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Roosting, Site Fidelity, and Food Sources of Urban Gulls In Massachusetts: Implications For Protecting Public Water Supplies

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ROOSTING, SITE FIDELITY, AND FOOD SOURCES OF URBAN GULLS IN
MASSACHUSETTS: IMPLICATIONS FOR PROTECTING PUBLIC WATER
SUPPLIES

A Dissertation Presented

by

DANIEL E. CLARK

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of

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February 2014

Wildlife, Fish, and Conservation Biology

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MASSACHUSETTS: IMPLICATIONS FOR PROTECTING PUBLIC WATER
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DEDICATION

To my wife and family for their patience, constant support, and love.

ABSTRACT

ROOSTING, SITE FIDELITY, AND FOOD SOURCES OF URBAN GULLS IN

MASSACHUSETTS: IMPLICATIONS FOR PROTECTING PUBLIC WATER

SUPPLIES

FEBRUARY 2014

DANIEL E. CLARK, B.S., UNIVERSITY OF MASSACHUSETTS AMHERST

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Anyone who has spent time in coastal New England has seen gulls flying

overhead and heard their familiar sound; gulls may be one of the most recognizable birds

in the world. There are over 50 species of gulls worldwide, and many of them are closely

associated with human development or activities. In Massachusetts, there are several

common gull species including herring (*Larus argentatus*), great black-back (*Larus

marinus*), laughing (*Leucophaeus atricilla*), and ring-billed (*Larus delawarensis*).

While coastal encounters with gulls are ubiquitous, gulls can also be found inland,

and ring-billed and herring gulls are now a common sight at lakes, parks, and commercial

parking lots dozens or hundreds of kilometers from the ocean. This inland population of

gulls presents unique challenges and exciting research opportunities. Because they are

often closely associated with human activity, concentrations of inland gulls can lead to

potential water quality concerns (when large roosts form on public water supply

reservoirs), airplane hazards (when groups of gulls concentrate near airports or flight

paths), or disease transmission (when gulls forage at landfills or waste water treatment plants then visit areas with people).

In the following chapters I explore various aspects of inland gull ecology during the non-breeding season. In chapter 1, I review the concept of philopatry in birds and discuss ways to assess site faithful behavior. In Chapters 2 and 3, I explore some of the ecological aspects of inland gulls. Chapter 2 examines the site fidelity of gulls to their wintering areas and my results suggest that gulls exhibit high winter-site fidelity but variable site persistence during the winter season. Chapter 3 explores roost site selection throughout the year and models roost selection in Massachusetts. My results indicate that ring-billed gulls prefer freshwater roosts, while herring gulls use saltwater roosts more often. In Massachusetts, both herring and ring-billed gulls select inland freshwater roosts based on the size of the water body and proximity to their last daytime location.

In Chapter 4, I detail the results of an experimental study trying to reduce the amount of anthropogenic food available to gulls at inland parking lots. Ring-billed gulls were the most common gull found in parking lots, and my educational approach to reduce feedings had mixed results; education seemed to reduce the number of feedings in some cases, but the number of gulls in each parking lot was not affected. In Chapters 5 and 6, I detail some applied management techniques. Chapter 5 discusses efforts to exclude gulls from a waste water treatment plant in central Massachusetts. Overhead stainless-steel wires were completely effective at preventing gulls from using structures at the treatment plant. Chapter 6 describes an innovative technique that was used to efficiently and effectively catch gulls during winter in highly urbanized environments. I captured over 1000 gulls using a net launcher in various parking lots and other urban areas.

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CHAPTER 1

SITE FAITHFUL BEHAVIOR IN BIRDS: DEFINING AND QUANTIFYING FIDELITY WITH IMPLICATIONS FOR CONSERVATION

Abstract

Site faithful behavior is common in birds and has been measured in a variety of ways. Site fidelity has important ecological implications because site faithful behavior to natal or breeding areas, wintering grounds, or migratory stopover sites can lead to local knowledge of an area, maximizing individual fitness through increased survival or reproduction. We reviewed contemporary avian literature to summarize how site fidelity is defined and quantitatively assessed, provide recommendations on terminology and methodology, and review the implications of site faithful behavior. We recommend using the term philopatry only in reference to natal philopatry and suggest researchers avoid using the term in relation to other site faithful behavior (breeding, winter, or stopover). Reporting return rates (through recaptures or resightings) is a straightforward and commonly used method to assess site fidelity, however it provides biased results, and we do not recommend its use. We recommend using telemetry data, multistate mark-resight models or a combination of both to assess site faithful behavior. Both techniques provide unbiased estimates of fidelity that are comparable among studies. Understanding and assessing avian site fidelity can be an important consideration when developing management plans for rare or abundant species, determining the impacts of changing ecological conditions, or controlling site-specific avian caused damage.

Introduction

Site faithful behavior has been studied in a variety of avian species, yet there is surprisingly little consistency in how fidelity is defined or measured. While some studies discuss philopatry in reference to wintering areas (Robertson and Cooke 1999, Robertson et al. 2000, Mehl et al. 2004), other studies attribute philopatric behavior to natal areas (Thibault 1993, Stenhouse and Robertson 2005) stopover (Merom et al. 2000), or breeding sites (Grotto et al. 1985, Lindberg et al. 1998, Winkler et al. 2004). Further, researchers have used a diversity of methods to asses fidelity, including resightings of tagged individuals (Fox et al. 1994, Robertson et al. 2000, Koronkiewicz et al. 2006, Guillemain et al. 2009, McKinley and Mattox 2010, Buchanan et al. 2012), capture/recapture models or transition probabilities of marked birds (Hestbeck et al. 1991, Stenhouse and Robertson 2005, Belda et al. 2007, Williams et al. 2008), recaptures of banded birds (Thibault 1993, Somershoe et al. 2009, Monroy-Ojeda et al. 2013), and data from satellite or VHF transmitters (Petersen et al. 2012).

Site faithful behavior during the breeding season can have important ecological implications when individuals choose to return to, or remain in, a certain area or disperse to new areas. In heterogeneous habitats, site faithful behavior that leads to local knowledge may maximize feeding efficiency, minimize the cost of moving to a new area (e.g., increased risk of predation, locating and exploiting food resources), and increase survival, reproduction, or the chance of locating mates (Cooch et al. 1993, Lindberg and Sedinger 1997, Wheelwright and Mauck 1998). However, researchers assessing the benefits of site faithful behavior have reported conflicting results. Gauthier (1990) documented earlier nesting, larger clutch sizes, and increased nest success for female

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buffleheads (*Bucephala albeola*) returning to the same nesting sites, while other studies have reported no reproductive advantage of site faithful birds (Hepp and Kennamer 1992, Lindberg and Sedinger 1997). It is likely that site faithful behavior may be advantageous in certain conditions, but may become maladaptive if the local environment changes over time (Cooch et al. 1993).

Robertson and Cooke (1999) proposed that individuals return to the same sites during the non-breeding season to take advantage of prior knowledge of the area, including the location of patchy food resources, suitable roosting sites, or predator movements and habits. Individuals that use this local knowledge may more efficiently avoid predators or exploit food resources, thereby increasing their overwinter survival (Robertson and Cooke 1999). Further, good foraging conditions during the winter have been shown to increase female reproductive success in the subsequent breeding season in geese (Ankney and MacInnes 1978) and other waterfowl (Raveling and Heitmeyer 1989).

Given the important ecological implications of site faithful behavior and the continued interest in fidelity related research, it is important to be consistent in both terminology and methods of assessment. Our objectives are to clearly define philopatry and other types of site faithful behavior and recommend usage, review methods that can be used to assess site fidelity and suggest appropriate applications, and discuss the implications of site faithful behavior in relation to avian conservation and management.

Terminology

Because authors have used the terms philopatry, site faithful, and site fidelity to describe a wide variety of behavior, it is important to clearly define each term, discuss the implications associated with each, and make recommendations for their usage.

Philopatry – Natal philopatry means not dispersing far from, or returning to, a birthplace for reproduction, while the term breeding philopatry is often defined as returning to the same breeding area each year, regardless of where an individual was born (Pearce 2007). Any assessment of breeding philopatry would include immigrating individuals, while natal philopatry is restricted to only locally born individuals. Pearce (2007) convincingly argued that the term philopatry should only be used when discussing natal philopatry because there are important genetic and demographic implications associated with the term. Natal philopatry increases the probability of breeding with a close relative and has been suggested as a main function of philopatry, not simply a consequence (Shields 1982). This inbreeding may be adaptive in preserving co-adapted gene complexes, reducing the cost of meiosis, and promoting speciation (Shields 1982, Wheelwright and Mauck 1998, Pearce 2007). When philopatry is used to describe other types of site faithful behavior (i.e., breeding philopatry, winter philopatry) it can lead to confusion because the genetic or demographic outcome expected with that term may not exist (Pearce 2007). As a result, philopatry should only be used in reference to natal philopatry and not be applied to describe other types of site faithful behavior.

Site faithful/site fidelity – These terms refer to individuals returning to the same area annually. Site fidelity can be attributed to wintering areas, breeding sites, or migratory stopover areas. While site fidelity should ideally include a common definition of how close an individual must return to the previous year's area to be considered site faithful (Lindberg et al. 1995), there is currently no accepted standard distance; most studies consider individuals site faithful if they return to an arbitrarily defined study area. For example, Mittelhauser et al. (2012) concluded purple sandpipers showed high winter

site fidelity because most individuals moved ≤5 km from capture sites, while McKinley and Mattox (2010) suggested raptors seen in subsequent winters within 3 km of the original banding site were site faithful. Unlike philopatry, the probability of site fidelity (or dispersal) is an estimable parameter (Kendall and Nichols 2004).

