for 23.81% (*n* = 5) of observations at this site compared to 3.75% (*n* = 33) of all daytime observations throughout the study area (Table 5-7). I observed artificial feeding at 5 sites during daytime surveys. At Chaparral Park, the largest flocks I observed during daytime surveys were being fed ($\bar{x}$ = 20.13, SE = 5.41) as was seen for predawn surveys.

Association with Domestic Geese. – I observed domestic and domestic-Canada goose hybrids with Canada goose flocks at 8 sites within the study area (Table 4-5). For both predawn and daytime surveys I observed domestics with Canada geese 494 times. Numbers of domestics/hybrids associated with a Canada goose flock ranged from 1 to 45, averaging 7.42 ± 0.39. I consistently saw the largest numbers of domestics at Chaparral Park. The mean number of domestics associated with Canada geese at this site was 9.71 ± 0.58. I observed domestic-Canada goose hybrids in the Chaparral Park area and in the McCormick Ranch area. At Chaparral Park, there was 1 breeding pair consisting of a Canada goose female and a hybrid male.

DISCUSSION

Habitat Characteristic Selection

I evaluated 8 habitat characteristics of sites within the Indian Bend Wash study area to determine what factors are influencing site selection by this population of Canada geese. Previous studies of resident Canada geese populations have found that geese select feeding sites based on safety considerations (Conover and Kania 1991, Gosser et al. 1997). Conover and Kania (1991) suggested modifying nuisance sites by planting tall trees around the lawn and body of water may also make a site less attractive. They found that geese prefer easy flight access in and out of an area, selecting sites with a flight clearance angle less than 13°. I found that habitat characteristics associated with safety are likewise playing a large role in site selection by geese in Scottsdale.

I considered goose site selection for the 4 home areas within the study area for both the predawn and daytime survey periods. Overall, predawn models had higher adjusted R^2 values than daytime models. Predawn models also had more significant P-values than daytime models. This suggests the predawn models are better fit than daytime models and explain more of the uncertainly associated with the probability of goose selection of different sites. This can be explained by difference in predawn and daytime usage of geese. Geese I observed during predawn surveys were overnight roosters. During the daytime, geese utilized their habitat for a variety of purposes. The most common daytime activity I observed was foraging/feeding, closely followed by resting and active transport. Thus, during the predawn survey period, geese are selecting sites for a much more specific purpose. Geese were observed moving throughout the study area during the day and consistently returning to specific roost sites at sundown. Another factor which may be influencing the level of fit of predawn versus daytime models is the presence of human disturbance during the day. Disturbance increases amount of movement of geese during the day, creating a factor outside of habitat characteristics which may be impacting goose site selection.

For all predawn models, the most common habitat characteristics with a significant effect on goose numbers were minimum FCA, maximum FCA, average FCA, lake area and property type. This suggests that geese are primarily selecting overnight roosting sites based upon lake size.

Resting was the primary predawn behavior for most sites with the exception of sites in the McCormick Ranch area. At McCormick Ranch –

Camelback Lake the most frequent behavior exhibited during predawn surveys was active transport. This behavior was primarily exhibited by winter migrants. Winter migrants exhibited a distinct behavior pattern from residents, following a traditional wild goose routine of leaving overnight roosts at first light to travel to daytime feeding sites (Ogilvie 1978). Large groups (97.33 ± 18.10) were observed swimming on McCormick Ranch – Camelback Lake just prior to sunrise after which migrants would fly out to feed on agricultural crops outside of the study area. Resident geese would typically remain at their overnight roost location and either continue to rest or begin grazing after sunrise. The presence of winter migrants likely impacted the explanatory power of the predawn winter model for the McCormick Ranch area. This model had the lowest adjusted R^2 value.

The predawn models for the Chaparral Park area and the McCormick Ranch area were much better fit and had higher explanatory power than predawn models developed for the South End area. This is most likely related to the consistency of use of these areas. The site with the most observations was Chaparral Park. This site consistently had high numbers of geese year round, both during predawn and daytime surveys. The spring and winter predawn models developed for Chaparral Park both explained greater than 90% of variation in goose numbers. Sites within the South End area typically had fewer geese and were not consistently used for roosting.

The most common independent variables included in daytime habitat models were the same as those included in predawn models: minimum FCA, average FCA, lake area and land use. This may be explained by human disturbance which is highly variable dependent on property type. Daytime models included a greater variety in independent variables compared with predawn models. This may be explained by the differences in daytime site usage by geese. During predawn periods, geese were primarily roosting. During the daytime, geese were most often observed foraging/feeding, resting and in active transport. This indicates that there is more complexity in what geese are selecting for during the daytime.

Geese at Chaparral Park exhibited the top 3 common daytime activities (foraging/feeding, resting, and active transport) in near equality. This site offers one of the largest lakes providing a safe escape from any threat. While daytime models in other areas included a wider variety of independent variables, FCA and lake area were the only variables with a significant effect on goose numbers during any of the 4 seasons. Chaparral Park geese also utilized 2 other sites adjacent to this site: Chaparral Park – West and Camelback Park. Use of these sites was lower than Chaparral Park and the main activity observed was foraging/feeding (53.45% of observations). This suggested that while geese utilized Chaparral Park for all major activity categories (including nesting), their use of the 2 adjacent sites was more specialized for daytime foraging/feeding. These 2 sites were much smaller and had limited human use compared to Chaparral Park.

The winter model for the Chaparral Park area had a much lower adjusted R^2 value than other seasons. The lack of explanatory power for winter may be explained by the presence of migrants. Migrants exhibited a different daytime behavior pattern than residents and may be selecting daytime sites for different criteria.

Unlike Chaparral Park area, McCormick Ranch area daytime models included a wide variety of habitat characteristics with significant effects on goose numbers. All 8 possible independent variable as well as several interactions were included in daytime models for this area. Daytime models had lower explanatory power for this area than for Chaparral Park. This may be attributed to the inconsistent use of sites in this area. While large numbers of geese were present in the Chaparral Park area every week of the year, geese used the McCormick Ranch area more sporadically, especially during daytime.

Geese were most often observed at McCormick Ranch – Camelback Lake during predawn surveys but also utilized it during the daytime periodically. Active transport (swimming) was the most common activity for geese at this site, followed by foraging/feeding and resting. At McCormick Ranch – Camelback Lake – North, a small adjacent site, geese were observed foraging/feeding 41.67% of the time. This site had more daytime use and very little predawn use.

As with the Chaparral Park area, the winter model for the McCormick Ranch area had the lowest explanatory power, explaining 7.22% of variation in goose numbers. This model also had a lower P-value (0.013). More winter migrants were observed at McCormick Ranch than in any other areas within the Indian Bend Wash study area. As mentioned previously, migrants typically left the study area at sunrise using the area primarily for overnight roosting. However, migrants were observed returning to the study area during the midday on some surveys. This distinct behavioral pattern of migrants likely negatively impacted the ability of the habitat model to identify selection criteria of resident geese.

Continental Golf Course – North was used almost exclusively for foraging/feeding. This site was a common daytime destination for geese from the Chaparral Park and South End areas (see Spatial Dynamics section). Geese did not use this site as a home area and were not observed overnight roosting. Habitat models developed for this area had very low explanatory power indicating that geese were selecting these sites for criteria outside of the 8 independent variables considered in habitat models. A long drainage ditch extends throughout this area and geese were typically observed at this site when the drainage ditch was flooded. It is likely this is what geese were selecting for, rather than for permanent habitat characteristics.

In the interest of management of this population, it is important to identify where geese were breeding. Breeding behavior was only observed at 5 sites: Camelback Park, Chaparral Park, Coronado Golf Course, McCormick Ranch – Camelback Park and Vista del Camino Park – North. As discussed in the nesting section, the island at Chaparral Park was the primary nesting site within the Indian Bend Wash study area. The presence of this island and the safety it provides for nesting and resting (both overnight roosting and daytime resting) is likely a major attractant to this site.

The public often enjoy feeding geese in urban areas, which contributes to the attraction of sites where feeding occurs. I observed artificial feeding at 5 sites during daytime surveys: Chaparral Park, Eldorado Park – North, Eldorado Park – South, McCormick Ranch – Camelback Lake and Vista del Camino Park – McKellips Lake. I observed specific individuals feeding large quantities of seed or bread to geese on a regular basis at both Chaparral Park and McCormick Ranch – Camelback Lake. At Chaparral Park, artificial feeding attracted the largest flocks observed during both predawn and daytime surveys. These flocks included domestic geese.

The habitat models presented in this chapter can be used to guide habitat modification as part of a management program. Management can be targeted at specific sites and specific goose attractants. Additionally, since models were developed for each season, sites can be modified in a manner specifically targeted at resident populations or winter migrants, depending on identified management needs. Sites can be modified to be less attractive to geese by increasing characteristics which have a negative effect and decreasing characteristics which have a positive effect.

Association with Domestic Geese – There is no indication that domestic geese acted as decoys to attract Canada geese to sites throughout the Indian Bend Wash study area. I only observed domestics and domestic-Canada goose hybrids at 8 (33.33%) of 24 sites where I detected Canada geese. Additionally, I observed the highest numbers of migrants at the McCormick Ranch area both winters of the study while most domestics were located at Chaparral Park. If domestics were attracting migrants, a significant increase in migrants at Chaparral Park would be expected. At sites where I observed domestics, they were frequently mixed in the same flocks as Canada geese and displayed similar behavior patterns. There is indication of interbreeding between domestics and Canada geese; I observed hybrids in the Chaparral Park area and in the McCormick Ranch area. Domestic geese at Chaparral Park nested on the island along with Canada geese. There was 1 breeding pair at this location consisting of a Canada goose female and a hybrid male. Domestic geese and hybrids did not appear to leave their home locations and were never observed flying.