Methods

We conducted a computer search of the literature to identify publications dealing with avian philopatry or site fidelity. Searches were conducted in Google Scholar® and the ISI Web of Knowledge[SM], Web of Science®.   We used several keywords, including "philopatry", "winter-site fidelity", "site fidelity", and "avian or bird". We restricted our search to 1980-2013 because we felt this time period provided the most comparable techniques and terminology. Relevant literature was reviewed to determine: 1. what species was studied, 2. how fidelity was defined, 3. what type of fidelity was assessed (i.e., breeding, winter, etc.), and 4. what method(s) was used to assess site fidelity. While the search was not exhaustive, it provided a comprehensive assessment of the variety of methods used to assess site faithful behavior.

Results

Quantifying site faithful behavior – We located 35 articles in 14 journals using our search terms. Most articles (21) were from the 2000's, while 13 were from the 1990's, and only one was from the 1980's. Avian journals (i.e., Auk, Condor) contained the most articles, while statistical or wildlife journals contained the fewest. A variety of methods have been used to determine site faithful behavior in birds (Table 1.1). While each method has some advantages and disadvantages, there are certain methods that provide limited useful data and should be avoided.

Return rates of banded birds – A common method of assessing site fidelity is to report the number of banded birds returning to a specified area. Return rates (i.e. number of birds captured in relation to the total number of birds marked) are a composite of the probability that an animal will survive to the following year (survival rate), return to the study area (homing rate), and be recaptured in the study area (recapture rate) (Hestbeck et al. 1991, Robertson and Cooke 1999). While homing rate is a more direct measure of fidelity, most studies using band returns simply report the return rate of banded birds (Cooch et al. 1993, Somershoe et al. 2009, Monroy-Ojeda et al. 2013). Because the return rate is a composite of several probabilities, it is difficult to make comparisons among studies when just return rate is reported. Further, return rates can be greatly influenced by variations in annual survival and recapture probabilities among sexes, species, or populations and represent minimum estimates of fidelity (Lindberg et al. 1998). Although return rates are relatively easy to obtain and do establish a minimum estimate of fidelity, just reporting return rates to assess site faithful behavior should be discouraged in future research as it provides little useful or comparable information.

Resightings – Like band returns, several studies have used resightings of marked individuals in subsequent years as evidence for fidelity (Flynn et al. 1999, Koronkiewicz et al. 2006, McKinley and Mattox 2010). Although resightings don't rely on capturing and handling individuals in subsequent years, many of the same limitations associated with band returns exist with this method. Resighting probabilities and survival can vary from species to species, or even within a species experiencing different environmental conditions, making comparisons difficult. In addition, resightings do not allow the estimation of the proportion of the birds alive in a particular area that returned to the

same area used in the previous year (Hestbeck et al. 1991). Like band returns, resightings

are return rates and not a true estimate of fidelity and should be discouraged.

Telemetry Data – Studies using telemetry data to assess site fidelity are less

common than studies using other methods (Table 1.1). However, telemetry data

(particularly satellite or GPS transmitters) can provide detailed information about the

yearly movements of individuals that cannot be obtained through band returns or

resightings. Further, because individuals are followed until death (or transmitter loss),

there is no need to calculate detection probabilities. Typically, some measure of home

range overlap or utilization is calculated for successive years (Garcia-Ripolles 2010,

Petersen et al. 2012). Utilization distributions (50% or 95%) can be compared between

years, and the volume of intersection between 2 utilization distributions can be calculated

(Fieberg and Kochanny 2005). While detailed yearly movements can be obtained

through telemetry data, most studies are disadvantaged by small sample sizes (i.e., high

transmitter costs), or lifespan of the equipment (i.e., transmitter fails prior to individuals

returning). However, telemetry data can prove useful in visualizing annual movements,

provide unbiased assessments of fidelity (although with typically few individuals), and be

used in combination with mark-recapture techniques (see mark-recapture methods).

Mark-recapture methods – An increasingly common technique to assess site

fidelity is to use recapture (i.e., band recoveries, resightings, recaptures, telemetry) data

to construct individual life histories to calculate transition probabilities within a capture-

recapture framework (Hestbeck et al. 1991, Lindberg et al. 1995, Williams et al. 2005,

Stenhouse and Robertson 2005). Hestbeck et al. (1991) developed multistate mark-

resight models based on the standard Jolly-Seber model that allow for the maximum

likelihood estimates of transition probabilities (probability of moving from one location to another) and site fidelity (1 – transition probability). These multistate models calculate unbiased estimates of fidelity that are not confounded by detection, dispersal, or mortality probabilities (Lindberg et al. 1995). Studies with individually marked birds can model survival, transition, and resighting probabilities for specific populations, subpopulations or between various study areas (Williams et al. 2005). Program MARK allows the efficient and flexible analysis of large capture-recapture data sets to generate these survival, resighting, and transition probabilities (White and Burnham 1999). In addition, a flexible analysis framework allows researchers to use a combination of available data including band returns (dead animals), recaptures, resightings and/or telemetry for analysis.

While these maximum likelihood methods can provide unbiased estimates of fidelity, they are based on models with explicit assumptions. Hestbeck et al. (1991) described the assumptions associated with these models (using Jolly-Seber models as a reference) and the effects of violations of the assumptions. Hestbeck et al. (1991) concluded that violating the assumptions of equal probability of capture, independence of sighting probability, survival, and movement, and retention of marks (i.e., neck bands, wing tags) would result in negligible effects. Further, while the assumption of instantaneous sampling can never be strictly met, Hestbeck et al. (1991) recommended that the sampling period be small compared to the length of time between sampling. The fifth assumption of nonpermanent emigration can be problematic in many studies, but Hestbeck et al. (1991) suggested making estimates during periods when migration or smaller scale movements would be small.

Discussion

Philopatry has been used to describe a wide variety of site faithful behavior in birds. However, discussions about avian philopatry should be limited to describing natal philopatry because this type of site faithful behavior can influence the extent of inbreeding in bird populations. Weatherhead and Forbes (1994) suggested two alternative hypotheses to explain natal philopatry in non-cooperatively breeding birds: optimal-inbreeding and dispersal-cost. Optimal-inbreeding suggests natal philopatry evolved to increase the probability of breeding with close relatives, thereby reducing the cost of meiosis and preserving co-adapted gene complexes (Shields 1982, Weatherhead and Forbes 1994). If optimal-inbreeding were important, then most birds (migratory and resident) would exhibit high levels of philopatry. In contrast, the dispersal-cost theory suggests that philopatry is closely related to costs associated with bird migration. Migrating birds must pay a "dispersal cost" by giving up local knowledge of their natal area and learning to exploit resources in unfamiliar areas (Weatherhead and Forbes 1994). For resident young, there is an advantage of staying close to their natal area because they can retain local knowledge. If optimal-inbreeding was relatively unimportant, then young of resident bird populations should be more philopatric than migrating species. Results from multiple studies of passerine birds suggest that ecological factors influencing dispersal (i.e., dispersal-cost theory) are more likely than a genetic based theory to explain patterns in natal philopatry (Weatherhead and Forbes 1994). Further, Wheelwright and Mauck (1998) reported that the migratory savannah sparrow (*Passerculus sandwichensis*) was highly philopatric and avoided breeding with

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close relatives, suggesting that genetic based theories of philopatry may be relatively unimportant.

The dispersal-cost theory suggests that migratory birds relinquish their local knowledge of natal areas when they disperse and therefore, when they return to breed, they only need to find a suitable breeding location, not a familiar one (Weatherhead and Forbes 1994). However, a variety of migratory birds return to the same natal, breeding, or wintering areas each year. It is likely that site faithful behavior is also influenced by ecological or ecogenetic components. Site faithful behavior would be advantageous to all birds because local knowledge can increase success at finding food, escaping predators, finding mates, or reproducing (Lindberg and Sedinger 1997, Robertson and Cooke 1999). Further, ecogenetic considerations suggest that natal philopatry or breeding site fidelity would increase the probability of producing offspring well adapted to local conditions (Wheelwright and Mauck 1998).

A variety of methods have been used to assess site fidelity in birds; some approaches provide unbiased, comparable results while others do not. Reporting the same individuals (band returns or resightings) in an area in subsequent years is a commonly used technique to document site faithful behavior. This method is straightforward and relatively easy, yet it provides biased results, makes comparisons among studies difficult, and should be discouraged. Homing rates (the proportion of birds returning to the study site out of the total number of birds sighted anywhere) would provide a better estimate of site faithful behavior since survival rates are included. However, this would require an effort to locate birds in both the study area and all potential areas and would overestimate homing rate if survey efforts were low in those

other areas. Given the difficulty in surveying large areas for marked birds, calculating homing rates is an unlikely approach and is seldom reported.

Estimates of fidelity using mark-recapture models provide an unbiased assessment of site faithful behavior if model assumptions can be met. Further, the multistate models that have been developed allow for flexible data collection (resightings, recovered bands, telemetry) and the ability to utilize a combination of data types. Using models to generate transition probabilities and fidelity (1 – transition probability) can provide easily comparable estimates of site faithful behavior and a consistent reporting parameter (0 – 1). This method does require multiple years of observations and multiple study areas (if calculating transition probabilities between areas) in order to construct individual life histories for each marked bird.

Telemetry data can offer unbiased estimates of site fidelity and also have the distinct advantage of providing visual representations of seasonal movements. In addition, telemetry data can provide detailed information on dispersal, site tenacity (persistence of an individual in a given area), and spatial/temporal aspects of fidelity (i.e., return date to breeding area) that would be challenging to obtain through mark-resighting studies. However, given the relative cost of using telemetry (particularly satellite and/or GPS transmitters), most studies are limited in how many individuals can be followed. In addition, the lifespan of a transmitter or bird is unpredictable, and the transmitter may stop working before the animal can potentially return to the study area.

Implications for Conservation and Management

Identifying and understanding site faithful behavior in birds can be important considerations when monitoring populations or developing management plans. While it

is important to identify and conserve critical breeding grounds for avian species, discovering, protecting, and managing wintering areas of site faithful birds can also be important for overwinter survival and long-term population dynamics. The effects of fidelity on the stability or recovery of different breeding populations can be important when catastrophes occur. For example, common eiders (*Somateria mollissima*) nesting along the Beaufort Sea coast of Alaska winter almost exclusively along the St. Lawrence Island and Chuckotka Peninsula (Petersen et al. 2012). Catastrophic mortality (e.g., oil spill, weather) on the wintering grounds would directly affect this genetically distinct breeding population. However, other sub-populations of eiders are faithful to several wintering areas, and any one event would not likely have a major impact on the population (Petersen et al. 2012).

Identifying and assessing both winter and breeding-site fidelity may be important in some species. Recognizing sub-populations of species that maintain distinct breeding sites but mix during winter can be critical when making management decisions. Management actions during the winter to reduce or increase a population may have a disproportionate effect on certain sub-populations. For example, lesser snow geese (*Chen caerulescens caerulescens*) breeding in distinct areas of Canada and Russia share a wintering area in northern California (Williams et al. 2005). The Canadian population has increased exponentially while the Russian population has fluctuated. Knowing both the winter and breeding-site fidelity of this species would avoid winter management activities that may further reduce the Canadian population (Williams et al. 2005).

Strong site fidelity can also have important implications in changing environments or when species are rare or uncommon. For uncommon species, fidelity

could lead to demographic concerns. High breeding site fidelity of piping plovers (*Charadrius melodus*) and savannah sparrows could lead to smaller effective population sizes if environmental factors decrease local survival and there is little immigration from other populations (because of high site fidelity). Small effective populations are more prone to local extinction. Further, the advantages of site faithful behavior in maximizing knowledge of local food sources may only be apparent in stable environments. Lesser snow geese breeding and rearing young in declining traditional feeding areas had significantly smaller goslings with lower survival (Cooch et al. 1993). In addition, strong winter-site fidelity in areas of declining habitat may result in individuals having difficulty finding appropriate sites if suitable areas are uncommon and already occupied by territorial individuals (Koronkiewicz et al. 2006). Recognizing important breeding or wintering habitat that may be declining can help direct efforts to protect or manage remaining areas.

In situations where birds are causing specific problems, knowledge of site faithful behavior can lead to improved management decisions. Ring-billed (*Larus delawarensis*) and herring gulls (*L. argentatus*) have high site fidelity to wintering areas in the Northeast United States (See Chapter 2). These gulls can also cause water quality concerns when they roost on water supply reservoirs or aviation hazards when they are located in close proximity to airports. Using knowledge about site faithful behavior would aid efforts to control this wintering sub-population (through food reduction or directed harassment). Control programs would have a higher chance of success than similar programs targeting a nomadic or randomly dispersed population because the same site faithful birds would be targeted each year.

Table 1.1. Summary of methods used to assess site fidelity in various birds.

Site/Method[a]	No. Studies	Species	References
Winter			
Band Returns	4	Passerines, redshank	Somershoe et al. 2009, Burton 2000, Monroy-Ojeda et al. 2013, Reitsma et al. 2002
MRM/TP	4	Geese, redshank, passerines	Hestbeck et al. 1991, Burton 2000, Williams et al. 2005, Belda et al. 2007
Telemetry	4	Redshank, eider, vulture, ducks	Burton 2000, Petersen et al. 2012, Garcia-Ripolles et al. 2010, Iverson and Esler 2006
Resightings	5	Pink-footed geese, flycatcher, teal, raptor, ducks	Fox et al. 1994, Koronkiewicz et al. 2006, Guillemain et al. 2009, McKinley and Mattox 2010, Roberston et al. 2000
Natal/Breeding			
Band Returns	3	Snow geese, sparrow, bufflehead, shearwater	Cooch et al. 1993, Wheelwright and Mauck 1998, Gauthier 1990, Thibault 1993

Table 1.1 continued.

Site/Method[a]	No. Studies	Species	References
MRM/TP	5	Brant, Sabine's gull, plovers	Lindberg et al. 1995, Stenhouse and Robertson 2005, Nol et al. 2010, Cohen et al. 2006, Lindberg and Sedinger 1997
Telemetry	-	-	-
Resightings	3	Plover, sandpiper, stilt	Flynn et al. 1999, Gratto et al. 1985, James 1995
Migration/Stop-over			
Band Returns	2	Red knot, passerines	Buchanan et al. 2012, Merom et al. 2000
MRM/TP	-	-	-
Telemetry	-	-	-
Resightings	-	-	-

[a] Site: type of site-faithful behavior being studied; Method: assessment used to determine fidelity. Band returns: banded individuals captured in subsequent years, MRM/TP: Mark-recapture methods and/or transitional probabilities calculated using histories of marked individuals; Telemetry: satellite or VHF telemetry data; Resightings: sighting marked individuals in subsequent years as evidence for fidelity.

CHAPTER 2

FIDELITY AND PERSISTENCE OF RING-BILLED AND HERRING GULLS TO WINTERING SITES

Abstract

While the breeding ecology of gulls has been well studied, the movements and spatial organization of gulls during the non-breeding season is poorly understood. We studied the winter-site fidelity and site persistence of ring-billed (*Larus delawarensis*) and herring gulls (*L. argentatus*) to areas in Massachusetts during 2008-2012. We satellite tracked 10 ring-billed and 6 herring gulls over multiple winters and followed >300 wing-tagged ring-billed gulls to determine winter-site fidelity and persistence. The proportion of home range (95% minimum convex polygon) overlap between years was 0-1.0, and overlap between kernel utilization distributions ranged from 0.31-0.79. Gulls remained in Massachusetts during the non-breeding season an average of 74-161 days (herring) and 20-167 days (ring-billed). The probability of a tagged ring-billed gull returning to the same site in subsequent winters was very high; conversely, there was a low probability of a gull returning to a different site. Results from this study provide evidence that ring-billed and herring gulls exhibit high winter-site fidelity, but variable site persistence during the winter season, leading to a high probability of encountering the same individuals in subsequent winters. Management programs designed to reduce the impacts of wintering gulls on drinking water supply reservoirs or aviation hazards should consider the results of this study when formulating strategies to manage gulls at the landscape level.

Introduction

Philopatry is the return of an individual to its birthplace for reproduction and is
directly related to population structure and gene flow (James 1995). Philopatric behavior
can lead to a reduction in gene flow among groups of individuals that are breeding in
geographically distinct locations (Stiebens 2013). Although philopatry is specifically
related to reproduction and has quantifiable genetic and evolutionary consequences, some
ornithological literature expands the definition of philopatry to include all types of site
faithful behavior including site fidelity to wintering areas, migratory stopover sights, and
molting areas (Robertson and Cooke 1999, Mehl et al. 2004). However, these other types
of fidelity should not be considered philopatry and instead should be used to describe site
specific attributes (i.e., winter-site fidelity, breeding-site fidelity) (Pearce 2007). Site
faithful behavior has been documented in a diversity of avian species, and being site
faithful during the breeding or non-breeding season can have a variety of ecological and
evolutionary influences on bird populations.

Seasonal movements and site fidelity can influence an individual's ability to find
a suitable breeding colony or mate, or take advantage of seasonally and spatially
predictable food resources (Foote et al. 2010), yet very little is known about the site
fidelity of gulls during the non-breeding season. Spaans (2000) studied winter-site
fidelity of black-headed gull (*Larus ridibundus*) in the Netherlands and documented
average return rates to the study site of 59%. However, other studies during the non-
breeding season have relied on band returns from dead and recovered gulls to document
movements (Southern 1974, Gabrey 1996). While this is helpful to show the non-
breeding season distribution, these data do not provide insight into site fidelity, inter-year

movements, or persistence at a wintering area. Because conditions during the non-breeding season may limit populations, returning to the same non-breeding area each year may provide an evolutionary advantage through increased familiarity with local food resources and roosting areas, or predator avoidance (Somershoe et al. 2009). Winter-site fidelity has been documented in other birds, including Eurasian teal (*Anas crecca*), various passerines, and pink-footed geese (*Anser brachyrhynchus*) (Fox et al. 1994, Guillemain et al. 2009, Somershoe et al. 2009).

Ring-billed (*L. delawarensis*) and herring gulls (*L. argentatus*) are year-round residents in Massachusetts, but inland populations increase dramatically during the fall and winter. Roosting gulls choose large inland water bodies in close proximity to their foraging areas (see Chapter 3), which can lead to conflict when these roosts are also used for recreation, as water supplies, or are in close proximity to airports (Dewey and Lowney 1997, Nugent 2009, Converse et al. 2012). Inland gulls in Massachusetts often roost on Wachusett and Quabbin Reservoirs, which serve as the unfiltered water supply for over 2 million consumers in greater Boston (D. Clark unpublished data). Since the early 1990s, an extensive bird harassment program has been used to exclude gulls from critical areas of each reservoir (Metropolitan District Commission 1992). Recent efforts have also focused on reducing the amount of anthropogenic food around each reservoir (e.g., landfills, handouts, etc.) (see Chapter 4).