CHAPTER 6

MANAGEMENT IMPLICATIONS

I evaluated 6 categories of management techniques for addressing resident Canada goose problems identified in the literature: 1) Discontinuance of feeding; 2) Habitat Modification; 3) Hazing and Scaring Techniques; 4) Chemical Repellents; 5) Control of Reproduction; and 6) Removal. These are techniques that have been implemented in other urban areas to control and manage resident Canada geese. I evaluated management techniques based upon advantages and disadvantages and success of each technique as presented in the literature. I further evaluated techniques based upon information on the population dynamics and habitat selection of resident Canada Geese in the Indian Bend Wash area gained during this study. I present several alternative options based on the level of risk resident Canada geese pose in terms of property damage and human health and safety concerns.

Alternative A – Resident geese not determined a threat

Under this alternative it is suggested that City of Scottsdale actively promotes a discontinuance of feeding of Canada geese within city parks through public outreach and education. Continuance of feeding makes it more difficult to limit the number of geese utilizing a site (Gosser et al. 1997) and contributes to the attraction of sites where feeding occurs. I observed artificial feeding at 5 sites: Chaparral Park, Eldorado Park – North, Eldorado Park – South, McCormick Ranch – Camelback Lake and Vista del Camino Park – McKellips Lake. I recommend public outreach at these sites, especially at Chaparral Park. I observed specific individuals feeding large quantities of bread to geese on a regular basis at this park, attracting large flocks of geese. Education at public events as well as signage should be considered.

Alternative B. – Resident geese determined a moderate threat

Under this alternative it is suggested that management is implemented to limit future recruitment into the population as well as implement habitat modifications. This is a nonlethal management alternative. I suggest an integrated approach including control of reproduction and habitat modification. Control of reproduction of urban flocks can stabilize the existing flock size, thereby limiting population growth (Smith et al. 1999, USDI 2005). I suggest that the city of Scottsdale destroy Canada goose eggs under the Resident Canada Goose Nest and Egg Depredation Order. This order authorizes local governments to apply for depredation permits to destroy goose nests and eggs. Nesting within the Indian Bend Wash study area primarily occurred on the island at Chaparral Park. This site should be targeted for egg destruction. It is important that a long term egg destruction program is implemented to maintain the current population level.

Another option for controlling reproduction of this population that should be considered is making the island at Chaparral Park less attractive as a nesting location through habitat modification. Nest locations are consistently selected based on safety concerns (Smith et al. 1999). Islands are often preferred nesting sites, as they provide security from potential predators and are removed from frequent human use (Ogilvie 1978, Smith et al. 1999). Data suggests that Canada geese in the Indian Bend Wash study area may preferentially nest on Chaparral Island to avoid human disturbance. By allowing human access to the island it would no longer be a safe nesting location and nesting should subside.

Additional habitat modifications which can be implemented throughout the study area can be identified from the habitat modeling portion of this study. The habitat models presented in Chapter 5 identify which habitat characteristics have a significant effect on goose numbers. Habitat modification techniques include eliminating, modifying, reducing access to areas that attract geese, or making a site appear less safe for geese (Gosser et al. 1997, Smith et al. 1999). Conover and Kania (1991) found that urban/suburban Canada geese in Connecticut selected foraging sites based primarily on safety considerations. They suggested planting tall trees around the lawn and body of water to increase the flight clearance angle (FCA) since geese prefer easy flight access in and out of an area. I suggest this approach for the Indian Bend Wash study area. The most common habitat characteristics identified as having a significant effect on goose numbers in the 28 habitat models produced were FCA, lake area and property type. Modifying the landscaping at sites within the study area to increase FCA should make sites less attractive to geese.

Alternative C – Resident geese determined a high risk

Under this alternative it is suggested that management is implemented to reduce the current population of resident geese as well as limit future recruitment into the population. This alternative includes lethal and nonlethal control measures. I suggest an integrated approach including removal of adult geese in addition to control of reproduction and habitat modification. There is currently a core population level of approximately 300 resident geese. If this population level is considered larger than desired, a target population level should be determined and established through adult removal. Removal of Canada geese is the most effective way to reduce the size of an urban flock. If geese are captured for removal, it should be done in the summer when no migrants are present in urban areas, ensuring that only resident geese are removed (USDI 2005). Once a desired population level is reached through lethal control methods, I suggest that reproductive control be implemented as discussed in alternative B.

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APPENDIX A

CANADA GOOSE OBSERVATION FORM

This form is designed for the collection of information from the public reporting observations of banded Canada geese throughout the Phoenix metropolitan area. Please fill in all information to the best of your ability. Please email completed form to Elizabeth Ray at Elizabeth.Ray@asu.edu.

Personal contact information:

Name (Last, First)	
Phone Number	
Email Address	

Observation information:

Date and Time		
City		
Name of Park or Lake		
How many Canada geese did you observe?		
Were any domestic geese present?	Yes ☐ No ☐	How many?
Were any goslings present?	Yes ☐ No ☐	How many Canada / domestic goslings?
How many geese had neck bands?		
Please list all bands you were able to read:		
What was the main activity of the geese you observed? (*Grazing, Artificial Feeding (eating bread, popcorn, etc.), Swimming, Walking, Resting, Tending goslings, Alert/fleeing (responding to a disturbance of some kind), Other (please specify)*)		
Please include any additional comments regarding your observation:		

Thank you for your help

APPENDIX B

SEASONAL CANADA GOOSE DISTRIBUTION WITHIN THE INDIAN BEND WASH STUDY AREA SCOTTSDALE, ARIZONA

Figure B-1. Mean seasonal predawn Canada goose distribution within the Indian Bend Wash study area during the summer of 2009.

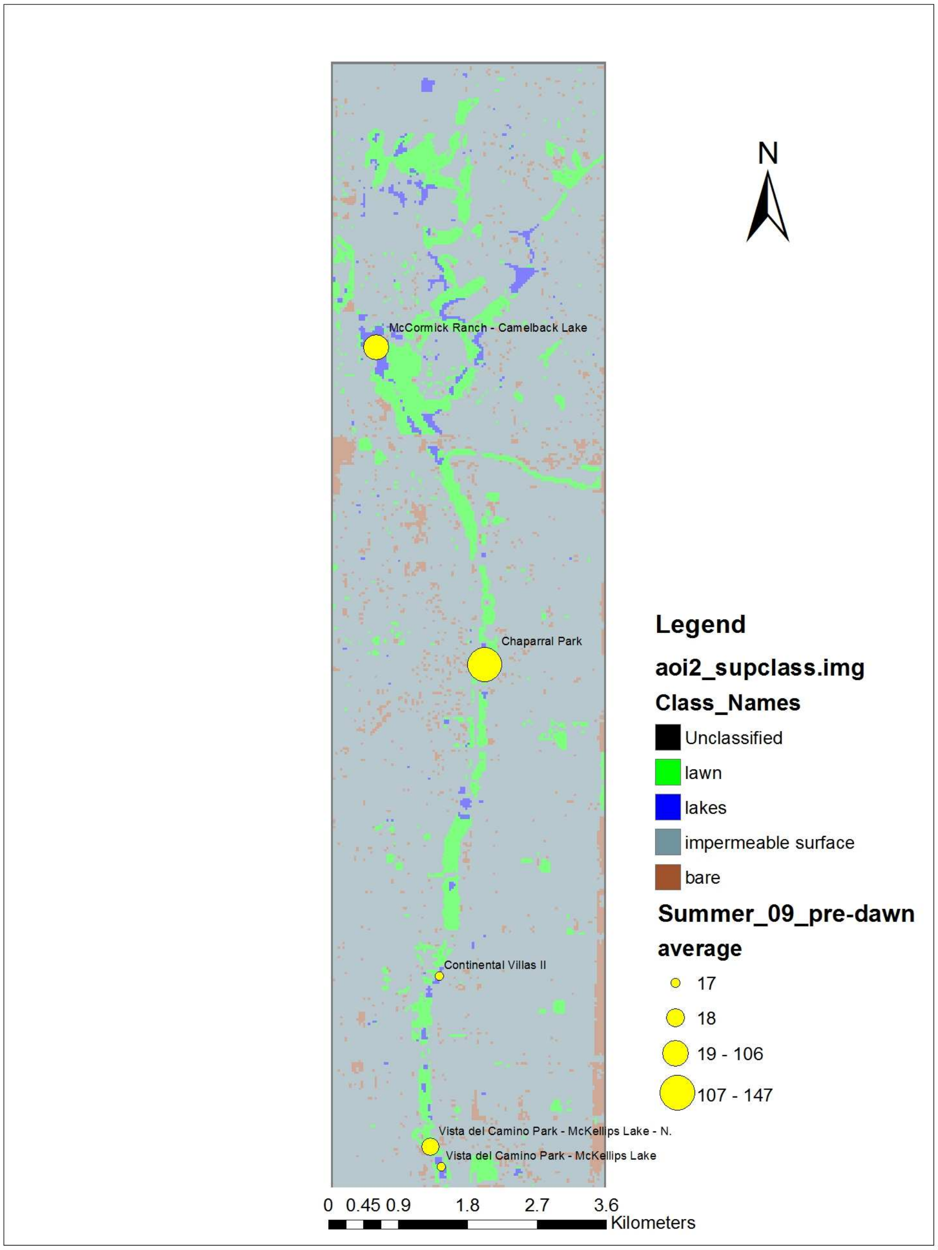


Figure B-2. Mean seasonal daytime Canada goose distribution within the Indian Bend Wash study area during the summer of 2009.