Site fidelity in wintering gulls can be a critical consideration when developing or implementing harassment and food reduction programs. Our goal was to assess and quantify the winter-site fidelity of ring-billed and herring gulls to areas within central Massachusetts. We wanted to determine the likelihood that gulls roosting on Wachusett

and Quabbin Reservoirs, or foraging on nearby anthropogenic food, were the same individuals over successive years. In addition, we were interested in determining how long individual birds persisted in the study areas during the non-breeding season. We also wanted to determine if gulls routinely moved between study areas. To address these issues we used satellite telemetry and wing-tagging to study wintering ring-billed and herring gulls during 2008-2012 to determine the winter-site fidelity and site persistence of gulls to central Massachusetts. The results of this study provide original information about the spatial organization of ring-billed and herring gulls during the non-breeding season and also provide drinking water supply managers information that can be used to develop or refine harassment or food reduction programs.

Study Area

This study was conducted in Massachusetts in Worcester, Franklin, Hampshire, Hampden, and Suffolk counties. We captured ring-billed and herring gulls at 37 trapping locations in urban or suburban areas around the cities of Worcester (42°15'N, 71°48'W) and Springfield (42° 6'N, 72°35'W) from October to April 2008-2011 (Fig. 2.1). A small number of gulls were also captured at four locations in the greater Boston area. Trapping sites were chosen opportunistically based on the presence of gulls and were comprised of a variety of locations, including landfills, parking lots, waste water treatment plants, and fresh and saltwater beaches.

Methods

Satellite Tracking – We used a Coda net launcher, placed on the ground under the side of a 4-wheel pick-up truck, to capture gulls (Clark et al. in press). A large pile of bait was placed 3–4.5 m in front of the launcher, and the launcher was detonated from

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inside the truck's cab (Clark et al. in press). Captured ring-billed gulls were fitted with

solar powered 9.5 g (Microwave Telemetry, Columbia, MD; use of trade names does not

constitute an endorsement by the U. S. Government) or 9.5 g (Northstar Science and

Technology, King George, VA) ARGOS platform terminal transmitters (PTTs). Herring

gulls were fitted with solar powered 22 g or 30 g GPS transmitters (Microwave

Telemetry) or 11.5 g PTTs (Northstar Science and Technology). Transmitters

represented <3 % of body mass of the birds and were attached as backpacks with loops

around the neck and body. The harness consisted of 6 mm wide tubular Teflon ribbon

(Bally Ribbon Mills, Bally, PA), braided nylon fishing line as thread, cyanoacrylate

adhesive, and a 2.5 cm x 2.5 cm leather breast piece. Attachment was adapted from the

procedure described by Snyder et al. (1989), but without the feather shield.

GPS-equipped transmitters were programmed to transmit 6 times per day (mid-

morning, noon, mid-afternoon, late afternoon, evening, and night); times shifted slightly

seasonally to account for longer days. ARGOS PTTs were programmed to turn on and

transmit for 8 hours each day, then turn off for 18 hours. This 26-hour duty cycle

ensured that some transmissions occurred during all possible 24-hour time periods.

PTTs used the ARGOS system to transmit locations from tagged birds via

satellite. Each successful transmission was assigned a Location Class (LC) based on the

quality of the reception (ARGOS 2013). ARGOS classified locations into one of 7

classes (Z, B, A, 0, 1, 2, 3 in ascending order of accuracy). While ARGOS provided an

associated accuracy assessment for LCs 0-3, we assessed transmitter accuracy (mean

distance between test location and true position) independently in the field before

deployment by activating and placing transmitters on a flat roof for ≥2 weeks. All

locations from these test transmitters were collected and compared to the actual location. GPS transmitter accuracy was ±18 m for the 22 g models and ±30 m for the 30 g models. For PTTs, we used LC A, 0, 1, 2, and 3. Transmitter accuracy for the 9.5 g Microwave models was ±5491 m (A), ±7556 m (0), ±1890 m (1), ±1217 m (2), and ±354 m (3). Accuracy for the 9.5 g Northstar was ±2396 (A), ±5625 (0), ±1572 m (1), ±587 m (2), and ±336 m (3). For 11.5 g transmitters, accuracy was ±6015 (A), ±6741 (0), ±1959 m (1), ±858 m (2), and ±218 m (3).

Patagial tagging – Captured gulls not fitted with satellite transmitters were marked with patagial tags (Fig. 2.2). Tags were made out of 284 g/m^2 vinyl coated polyester fabric (Seattle Fabrics, Seattle, WA; Bondcote, Pulaski, VI) treated for ultra-violet stabilization and were color coded based on species and capture location. Sighting probability can be influenced by tag color, (e.g., darker colors are less visible to observers) tag retention, or survival (e.g., differential mortality with different color tags) (Seamans et al. 2010). We used vibrant or florescent colors to increase sighting probability and assumed tag loss was similar among colors. Seamans et al. (2010) reported higher resighting rates with orange and yellow tags; we used florescent orange, orange, florescent yellow, and yellow tags on all ring-billed gulls. Although less vibrant colors (e.g., green or blue) were used on herring gulls, they were clearly visible. Wing-tags were about 17 x 6 cm for ring-billed and 18.5 x 7.5 cm for herring gulls and were dumbbell shaped (Southern 1971). Tags were folded in half over the leading edge of the wing and we used a leather punch to make a small hole through the tag and patagium about 2 cm behind the wing chord. The tag was attached using a 3 mm aluminum washer over a 3 mm x 19 mm aluminum pop rivet, which was pushed through the hole from the

underside of the wing. Another 3 mm aluminum washer was placed on top of the exposed pop rivet, and the rivet was compressed (Stiehl 1983). Both wings received wing-tags. The top and bottom side of each wing-tag were marked with a unique alpha-numeric code using permanent black ink.

Data Analysis

Satellite Data – All satellite locations were filtered using ArcGIS 10.0 to only include individuals that were tracked for >1 non-breeding season (i.e., individuals that were tracked for at least 12 months post-capture). Locations were further filtered to include only locations within Massachusetts. All locations were plotted in Quantum GIS 1.7.3 and annual 95% minimum convex polygons were drawn using the HomeRange plugin (Mohr 1947, Quantum GIS Development Team 2012, open source; http://www.qgis.org/). We calculated the proportion of overlap between home range polygons for successive years. An overlap of 0 would indicate no overlap between successive years, while an overlap of 1.0 would indicate 100% overlap between years. In addition, we calculated between year estimates of overlapping habitat use using the kernaloverlap feature of the R package adehabitat (Calenge 2006, R Core Team 2012). This package implements the index of overlap between utilization distributions of 2 animals (or 1 animal over 2 years) as described by Fieberg and Kochanny (2005). The choice "VI" was used in the calculations to compute the volume of the intersection between the 2 utilization distributions. The VI index ranges between zero (no overlap) and 1 (ranges with the same utilization distribution) (Fieberg and Kochanny 2005). To quantify site persistence, the arrival and departure date from Massachusetts was determined for each gull and the average length of stay in Massachusetts was calculated.

Wing-tag resightings – Opportunistic surveys were made throughout central and eastern Massachusetts during 2008-2012 to locate tagged gulls. In addition, efforts were made to advertise the study (e.g., newspaper articles, website) to the general public, local and regional birding groups, and other gull researchers to encourage people to report sightings. Brightly colored wing-tags and the gulls' frequent use of human dominated habitats (e.g., beaches, parking lots, recreational lakes) allowed resightings of individual gulls within and outside of Massachusetts during the non-breeding season. However, we only had a sufficient number of resightings of ring-billed gulls to conduct the analyses; herring gulls were not included. For each sighting, we recorded the tag color, individual tag number, date, specific location, and general study area (Wachusett, Quabbin, Boston, or Other). To determine site persistence of tagged ring-billed gulls, we calculated the number of gulls seen inside or outside the study area up to 20 weeks post-capture.

In the analysis, we only used sightings obtained from December-January each year in order to ensure that gulls had reached their wintering area. We used observations of wing-tagged ring-billed gulls seen at least once during December-January to construct a complete history for each individual to calculate transition rates (Ψ), or movement between study areas (Hestbeck et al. 1991, Williams et al. 2005). The analysis was applied to three, independent cohorts (e.g., capture areas) of gulls for each year (2008-2012). We denoted four regions (movement areas) as A for Wachusett, B for Quabbin, C for Boston, and D for any area outside Massachusetts. A 0 indicated an occasion when an individual was not observed during a sampling period. For example, history A00AA denotes a gull captured and released in 2008 in the Wachusett study area, not seen in 2009 or 2010, and seen again in the Wachusett study area during either December or

January in 2011 and 2012. We used the multi-state with recaptures in Program MARK

(White and Burnham 1999) to model survival, resighting probabilities, and transition

rates for each cohort of gulls. Our global model contained 20 estimated parameters for 5

years, 3 rates (survival (S), resighting probability (p), and transition rate (Ψ)), and 4

wintering areas (g) (Wachusett, Quabbin, Boston, and Other). We evaluated 5 nested

models to evaluate differences related to time-constant vs. time-specific demographic

rates, and similarity or differences in demographic parameters among the 4 wintering

sites. To test for overdispersion of the global model, we calculated the variance inflation

factor ($\hat{c}$) (Burnham and Anderson 2002). There was evidence of overdispersion

($\hat{c}$=4.60), so the quasi-likelihood method, QAICc, was used (Anderson et al. 1994). We

used QAIC values, QAIC weights (w_i), and differences in QAIC (Δ_i) to determine the

relative support for each model and considered the model with the lowest QAIC to be the

most parsimonious model (Burnham and Anderson 2002). Winter site fidelity was

determined from transition rates (fidelity = 1.0 − transition probability) using the selected

model.

Results

Satellite Data – We deployed 21 satellite transmitters on ring-billed gulls and 14

on herring gulls. Six herring and 10 ring-billed gulls provided locations for ≥12 months

and were used in the analysis. Herring gulls arrived in Massachusetts between October

and December each year and left between March and May (Table 2.1). Herring gulls

remained in Massachusetts an average of 74-161 days. Overlap between minimum

convex polygons ranged between 0.42-1.0 for successive years, and overlap between

kernel utilization distributions ranged between 0.38-0.79 (Table 2.1, Fig. 2.3).

Ring-billed gulls arrived in Massachusetts between July and November each year and departed between November and March, although most birds were gone by December, and only one bird remained until March (Table 2.2). On average, ring-billed gulls remained in Massachusetts 20-167 days. Home range overlap of calculated minimum convex polygons was 0.0-1.0, and overlap between kernel utilization distributions ranged between 0.31-0.78 (Table 2.2, Fig. 2.4).

Wing-tag resightings – Between 2008-2012, 666 ring-billed gulls were tagged and released in the Wachusett study area, and 1,476 resightings were recorded on 427 individuals (64%) during the non-breeding season (November-March). In the Quabbin study area, 322 gulls were tagged during this period and 500 resightings were recorded on 172 individuals (53%). In the Boston study area, 17 gulls were tagged, and 9 individuals were resighted 25 times (53%). For up to 20 weeks post-capture, an increasing number of tagged Wachusett gulls were seen outside than inside the study area (Fig. 2.5). For Quabbin gulls, the trend was less apparent, but slightly more gulls were seen outside the study up to 20 weeks post-capture (Fig. 2.5).

We were able to construct complete histories for 4 ring-billed gulls captured in the Boston study area, 79 gulls from the Quabbin study area, and 240 gulls from the Wachusett study area. We evaluated 6 potential models (including a constant model: $\{S(_g)p(_g)\ \Psi(_g)\}$; survival, sighting probability and transition probability constant over time but different between study areas) of yearly apparent survival, resighting, and transition probabilities of ring-billed gulls captured and tagged in Wachusett, Quabbin, or Boston. The best model was the general model, and it showed strong support ($\Delta_i = 0$; $w_i = 0.999$) that survival, resighting, and transition probabilities were all different between

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locations but were constant over time (Table 2.3). Very high transition probabilities of individual gulls returning to the same site each year were found for all locations (Table 2.4). Very low estimates of movement between study areas were found, although a low estimated rate of movement from the Quabbin study area to the Wachusett study area was detected (Table 2.5). Overall, only a few (i.e., <6) individuals originally captured in one of the study areas were seen in a different study area in subsequent years.

Discussion

Breeding-site fidelity in gulls has been identified or implied in a number of studies (Southern 1971, Threlfall, 1978, Southern and Southern 1985, Kinkel 1989, Smith et al. 1992, Gabrey 1996). Smith et al. (1992) reported 69% of wing-tagged silver gulls (*Larus novaehollandiae*) in New South Whales returned to the breeding colony a year after tagging. Kinkel (1989) reported site fidelity of ring-billed gulls to breeding colonies of 62-100% in the year following banding at a colony in Michigan. Stenhouse and Robertson (2005) documented site fidelity of 81-92% for Sabine's gulls (*Xema sabini*) breeding on Southampton Island in the Canadian arctic. Gabrey (1996) reported that ring-billed gulls were less likely to return to their natal colony than herring gulls and suggested that gulls may have strong fidelity to the lake where they hatched, not necessarily the colony.

Our data suggest that during winter, ring-billed and herring gulls exhibit high site fidelity of marked individuals to specific locations and very little movement between spatially distinct areas. Because this is the first study to document winter site fidelity in these species, it is difficult to make meaningful comparisons; however other studies of winter fidelity in birds have used a variety of indices as evidence for fidelity. Studies

using mark-recapture techniques have concluded that encountering, or capturing, individuals in subsequent winters is evidence for fidelity (Fox et al. 1994, Guillemain, et al. 2009, Somershoe et al. 2009, McKinley and Mattox 2010). Those studies using transition probabilities have reported fidelity rates of 0.34-0.97 (Williams et al. 2008, Foote et al. 2010). Our calculated transition probabilities and large home range overlap indices among years suggests that ring-billed and herring gulls are extremely site faithful to wintering areas within Massachusetts.

Robertson and Cooke (1999) proposed that individuals return to the same sites each year to take advantage of prior knowledge of the area. This knowledge could include the location of patchy (but potentially predictable) food resources, refugia from predators, locations of conspecifics and suitable roosting sites, or predator movements and habits. Individuals that use this local knowledge may more efficiently avoid predators or exploit food resources, thereby increasing their overwinter survival (Robertson and Cooke 1999). Further, good foraging conditions during the winter have been shown to increase female reproductive success in the subsequent breeding season in geese (Ankney and MacInnes 1978) and other waterfowl (Raveling and Heitmeyer 1989). Gulls returning to the same sites in Massachusetts each winter can take advantage of known roosting locations and predictable food sources. We have documented individual tagged gulls roosting on Wachusett Reservoir over successive years and also identified individuals in the same parking lots in consecutive years foraging on food provided by people (i.e., handouts of bread and other human-provided food) (See Chapter 4).

If gulls were moving through Massachusetts randomly or opportunistically, then efforts to reduce food resources within a defined geographic area would have minimal

impact on the number of gulls present, since additional gulls could arrive at any time and remain for an indefinite period before potentially moving on. Further, harassment programs often rely on conditioning gulls to move away from critical areas through repeated harassment efforts (D. Clark, pers. obs.). Randomly arriving birds would need to be constantly "trained", decreasing the efficiency and effectiveness of a program. Because gulls exhibit strong winter site fidelity, efforts to reduce local food sources could potentially impact local wintering gull populations because the same individuals are returning each year. Site faithful gulls returning to these anthropogenic food sources would encounter unfavorable conditions and potentially disperse to new areas or adjust their winter movements in subsequent years. It is unlikely that gulls site faithful to other wintering areas where no food reduction was occurring (e.g., other states outside Massachusetts) would leave their winter site and move to Massachusetts.

While satellite tagged gulls from our study showed very high site fidelity, site persistence was variable. Some ring-billed gulls only remained in Massachusetts for <30 days, while others remained for >160 days. In all cases but one, satellite tagged ring-billed gulls left Massachusetts by January. Herring gulls exhibited higher site persistence; all gulls remained in Massachusetts ≥70 days. Gulls leaving Massachusetts during the winter continued moving south; some individuals stopped in New York or New Jersey for the remainder of the winter, while others continued to move as far south as Florida. Stenhouse et al. (2012) tracked Sabine's gulls through their migration and reported individuals arrived at their autumn staging sites between mid-August and mid-September and stayed for an average of 45 days. These gulls arrived at their wintering sites between October and November and remained there for about 152 days. It is

possible that Massachusetts serves as a staging area for migrating ring-billed gulls;

however given when gulls are in Massachusetts (November-January), how long they stay,

and their movements before and after stopping in Massachusetts, a more plausible

explanation is that ring-billed gulls use multiple wintering sites (onward migration),

similar to what Mandernack et al. (2012) described for wintering bald eagles (*Haliaeetus*

leucocephalus). In most cases, staging areas are discrete locations used for relatively

short periods of time by migrating birds on their way to a specific destination (i.e.,

breeding or winter grounds). Ring-billed gulls leaving their breeding grounds often

drifted south through the late summer and early fall, arriving in Massachusetts in late fall

(D. Clark, unpub. data). Gulls all left Massachusetts sometime during the winter and

continued to move south, making at least one more stop before beginning to move north

in the spring. It is likely that competition for food, availability of freshwater roosts (i.e.,

how much ice cover is present), or changes in food abundance all influence gull

movements during the winter.

Although any individual gull's stay in Massachusetts may be relatively brief, our

data suggest that they use the same locations from year to year. This consistency

between winters appears independent of weather conditions and suggests that gulls are

encountering reliable sources of food and favorable roosting conditions each winter.

Gulls foraging in inland Massachusetts during the winter would encounter little natural

prey (e.g., insects, worms, or fish). We suggest that gulls returning to the same areas in

central Massachusetts each winter are instead taking advantage of reliable sources of

anthropogenic food (i.e., handouts in parking lots). Repeated sightings of wing-tagged

gulls in the same parking lot over successive winters, and evidence for an abundance of

human provisioned food (See Chapter 4), would suggest that high site fidelity is a result of prior knowledge of these foraging parking lots within central Massachusetts.