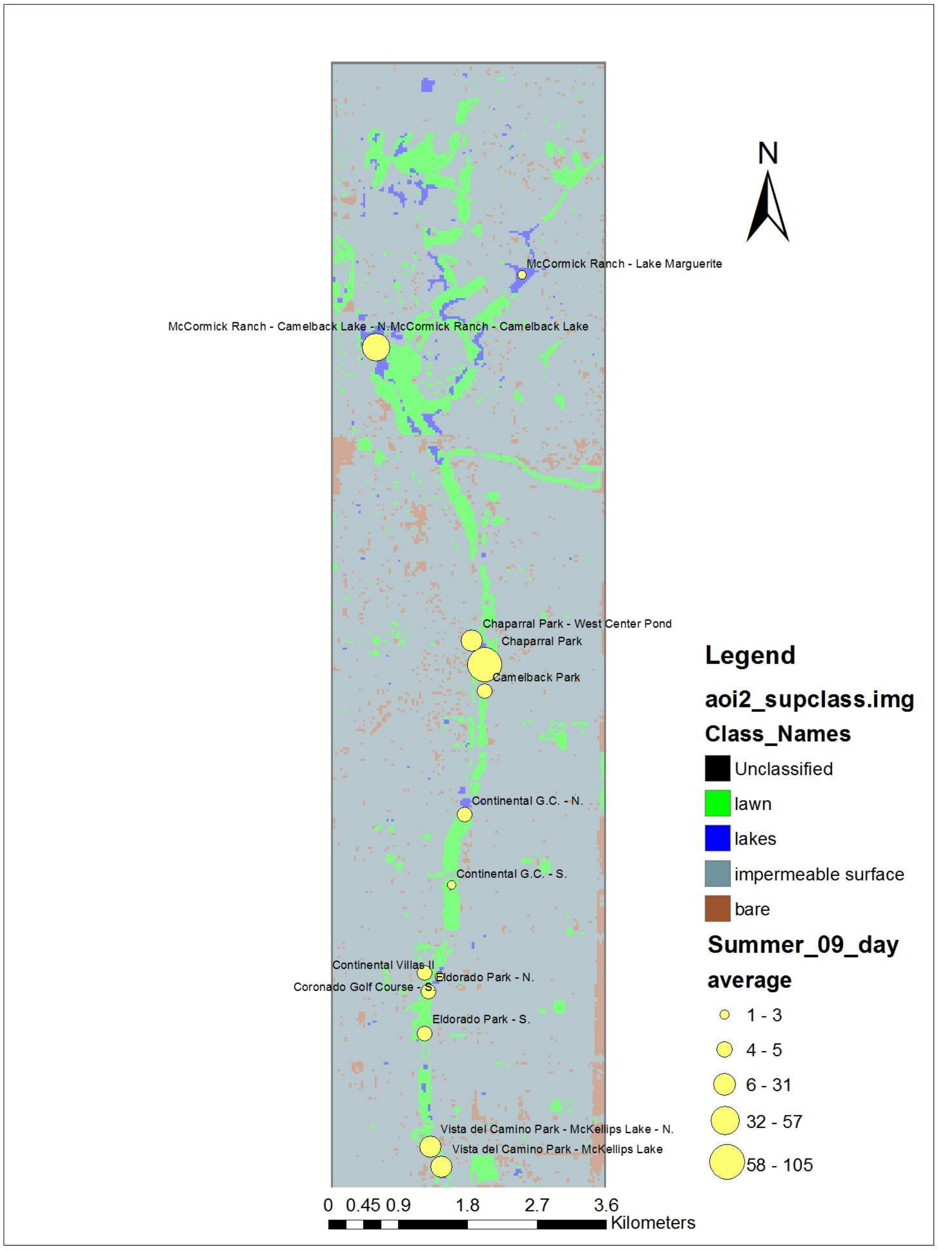


Figure B-3. Mean seasonal predawn Canada goose distribution within the Indian Bend Wash study area during the fall of 2009.

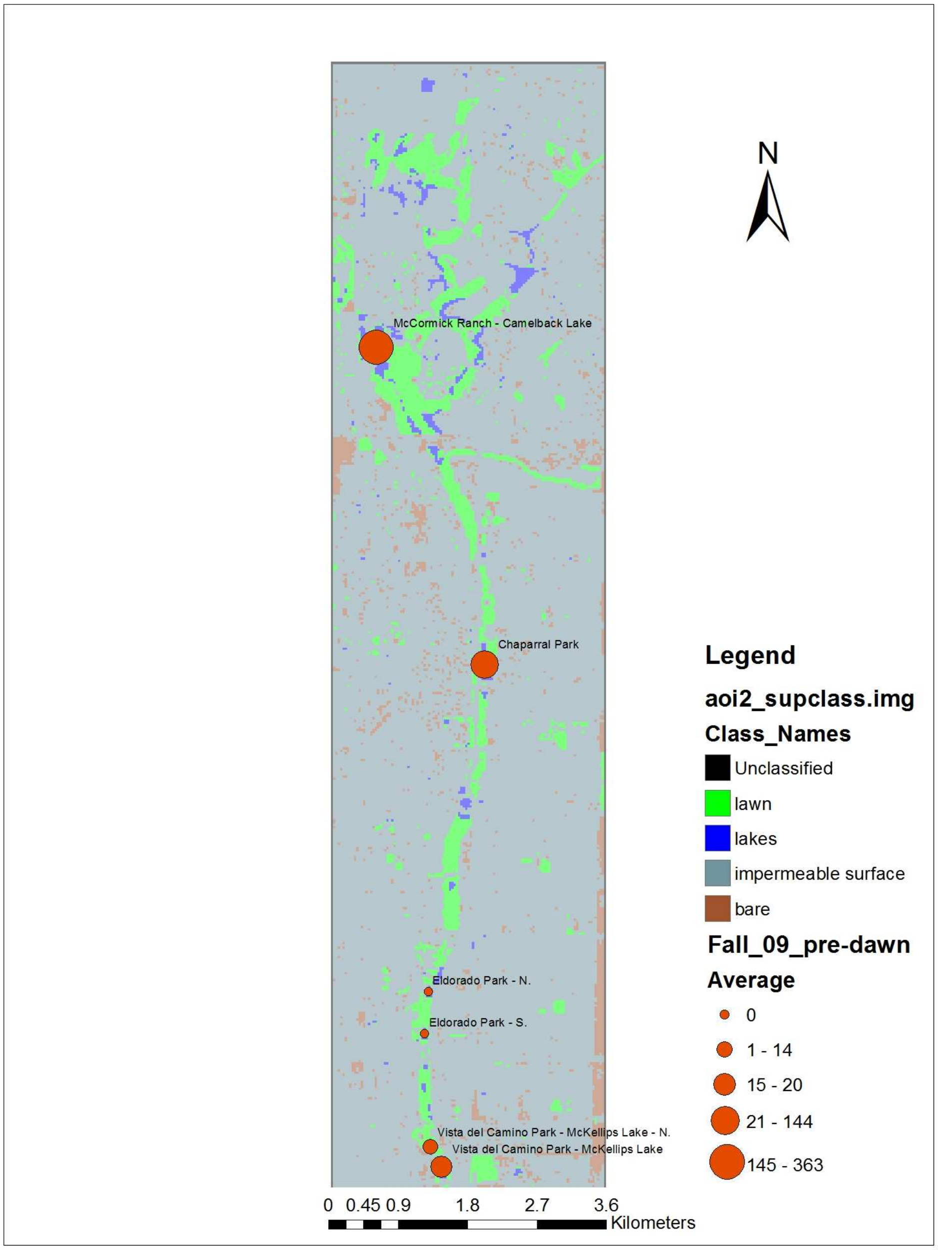


Figure B-4. Mean seasonal daytime Canada goose distribution within the Indian Bend Wash study area during the fall of 2009