Management Implications

Results from this study provide evidence that ring-billed and herring gulls exhibit high winter-site fidelity, but variable site persistence to areas within Massachusetts. Because gulls are not nomadic, it is possible that changes to food availability during winter within Massachusetts could affect the movements and abundance of wintering gulls. Because none of our tagged ring-billed gulls remained in Massachusetts throughout the winter, reductions in anthropogenic food, coupled with intense harassment on known roosting reservoirs, may be enough to prompt gulls to shorten their stay in Massachusetts. Further, if food reduction efforts could be sustained over multiple winters, it is plausible that these high fidelity birds would shift their winter movements and "pass over" Massachusetts in favor of wintering areas further south. Taylor and Kirby (1990) successfully moved about 8,000 lesser snow (*Chen caerulescens caerulescen*) and Ross' geese (*Chen rossi*) in advance of normal dispersal movements using a combination of food reduction, harassment, and hunting. If the number of gulls utilizing water supply reservoirs in central Massachusetts could be reduced, less effort would be needed implementing bird harassment programs necessary to maintain water quality standards.

Table 2.1. Tracking periods, arrival and departure dates, and home range overlap indices for herring gulls captured in Massachusetts, 2008-2012.

Gull	Capture Date	No. Months on Air	Arrival in MA					Departure from MA					Avg. No. days in MA[b]	95% MCP overlap	Kernel UD overlap
			Year 1[a]	Year 2	Year 3	Year 4	Year 5	Year 1	Year 2	Year 3	Year 4	Year 5			
80149	3-11-2008	16	3-11-08	12-7-08	-	-		4-1-08	4-9-09				123	0.82	0.38
80150	2-08-2008	18	2-08-08	12-31-08				3-17-08	3-15-09				74	0.96	0.39
87434	1-20-2009	19	1-20-09	-[c]				-[c]					-	0.42	0.98
33067	1-21-2009	44	1-21-09	12-14-09	12-20-10	1-2-12		6-16-09	5-2-10	5-10-11	4-18-12		129	0.64-0.98	0.31-0.79
33071	1-27-2009	21	1-27-09	-[d]				3-19-09					-	-	-
33073	11-5-2008	55	11-5-08	10-9-09	10-30-10	11-1-11	10-31-12	4-8-09	4-9-10	4-9-11	3-31-12	3-30-13	161	0.78-1.0	0.55-0.78

[a] Year of capture

[b] The year of capture was not used. Average number of days calculated based on year(s) following capture.

[c] Gull never left Massachusetts

[d] Gull never returned to Massachusetts but transmitter continued to function; gull was located in Connecticut and Long Island, NY

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Table 2.2. Tracking periods, arrival and departure dates, and home range overlap indices for ring-billed gulls captured in Massachusetts, 2008-2012.

Gull	Capture Date	No. Months on Air	Arrival in MA			Departure from MA			Avg. No. days in MA[b]	95% MCP overlap	Kernel UD overlap
			Year 1[a]	Year 2	Year 3	Year 1	Year 2	Year 3			
87425	11-10-2008	19	11-10-08	-	5-28-10	11-18-08	-	6-17-10	20	0.20	0.31
87426	11-5-2008	14	11-5-08	8-11-09	-	11-18-08	12-17-09	-	128	0.84	0.48
87427	10-29-2008	16	10-29-08	10-16-09	-	11-17-08	11-10-09	c	25	0.92	0.59
87428	11-10-2008	20	11-10-08	7-7-09	7-2-10	12-16-08	12-14-09	-	160	0.92	0.14-0.78
87429	12-4-2008	16	12-4-08	10-17-09	-	12-7-08	12-6-09	-	50	0.91	0.40
98656	12-7-2009	19	12-7-09	10-14-10	-	12-11-09	11-6-10	-	23	.11	0.37
98657	11-18-2009	13	11-18-09	7-15-10	-	12-17-09	12-19-10	-	167	1.0	0.40
98658	12-1-2009	34	12-1-09	11-10-10	11-24-11	12-18-09	12-11-10	1-28-12	48	0-0.40	0.13-0.53
98660	11-12-2009	18	11-12-09	10-13-10	-	12-6-09	12-6-10	-	54	0.83	0.77
98663	12-16-2010	21	12-16-10	10-7-11	10-14-12	3-21-11	3-15-12	12-29-12	118	0.85	0.54-0.71

a Year of capture
b The year of capture was not used. Average number of days calculated based on year(s) following capture.

Table 2.3. Models estimating apparent survival (S), transition probabilities (Ψ), and resighting probabilities (p) of ring-billed gulls captured in central Massachusetts, 2008-2012. We calculated the quasi-likelihood method (QAIC_c), QAIC differences (Δ), and AIC model weight (w_i) for each model. The best model is in bold.

Model	Log-likelihood	K[a]	QAIC_c[b]	ΔQAIC_c	Weight(w_i)
{S($_g$)p($_g$)Ψ($_g$)}[c]	**1078.33**	**18**	**271.98**	**0.00**	**0.99**
{S($_g$)p(.)Ψ($_g$)}	1121.25	20	285.67	13.69	0.001
{S(.)p(.)Ψ($_g$)}	1132.24	20	288.06	16.08	0.00
{S(.)p($_g$)Ψ($_g$)}	5301.71	20	1194.47	922.49	0.00
{S($_g$)p($_g$)Ψ(.)}	5314.21	28	1215.05	943.07	0.00
{S($_g$)p(.)Ψ(.)}	5363.67	27	1223.53	951.55	0.00

[a] Parameter includes intercept and ĉ.

[b] Values based on the inflation factor of the global model (ĉ=4.60).

[c] Constant model; survival, transition probabilities, and resighting probabilities are constant over time, but are different between study areas.

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Table 2.4. Resightings (December-January) of individual gulls within a location between years expressed as transition probabilities (Ψ)($\pm$SE).

Area	n^a	Ψ
Wachusett	96	0.864(0.02)
Quabbin	15	0.972(67.9)
Boston	3	0.750(0.22)
Other[b]	3	0.629(0.27)

[a] n is the number of individuals identified in each location using wing-tags and/or leg bands
[b] Other includes all areas outside the 3 defined study sites

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Table 2.5. Resightings (December-January) of individual gulls between locations expressed as transition probabilities (Ψ)($\pm$SE).

Area$_i$	Area$_j$	n_i^a	n_j	n_{ij}	Ψ_{ij}
Wachusett	Quabbin	96	15	2	0.013(0.09)
Quabbin	Wachusett	15	96	3	0.259(18.09)
Wachusett	Boston	96	3	6	0.023(0.009)

^{a} n is the number of individual gulls identified at each location using wing-tags and/or leg bands

Figure 2.1. Gull capture locations (●) and general study area in relation to Quabbin and Wachusett Reservoirs and Springfield, Worcester, and Boston (▲), Massachusetts.
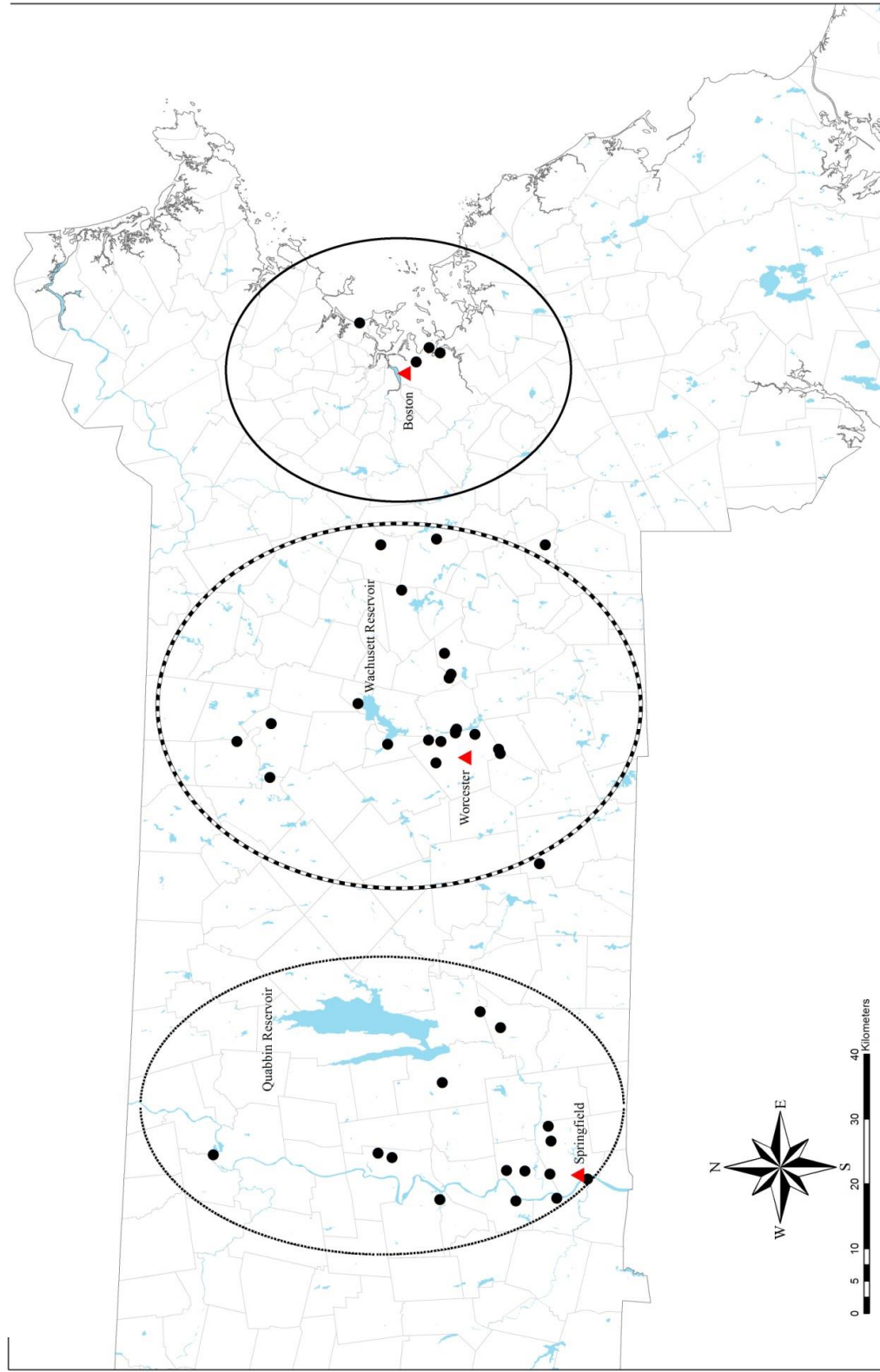
Figure 2.2. A ring-billed gull captured and marked with a color-coded patagial tag, colored leg band, and federal leg band (photo by Matt Palmer, Marlborough, MA).

Figure 2.3. Estimated home range for herring gull 33073 during 2008-2012.

Polygons represent 50th percentile kernel density estimates.
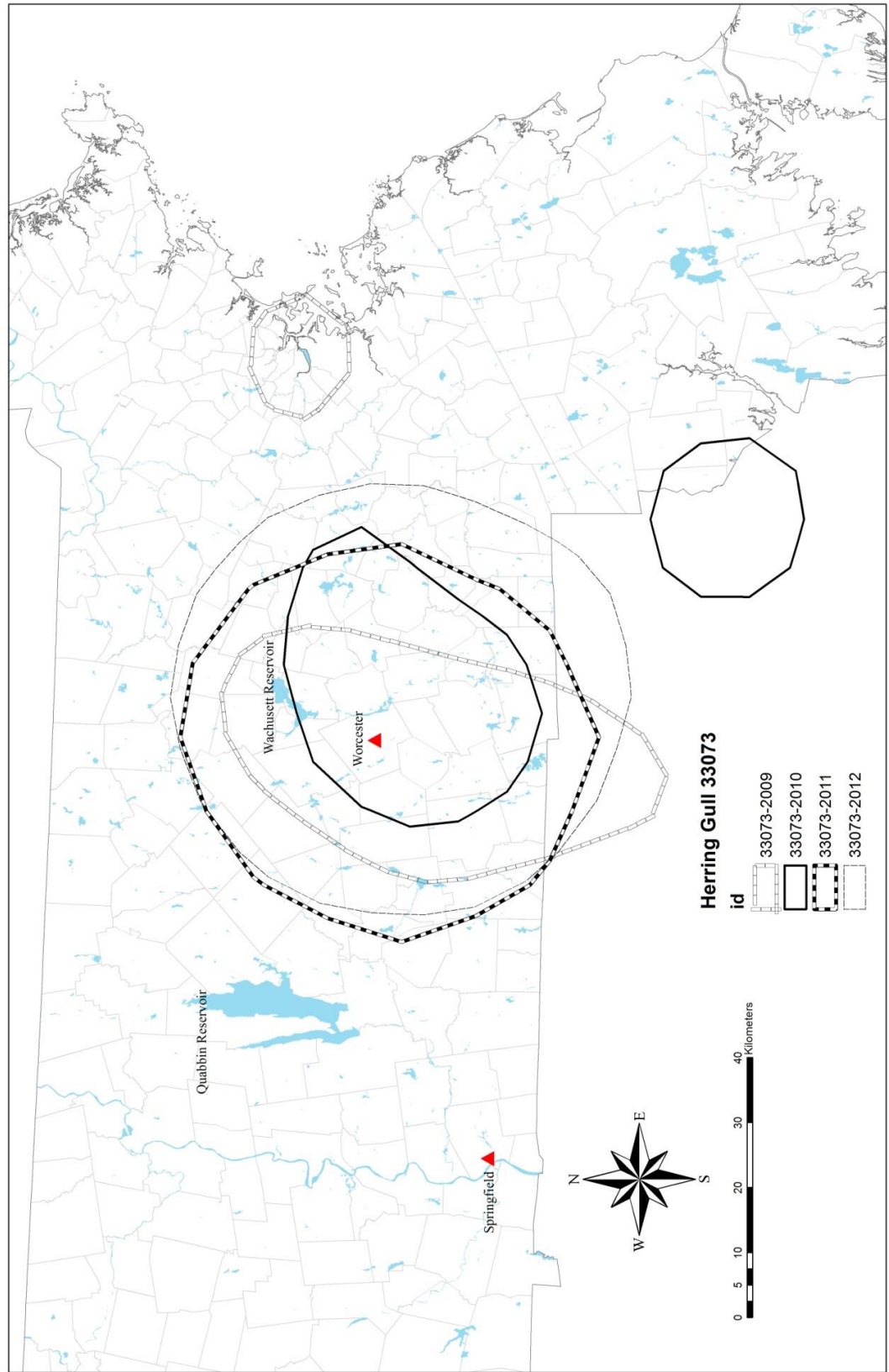
Figure 2.4. Estimated home range for ring-billed gull 98663 during 2010-2012. Polygons represent 50th percentile kernel density estimates.
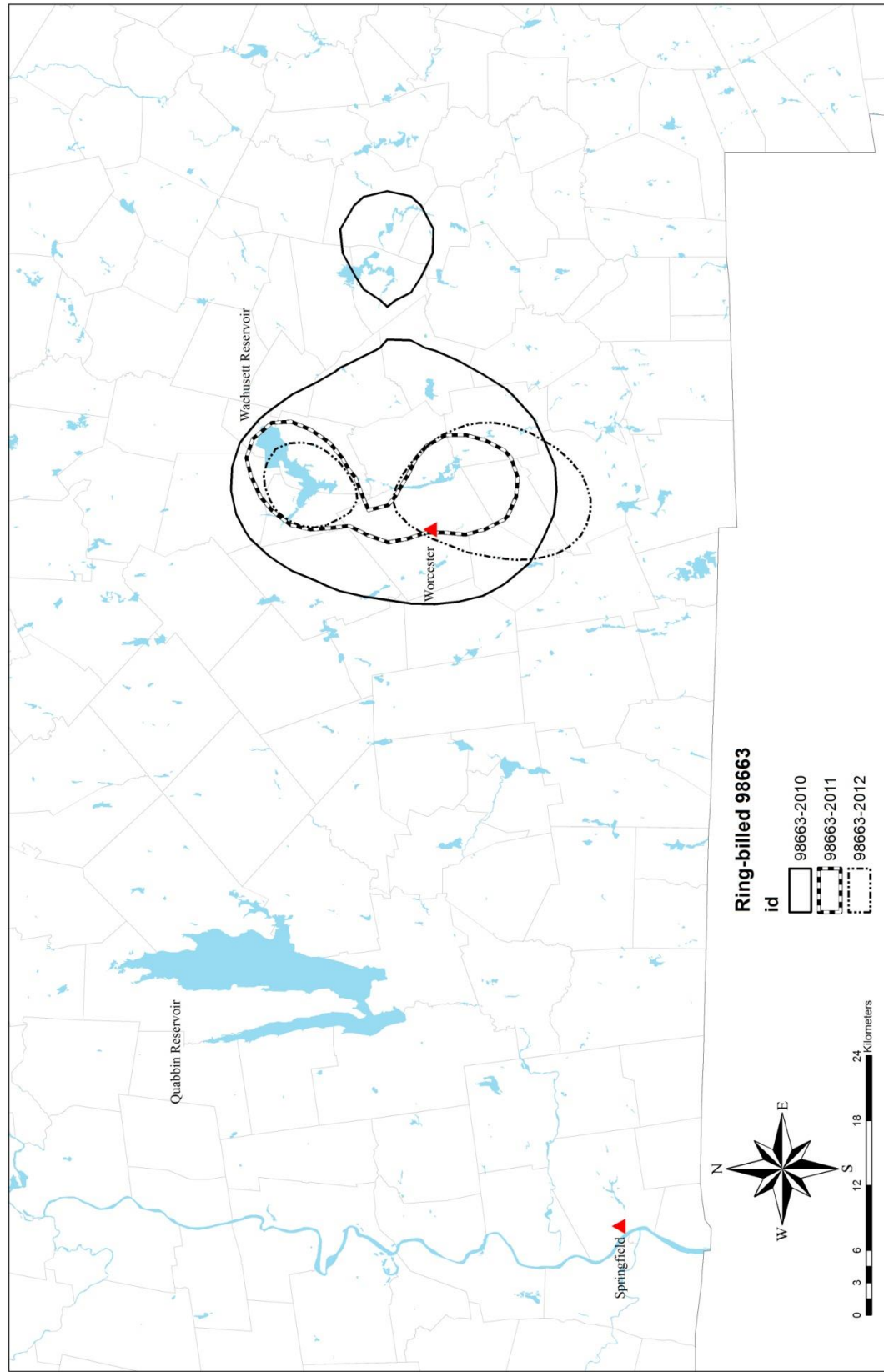
Figure 2.5. A. Number of wing-tagged ring-billed gulls seen inside and outside the Wachusett study area 20 weeks post-capture; B. Number of wing-tagged ring-billed gulls seen inside and outside the Quabbin study are 20 weeks post-capture.