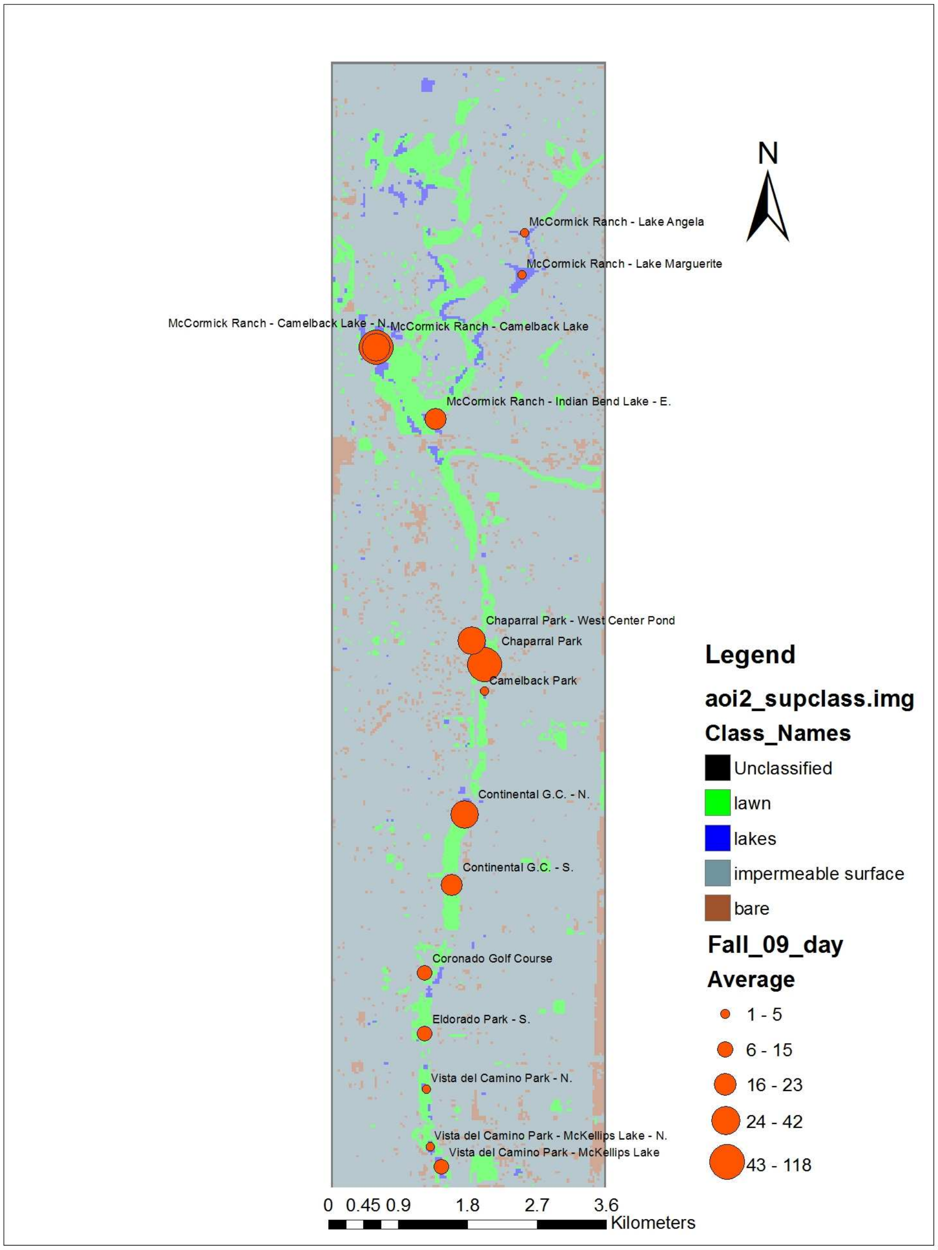


Figure B-5. Mean seasonal predawn Canada goose distribution within the Indian Bend Wash study area during the winter of 2009 – 2010.

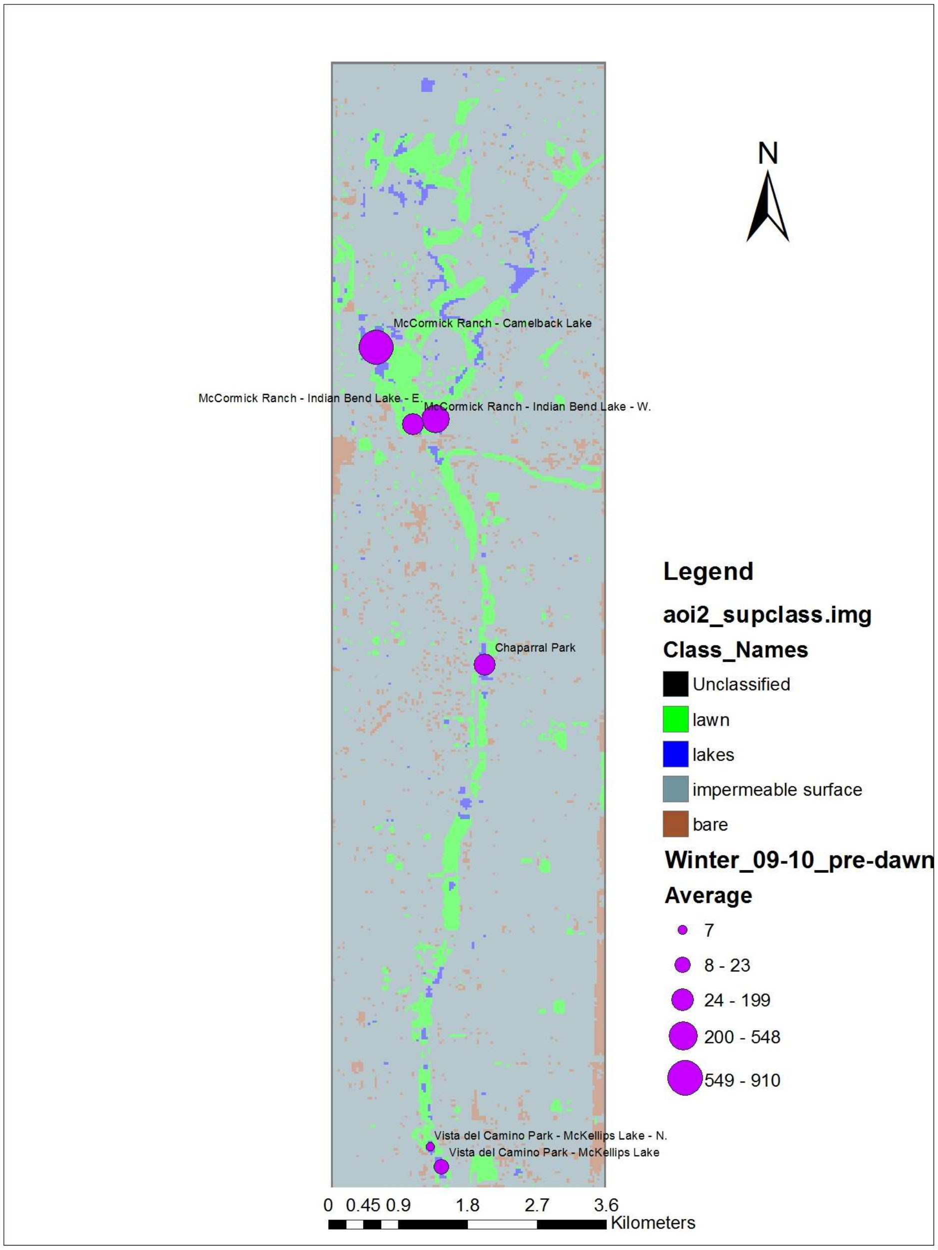


Figure B-6. Mean seasonal daytime Canada goose distribution within the Indian Bend Wash study area during the winter of 2009 – 2010.

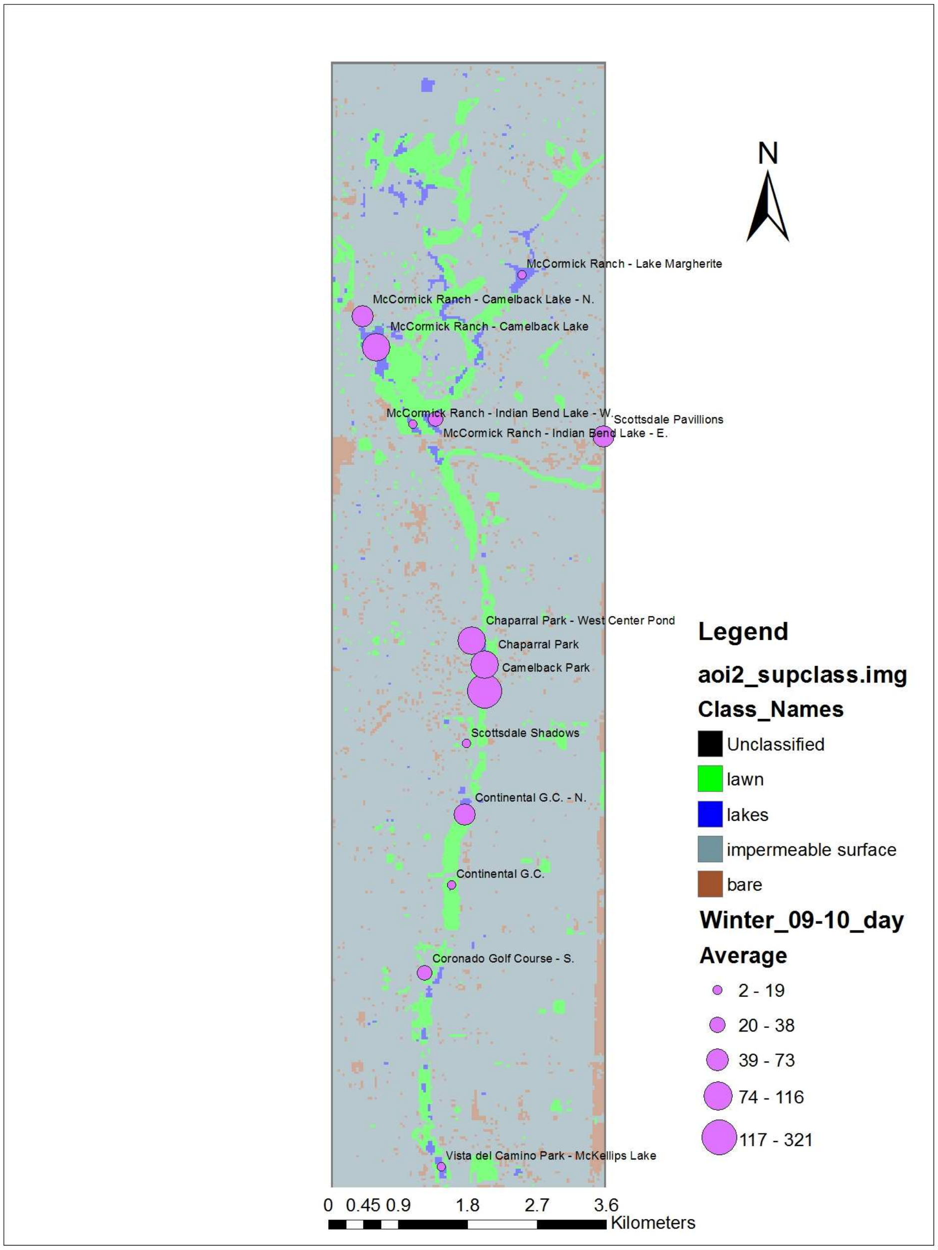


Figure B-7. Mean seasonal predawn Canada goose distribution within the Indian Bend Wash study area during the spring of 2010.

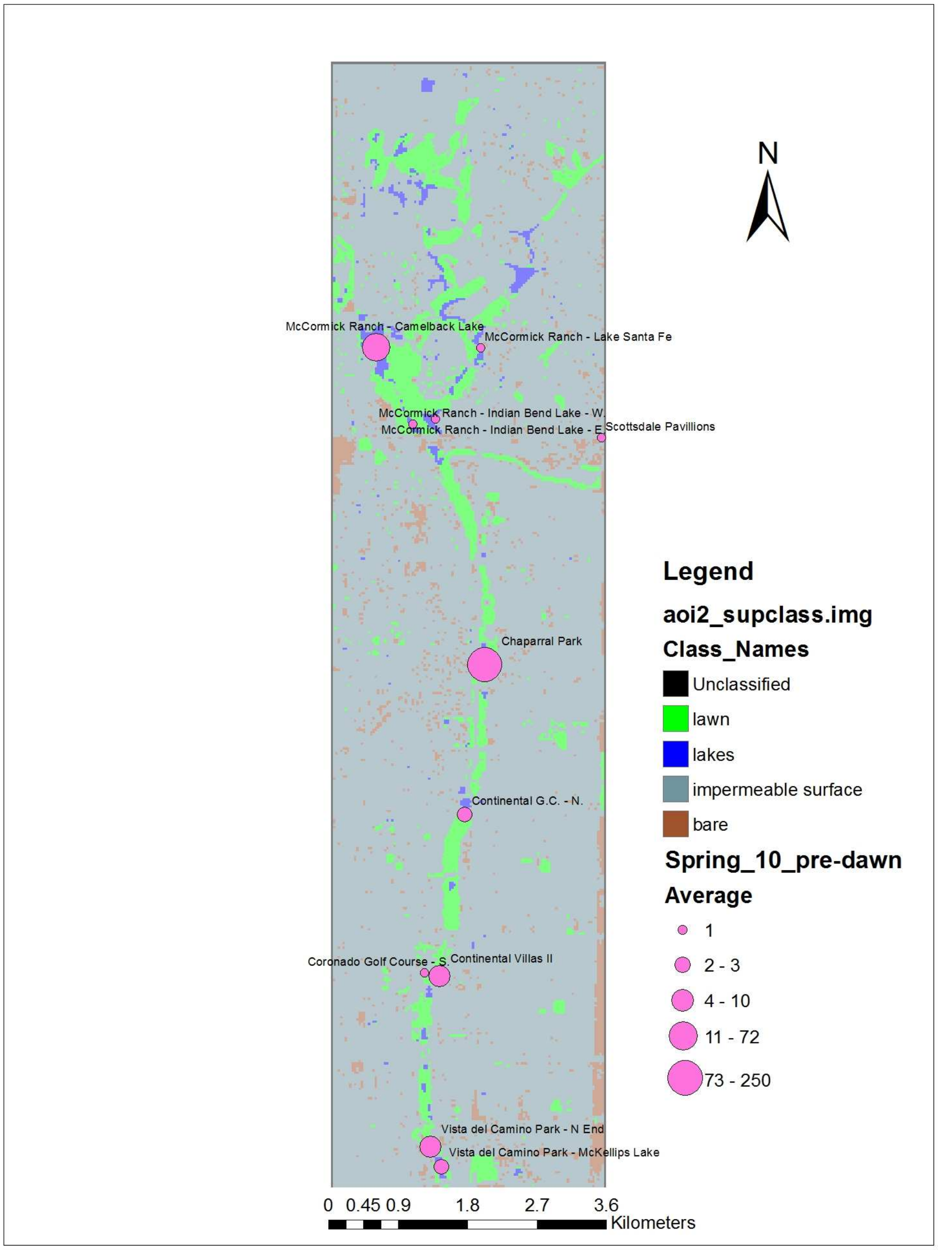


Figure B-8. Mean seasonal daytime Canada goose distribution within the Indian Bend Wash study area during the spring of 2010.

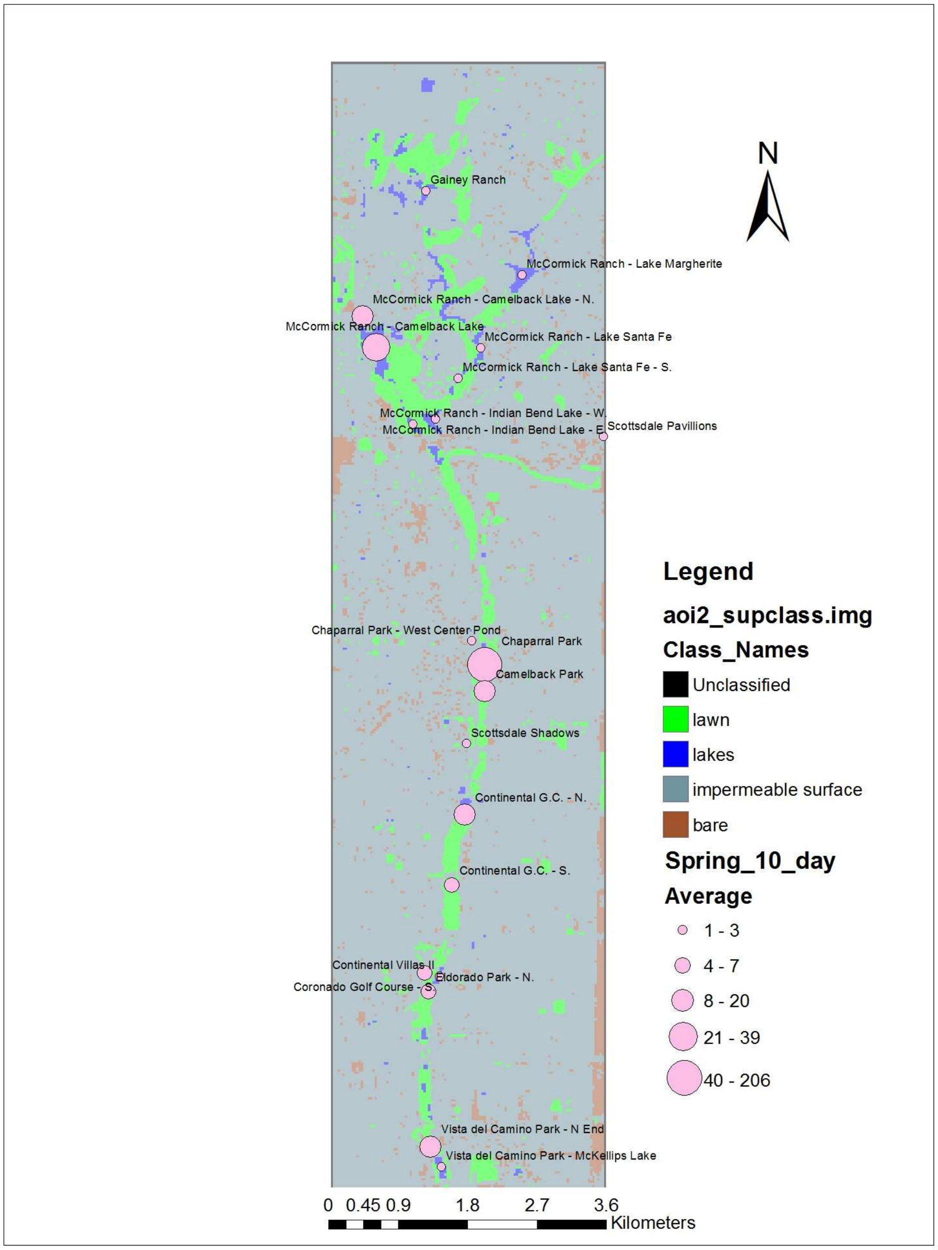


Figure B-9. Mean seasonal predawn Canada goose distribution within the Indian Bend Wash study area during the summer of 2010.

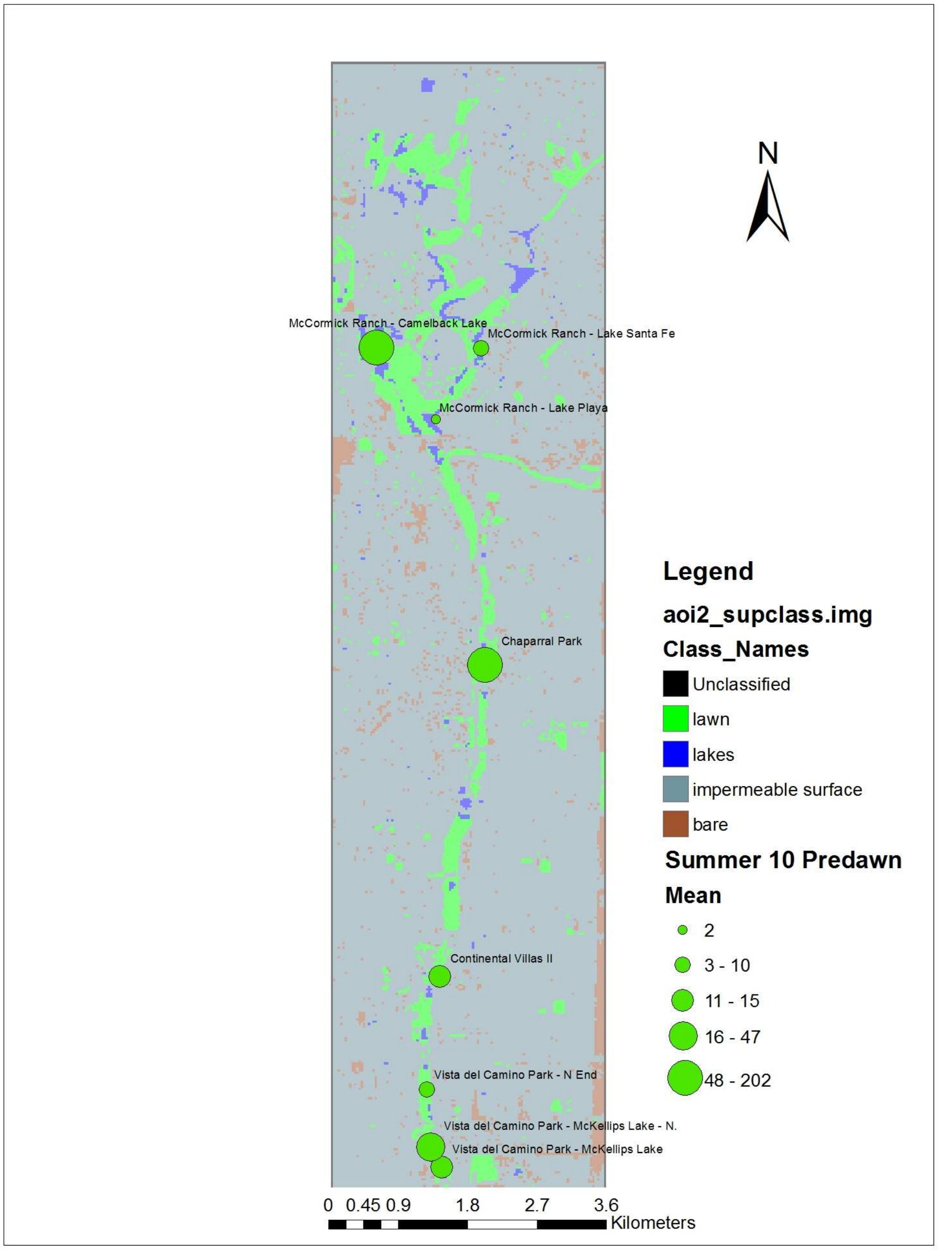
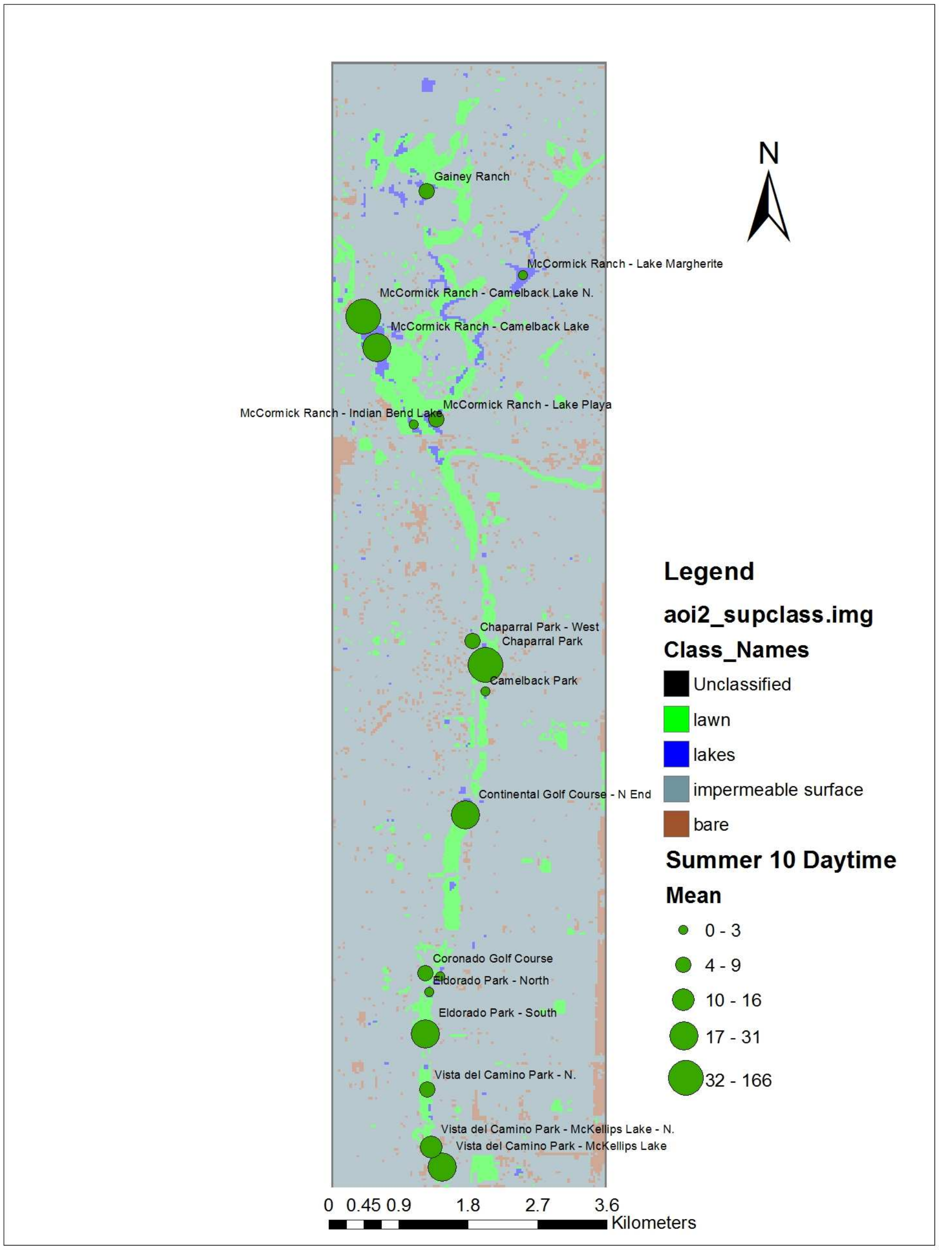


Figure B-10. Mean seasonal daytime Canada goose distribution within the Indian Bend Wash study area during the summer of 2010.



APPENDIX C

DETECTIONS OF COLLARED CANADA GEESE OUTSIDE THE INDIAN BEND WASH STUDY AREA, JUNE 2009 TO MAY 2010

Collar No.	Banding Location	Banding Age	Location(s) Detected[a]	No. of Times Detected
A01	McCormick Ranch	Adult	Gilbert Water Ranch, Gilbert	1
A05	McCormick Ranch	Adult	Agua Caliente, Scottsdale	3
A11	McCormick Ranch	Adult	Roadrunner Lake Resort Mobile Home Park, Scottsdale	3
A12	McCormick Ranch	Adult	Bayview Estates, Scottsdale	1
A13	McCormick Ranch	Adult	Agua Caliente, Scottsdale	1
A16 [b]	McCormick Ranch	Juvenile	Arrowhead Country Club, Glendale	1
A17	McCormick Ranch	Juvenile	Gilbert Water Ranch, Gilbert	1
A18	McCormick Ranch	Adult	Agua Caliente, Scottsdale	1
A19	McCormick Ranch	Juvenile	Gilbert Water Ranch, Gilbert ; 1351 Leisure World, Mesa	2
A20	McCormick Ranch	Juvenile	Gilbert Water Ranch, Gilbert	1
A29	McCormick Ranch	Juvenile	Johnson Lake, Banner Marsh, IL	1
A31	McCormick Ranch	Juvenile	Gilbert Water Ranch, Gilbert	1
A33	McCormick Ranch	Adult	Agua Caliente, Scottsdale	2
A34	McCormick Ranch	Juvenile	Gilbert Water Ranch, Gilbert	1
A38	McCormick Ranch	Juvenile	Agua Caliente, Scottsdale	1
A39	McCormick Ranch	Juvenile	Agua Caliente, Scottsdale ; Gilbert Water Ranch, Gilbert	2
A40	McCormick Ranch	Juvenile	Paradise Valley Golf Course, Paradise Valley	1
A41	McCormick Ranch	Juvenile	Gilbert Water Ranch, Gilbert	1
B16	Chaparral Park	Juvenile	Alta Mesa Golf Club, Mesa	1
B18	Chaparral Park	Juvenile	Gilbert Water Ranch, Gilbert	1
B20	Chaparral Park	Juvenile	Gilbert Water Ranch, Gilbert	1
B21	Chaparral Park	Juvenile	Gilbert Water Ranch, Gilbert	2
B31	Chaparral Park	Adult	Gilbert Water Ranch, Gilbert ; Western Skies Golf Course, Gilbert	4
B33	Chaparral Park	Adult	Gilbert Water Ranch, Gilbert	1
B38	Chaparral Park	Adult	Gilbert Water Ranch, Gilbert	1
B51	Chaparral Park	Adult	Riverview Park, Mesa	1
B52	Chaparral Park	Juvenile	Gilbert Water Ranch, Gilbert	1
B55	Chaparral Park	Adult	Gilbert Water Ranch, Gilbert	1
B56	Chaparral Park	Juvenile	Encanto Park, Phoenix	1
B57	Chaparral Park	Adult	Gilbert Water Ranch, Gilbert	1
B58	Chaparral Park	Adult	Gilbert Water Ranch, Gilbert	3
B59	Chaparral Park	Adult	Gilbert Water Ranch, Gilbert	2
B60	Chaparral Park	Juvenile	Starfire Golf Club, Scottsdale	1
B62	Chaparral Park	Adult	Gilbert Water Ranch, Gilbert	1
B65	Chaparral Park	Adult	Gilbert Water Ranch, Gilbert	1
B66	Chaparral Park	Juvenile	Gilbert Water Ranch, Gilbert	1
B69	Chaparral Park	Juvenile	Gilbert Water Ranch, Gilbert	1
B70	Chaparral Park	Juvenile	Gilbert Water Ranch, Gilbert	1
B71	Chaparral Park	Juvenile	Gilbert Water Ranch, Gilbert	1

Collar No.	Banding Location	Banding Age	Location(s) Detected[a]	No. of Times Detected
C09	Chaparral Park	Adult	Riverview Park, Mesa	1
C15	Chaparral Park	Juvenile	Gilbert Water Ranch, Gilbert	1
C17	Chaparral Park	Juvenile	Encanto Park, Phoenix ; Riverview Park, Mesa	2
C20	Chaparral Park	Adult	Gilbert Water Ranch, Gilbert	1
C22	Continental Villas II	Adult	Riverview Park, Mesa	1
C27	Continental Villas II	Juvenile	Anderson Springs, Chandler	1
C28 [b]	Continental Villas II	Adult	Riverview Park, Mesa ; Roosevelt Lake area	2
C29	Continental Villas II	Adult	Riverview Park, Mesa	1
C30 [b]	Continental Villas II	Adult	The Phoenix Zoo, Phoenix	2
C32	Continental Villas II	Adult	Camelback Golf Club, Scottsdale	1
C34	Continental Villas II	Adult	Camelback Golf Club, Scottsdale	1
C36	Continental Villas II	Juvenile	Red Mountain Park, Mesa	1
C37	Continental Villas II	Adult	Canal Park, Tempe ; Riverview Park, Mesa	2
C39	Continental Villas II	Adult	Encanto Park, Phoenix	1
C41 [b]	Continental Villas II	Adult	The Phoenix Zoo, Phoenix	2
C44 [b]	Continental Villas II	Adult	Canal Park, Tempe ; Riverview Park, Mesa ; The Phoenix Zoo, Phoenix	3
C47	Continental Villas II	Adult	Riverview Park, Mesa	1
C48 [b]	Continental Villas II	Adult	Encanto Park, Phoenix ; Superstition Springs Golf Course, Mesa	2
C50	Continental Villas II	Juvenile	Riverview Park, Mesa	1
C51	Vista del Camino Park	Adult	Gilbert Water Ranch, Gilbert	10
C52	Vista del Camino Park	Adult	Gilbert Water Ranch, Gilbert	6
C54 [b]	Vista del Camino Park	Adult	The Phoenix Zoo, Phoenix	2
C55	Vista del Camino Park	Adult	The Phoenix Zoo, Phoenix	1
C57	Vista del Camino Park	Adult	Selleh Park Pond, Tempe ; Shalimar Golf Course, Tempe	4
C58 [b]	Vista del Camino Park	Juvenile	The Phoenix Zoo, Phoenix	2
C60 [b]	Vista del Camino Park	Adult	Gilbert Water Ranch, Gilbert ; Val Vista & Main, Mesa	3
C66	Vista del Camino Park	Juvenile	The Phoenix Zoo, Phoenix	4
C68	Vista del Camino Park	Juvenile	Sun Lakes Country Club, Sun Lakes	1
C69	Vista del Camino Park	Adult	Gilbert Water Ranch, Gilbert	8
C71	Vista del Camino Park	Juvenile	The Phoenix Zoo, Phoenix	4
C72	Vista del Camino Park	Adult	Gilbert Water Ranch, Gilbert	1
C73	Vista del Camino Park	Adult	Gilbert Water Ranch, Gilbert	1
C76	Vista del Camino Park	Adult	Gilbert Water Ranch, Gilbert	3
C77	Vista del Camino Park	Adult	Papago Park, Phoenix	1
C80	Vista del Camino Park	Juvenile	Papago Park, Phoenix	1
C87 [b]	Vista del Camino Park	Adult	The Phoenix Zoo, Phoenix	7
C88	Vista del Camino Park	Adult	Gilbert Water Ranch, Gilbert	11

[a] All locations within state of Arizona if not otherwise indicated
[b] Outside detection included mortality. See Mortalities section for details.

APPENDIX D

OBSERVATIONS OF EACH ACTIVITY BY SITE DURING PREDAWN SURVEYS

Site	Activity	n	%	Mean flock size
Chaparral Park	Active Transport	39	23.35	38.00 ± 6.67
	Artificial Feeding	11	6.59	71.00 ± 17.10
	Breeding	4	2.40	19.50 ± 5.91
	Disturbance	1	0.60	10.00 ± 0.00
	Foraging/Feeding	12	7.19	39.98 ± 12.24
	Resting	100	59.88	36.59 ± 3.46
	Self-maintenance	0	0.00	
	Total	167	100.00	
Continental Villas East II	Active Transport	0	0.00	
	Artificial Feeding	0	0.00	
	Breeding	0	0.00	
	Disturbance	0	0.00	
	Foraging/Feeding	0	0.00	
	Resting	16	100.00	17.50 ± 2.94
	Self-maintenance	0	0.00	
	Total	16	100.00	
Coronado Golf Course	Active Transport	0	0.00	
	Artificial Feeding	0	0.00	
	Breeding	1	20.00	2.00 ± 0.00
	Disturbance	0	0.00	
	Foraging/Feeding	0	0.00	
	Resting	4	80.00	1.75 ± 0.25
	Self-maintenance	0	0.00	
	Total	5	100.00	
Eldorado Park - North	Active Transport	0	0.00	
	Artificial Feeding	0	0.00	
	Breeding	0	0.00	
	Disturbance	0	0.00	
	Foraging/Feeding	0	0.00	
	Resting	2	100.00	14.50 ± 11.50
	Self-maintenance	0	0.00	
	Total	2	100.00	
McCormick Ranch - Camelback Lake	Active Transport	40	32.79	97.33 ± 18.10
	Artificial Feeding	5	4.10	20.80 ± 6.63
	Breeding	3	2.46	8.00 ± 0.00
	Disturbance	0	0.00	
	Foraging/Feeding	17	13.93	56.82 ± 9.62
	Resting	28	22.95	84.86 ± 23.06
	Self-maintenance	25	20.49	78.16 ± 10.64
	Total	122	100.00	

Site	Activity	n	%	Mean flock size
McCormick Ranch - Camelback Lake - North	Active Transport	1	50.00	1.00 ± 0.00
	Artificial Feeding	0	0.00	
	Breeding	0	0.00	
	Disturbance	0	0.00	
	Foraging/Feeding	0	0.00	
	Resting	1	50.00	24.00 ± 0.00
	Self-maintenance	0	0.00	
	Total	2	100.00	
McCormick Ranch - Indian Bend Lake	Active Transport	0	0.00	
	Artificial Feeding	0	0.00	
	Breeding	0	0.00	
	Disturbance	0	0.00	
	Foraging/Feeding	1	20.00	15.00 ± 0.00
	Resting	4	80.00	71.25 ± 33.20
	Self-maintenance	0	0.00	
	Total	5	100.00	
McCormick Ranch - Lake Playa	Active Transport	1	7.69	3.00 ± 0.00
	Artificial Feeding	0	0.00	
	Breeding	0	0.00	
	Disturbance	0	0.00	
	Foraging/Feeding	0	0.00	
	Resting	11	84.62	228.55 ± 0.27
	Self-maintenance	1	7.69	2.00 ± 0.00
	Total	13	100.00	
McCormick Ranch – Lake Santa Fe	Active Transport	1	25.00	3.00 ± 0.00
	Artificial Feeding	0	0.00	
	Breeding	0	0.00	
	Disturbance	0	0.00	
	Foraging/Feeding	2	50.00	1.00 ± 5.00
	Resting	1	25.00	21.00± 0.00
	Self-maintenance	0	0.00	
	Total	4	100.00	
Scottsdale Pavilions	Active Transport	0	0.00	
	Artificial Feeding	0	0.00	
	Breeding	0	0.00	
	Disturbance	0	0.00	
	Foraging/Feeding	0	0.00	
	Resting	2	100.00	2.00 ± 0.00
	Self-maintenance	0	0.00	
	Total	2	100.00	

Site	Activity	n	%	Mean flock size
Vista del Camino Park - McKellips Lake	Active Transport	0	0.00	
	Artificial Feeding	0	0.00	
	Breeding	0	0.00	
	Disturbance	0	0.00	
	Foraging/Feeding	2	5.88	12.50 ± 10.50
	Resting	32	94.12	32.00 ± 2.04
	Self-maintenance	0	0.00	
	Total	34	100.00	
Vista del Camino Park - McKellips Lake - North	Active Transport	0	0.00	
	Artificial Feeding	0	0.00	
	Breeding	0	0.00	
	Disturbance	0	0.00	
	Foraging/Feeding	1	4.17	26.00 ± 0.00
	Resting	23	95.83	27.65 ± 3.19
	Self-maintenance	0	0.00	
	Total	24	100.00	
Vista del Camino Park - North	Active Transport	0	0.00	
	Artificial Feeding	0	0.00	
	Breeding	8	88.89	4.50 ± 0.94
	Disturbance	0	0.00	
	Foraging/Feeding	0	0.00	
	Resting	1	11.11	7.00 ± 0.00
	Self-maintenance	0	0.00	
	Total	9	100.00	

APPENDIX E

OBSERVATIONS OF EACH ACTIVITY BY SITE DURING DAYTIME SURVEYS

Site	Activity	*n*	%	Mean Flock Size
Camelback Park	Active Transport	7	31.82	219.00 ± 84.14
	Artificial Feeding	0	0.00	0.00
	Breeding	3	13.64	18.33 ± 9.87
	Disturbance	4	18.18	0.00
	Foraging/Feeding	7	31.82	14.00 ± 5.07
	Resting	0	0.00	17.43 ± 5.54
	Self-maintenance	1	4.55	3.00
	Total	22	100.00	
Chaparral Park	Active Transport	98	27.68	8.14 ± 0.94
	Artificial Feeding	23	6.50	20.13 ± 5.41
	Breeding	13	3.67	12.08 ± 1.78
	Disturbance	9	2.54	11.89 ± 4.29
	Foraging/Feeding	75	21.19	18.37 ± 2.49
	Resting	95	26.84	11.91 ± 1.26
	Self-maintenance	41	11.58	14.39 ± 2.63
	Total	354	100.00	
Chaparral Park - West	Active Transport	18	31.03	28.22 ± 9.76
	Artificial Feeding	0	0.00	0.00
	Breeding	0	0.00	0.00
	Disturbance	0	0.00	0.00
	Foraging/Feeding	31	53.45	27.55 ± 5.22
	Resting	8	13.79	10.75 ± 4.98
	Self-maintenance	1	1.72	27.00
	Total	58	100.00	
Continental Golf Course - North	Active Transport	4	11.11	13.75 ± 3.73
	Artificial Feeding	0	0.00	0.00
	Breeding	0	0.00	0.00
	Disturbance	0	0.00	0.00
	Foraging/Feeding	27	75.00	30.89 ± 4.82
	Resting	4	11.11	26.00 ± 2.02
	Self-maintenance	1	2.78	8.00
	Total	36	100.00	24.00 ± 16.37
Continental Golf Course - South	Active Transport	3	13.64	0.00
	Artificial Feeding	0	0.00	0.00
	Breeding	0	0.00	0.00
	Disturbance	0	0.00	0.00
	Foraging/Feeding	14	63.64	13.79 ± 3.16
	Resting	4	18.18	6.00 ± 1.83
	Self-maintenance	1	4.55	12.00
	Total	22	100.00	

Site	Activity	*n*	%	Mean Flock Size
Continental Villas East II	Active Transport	2	40.00	4.50 ± 1.50
	Artificial Feeding	0	0.00	0.00
	Breeding	0	0.00	0.00
	Disturbance	0	0.00	0.00
	Foraging/Feeding	0	0.00	0.00
	Resting	2	40.00	5.00 ± 2.00
	Self-maintenance	1	20.00	11.00
	Total	5	100.00	
Coronado Golf Course	Active Transport	6	17.65	8.5 ± 2.96
	Artificial Feeding	0	0.00	0.00
	Breeding	1	2.94	1.00
	Disturbance	1	2.94	11.00
	Foraging/Feeding	14	41.18	9.71 ± 2.25
	Resting	11	32.35	16.73 ± 2.65
	Self-maintenance	1	2.94	6.00
	Total	34	100.00	
Eldorado Park - North	Active Transport	8	38.10	4.00 ± 1.28
	Artificial Feeding	5	23.81	10.00 ± 2.37
	Breeding	0	0.00	0.00
	Disturbance	0	0.00	0.00
	Foraging/Feeding	5	23.81	8.20 ± 3.67
	Resting	2	9.52	9.00 ± 3.00
	Self-maintenance	1	4.76	13.00
	Total	21	100.00	
Eldorado Park - South	Active Transport	5	15.63	8.40 ± 3.91
	Artificial Feeding	2	6.25	13.50 ± 5.50
	Breeding	0	0.00	0.00
	Disturbance	1	3.13	33.00
	Foraging/Feeding	11	34.38	24.18 ± 7.48
	Resting	9	28.13	9.00 ± 1.99
	Self-maintenance	4	12.50	9.25 ± 2.06
	Total	32	100.00	
Gainey Ranch	Active Transport	1	20.00	9.00
	Artificial Feeding	0	0.00	0.00
	Breeding	0	0.00	0.00
	Disturbance	0	0.00	0.00
	Foraging/Feeding	1	20.00	3.00
	Resting	2	40.00	13.50 ± 0.50
	Self-maintenance	1	20.00	14.00
	Total	5	100.00	

Site	Activity	*n*	%	Mean Flock Size
McCormick Ranch - Camelback Lake	Active Transport	33	42.86	24.55 ± 8.78
	Artificial Feeding	2	2.60	34.00 ± 31.00
	Breeding	3	3.90	7.00 ± 2.65
	Disturbance	0	0.00	0.00
	Foraging/Feeding	17	22.08	10.35 ± 1.59
	Resting	14	18.18	22.36 ± 6.87
	Self-maintenance	8	10.39	33.25 ± 14.27
	Total	77	100.00	
McCormick Ranch - Camelback Lake - North	Active Transport	11	11.46	6.73 ± 1.65
	Artificial Feeding	0	0.00	0.00
	Breeding	0	0.00	0.00
	Disturbance	2	2.08	62.00 ± 40.00
	Foraging/Feeding	40	41.67	39.20 ± 5.56
	Resting	33	34.38	27.45 ± 4.20
	Self-maintenance	10	10.42	18.50 ± 5.52
	Total	96	100.00	
McCormick Ranch - Indian Bend Lake	Active Transport	3	75.00	16.67 ± 11.67
	Artificial Feeding	0	0.00	0.00
	Breeding	0	0.00	0.00
	Disturbance	0	0.00	0.00
	Foraging/Feeding	0	0.00	0.00
	Resting	1	25.00	13.00
	Self-maintenance	0	0.00	0.00
	Total	4	100.00	
McCormick Ranch - Lake Angela	Active Transport	0	0.00	0.00
	Artificial Feeding	0	0.00	0.00
	Breeding	0	0.00	0.00
	Disturbance	0	0.00	0.00
	Foraging/Feeding	0	0.00	0.00
	Resting	1	100.00	12.00
	Self-maintenance	0	0.00	0.00
	Total	1	100.00	
McCormick Ranch - Lake Margherite	Active Transport	2	25.00	6.00 ± 2.00
	Artificial Feeding	0	0.00	0.00
	Breeding	0	0.00	0.00
	Disturbance	0	0.00	0.00
	Foraging/Feeding	3	37.50	11.00 ± 4.93
	Resting	2	25.00	6.50 ± 5.50
	Self-maintenance	1	12.50	10.00
	Total	8	100.00	

Site	Activity	*n*	%	Mean Flock Size
McCormick Ranch - Lake Playa	Active Transport	6	50.00	46.17 ± 27.20
	Artificial Feeding	0	0.00	0.00
	Breeding	0	0.00	0.00
	Disturbance	1	8.33	17.00
	Foraging/Feeding	2	16.67	6.00 ± 4.00
	Resting	3	25.00	19.00 ± 15.50
	Self-maintenance	0	0.00	0.00
	Total	12	100.00	
McCormick Ranch - Lake Santa Fe	Active Transport	1	50.00	2.00
	Artificial Feeding	0	0.00	0.00
	Breeding	0	0.00	0.00
	Disturbance	0	0.00	0.00
	Foraging/Feeding	0	0.00	0.00
	Resting	1	50.00	4.00
	Self-maintenance	0	0.00	0.00
	Total	2	100.00	
McCormick Ranch - Rancho Lake	Active Transport	0	0.00	0.00
	Artificial Feeding	0	0.00	0.00
	Breeding	0	0.00	0.00
	Disturbance	0	0.00	0.00
	Foraging/Feeding	1	100.00	7.00
	Resting	0	0.00	0.00
	Self-maintenance	0	0.00	0.00
	Total	1	100.00	
Scottsdale Pavilions	Active Transport	0	0.00	0.00
	Artificial Feeding	0	0.00	0.00
	Breeding	0	0.00	0.00
	Disturbance	0	0.00	0.00
	Foraging/Feeding	2	28.57	15.00 ± 11.00
	Resting	5	71.43	49.60 ± 33.01
	Self-maintenance	0	0.00	0.00
	Total	7	100.00	
Scottsdale Shadows	Active Transport	0	0.00	0.00
	Artificial Feeding	0	0.00	0.00
	Breeding	0	0.00	0.00
	Disturbance	0	0.00	0.00
	Foraging/Feeding	4	100.00	5.25 ± 2.36
	Resting	0	0.00	0.00
	Self-maintenance	0	0.00	0.00
	Total		100.00	

Site	Activity	*n*	%	Mean Flock Size
Vista del Camino Park - McKellips Lake	Active Transport	3	6.25	5.33 ± 1.76
	Artificial Feeding	1	2.08	14.00
	Breeding	0	0.00	0.00
	Disturbance	1	2.08	11.00
	Foraging/Feeding	17	35.42	15.06 ± 2.43
	Resting	16	33.33	7.81 ± 2.40
	Self-maintenance	10	20.83	7.70 ± 1.61
	Total	48	100.00	
Vista del Camino Park - McKellips Lake - North	Active Transport	2	8.33	16.00 ± 15.00
	Artificial Feeding	0	0.00	0.00
	Breeding	0	0.00	0.00
	Disturbance	2	8.33	9.50 ± 2.50
	Foraging/Feeding	9	37.50	19.00 ± 3.44
	Resting	8	33.33	9.50 ± 2.04
	Self-maintenance	3	12.50	20.33 ± 6.89
	Total	24	100.00	
Vista del Camino Park - North	Active Transport	2	12.50	12.00 ± 4.00
	Artificial Feeding	0	0.00	0.00
	Breeding	8	50.00	41.00 ± 0.91
	Disturbance	0	0.00	0.00
	Foraging/Feeding	3	18.75	3.00 ± 1.00
	Resting	1	6.25	4.00
	Self-maintenance	2	12.50	15.50 ± 9.50
	Total	16	100.00	