A.
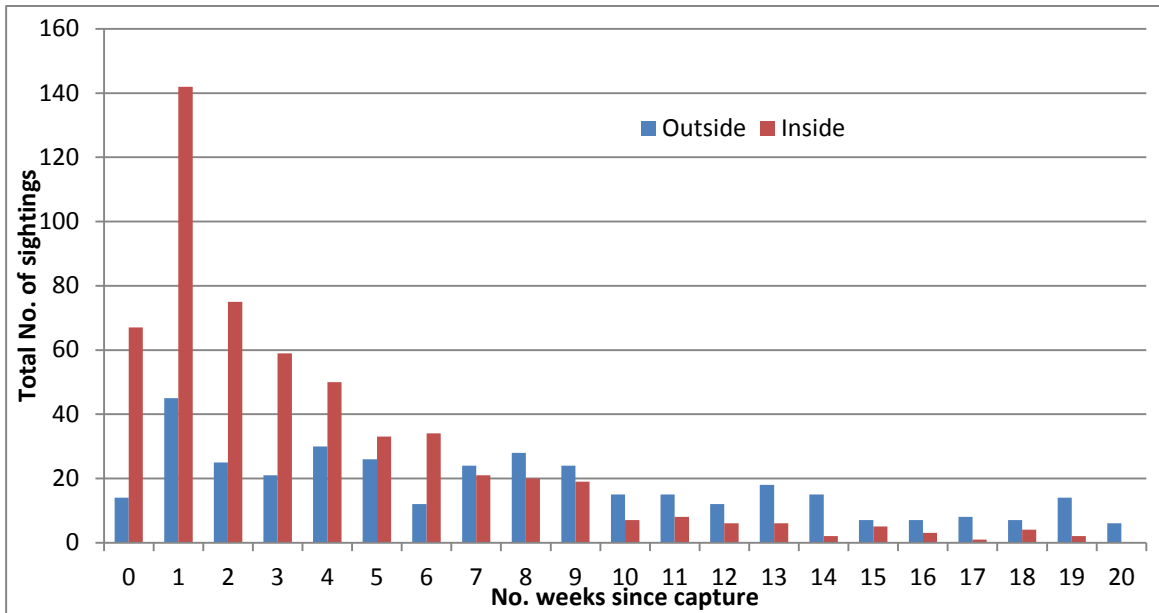
B.
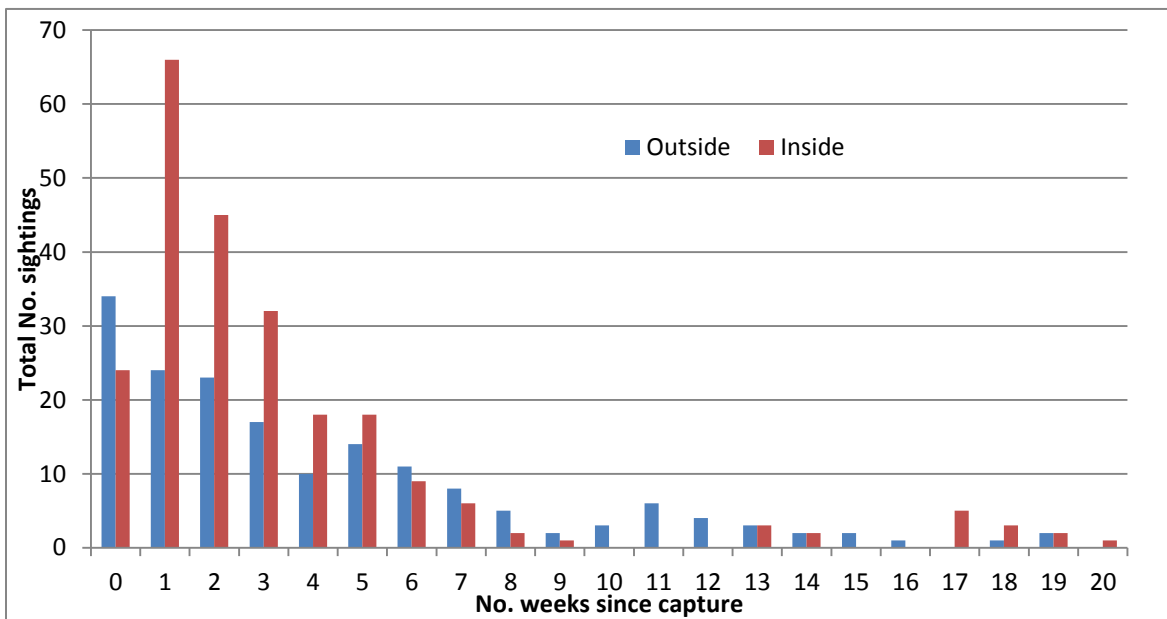
CHAPTER 3

ROOST SITE SELECTION BY RING-BILLED AND HERRING GULLS IN THE NORTHEAST, U.S.

Abstract

Gulls are commonly found roosting in large numbers on water, and their presence can have a variety of ecological impacts. Roost site selection can lead to water quality degradation or aviation hazards when roosts are formed on water supply reservoirs or in close proximity to airports. Harassment programs are frequently initiated in attempts to move or relocate roosting gulls and often have mixed results as gulls are reluctant to leave or keep returning. As such, knowledge of gull roost site selection and roosting ecology has both applied and ecological importance. We assessed the seasonal roost selection of ring-billed (*Larus delawarensis*) and herring gulls (*L. argentatus*) and also used an information theoretic approach based on satellite telemetry to model roost site selection in Massachusetts. Our results indicate that ring-billed gulls preferred freshwater roosts and will use a variety of rivers, lakes, and reservoirs. Herring gulls also regularly roosted on fresh water but used saltwater roosts more often than ring-billed gulls and also roosted on a variety of land habitats. Roost modeling showed that both herring and ring-billed gulls selected inland freshwater roosts based on size of the water body and proximity to their last daytime location; they choose the largest roost in closest proximity to where they ended the day. Management strategies aimed at reducing or eliminating roosting gulls should identify and try to eliminate other habitat variables (e.g., close-by foraging sites) that are attracting gulls before attempting to relocate or redistribute (e.g., through hazing programs) roosting birds.

Introduction

Communal roosting is common in birds and can be defined as a group of more than two individuals that come together to rest and sleep (Beauchamp 1999). Within the family Laridae, large communal roosts on inland and coastal waters are widespread and may number in the thousands or tens of thousands (Schreiber 1967, Gosler et al. 1995, Nugent 2009, D. E. Clark, Massachusetts Department of Conservation and Recreation, unpublished data). Gosler et al. (1995) speculated that the creation of man-made inland roosting sites such as reservoirs and flooded gravel pits, coupled with reliable inland sources of food (landfills, etc.), has increased the abundance of gull populations and their prevalence on inland water bodies.

There are a number of potential benefits to roosting communally, including reduced thermoregulation costs, increased predator detection, and safety in numbers from predators (Bilfleveld et al 2010). Additionally, communal roosts may function as communication centers where individuals share information about the location of patchily distributed food (Ward and Zahavi 1973). While there has been some research on the behavioral mechanisms driving the evolution of communal roosting, very little work has examined how or where birds choose sites for roosting. Further, most of these studies have relied on visual surveys of known or suspected roosting sites and have not assessed roost site occupancy through satellite transmitters (Schreiber 1967, Hickling 1973).

Roost site selection can have a variety of ecological and societal impacts. Gulls roosting on water supply reservoirs can lead to increased contamination and the potential for disease transmission (Benton et al. 1983, Hatch 1996, Nugent 2009). Further, gulls roosting on recreational water bodies (e.g., swimming beaches) can substantially increase

fecal pollution and the prevalence of other pathogens, leading to degraded recreational water quality (Fogarty et al. 2003, Jeter et al. 2009, Converse et al. 2012). Roosting gulls have also been linked to increased levels of phosphorus and nitrogen in freshwater ponds (Portnoy 1990). In addition, gulls moving between roosting and feeding sites may pose a major hazard to aviation (Gosler et al. 1995, Dewey and Lowney 1997). Gulls are the most commonly struck bird in the United States, and communal roosts near airports may increase risks to airplanes as approaching aircraft cross paths with gulls flying to and from roosting areas (Dewey and Lowney 1997).

In Massachusetts, U.S., 65% of the state's population depends on surface water reservoirs for their drinking water (Lent et al. 1997). Quabbin and Wachusett Reservoirs are the first and second largest bodies of fresh water in the state, respectively (MassGIS 2010). These reservoirs serve as the treated but unfiltered water supply for >2 million consumers in metropolitan Boston. Gulls roosting on these reservoirs were first noted anecdotally in the 1960s and have been formally monitored since the 1990s (Fig. 3.1). Seasonal fluctuations in the number of roosting ring-billed (*Larus delawarensis*) and herring (*L. argentatus*) gulls on Wachusett and Quabbin Reservoirs are strongly correlated with increased fecal coliform levels in water quality samples and subsequent water quality degradation (Metropolitan District Commission 1991, 1992). The presence of gulls on these reservoirs necessitates a costly and potentially hazardous bird harassment program in order to maintain source water quality standards. While harassment has been used successfully to reduce the impact of roosting gulls (see Benton et al. 1983, Nugent 2009, D. E. Clark, unpublished data), identifying important roost site characteristics may provide insight into why particular water bodies are selected. This

information could lead to preventative measures to exclude gulls completely or increase the efficiency or effectiveness of current programs.

The goals of this study were to characterize the seasonal roost selection of ring-billed and herring gulls and to identify the key environmental factors influencing selection of inland water roost sites in Massachusetts. Specifically, we used satellite telemetry to identify and characterize occupied roosts throughout the year and used satellite telemetry and statistical modeling to identify the relative importance of size and shape of inland water bodies, proximity between foraging locations and roost sites, and potential for disturbance in roost site selection.

Study Area

This study was conducted in Massachusetts in Worcester, Franklin, Hampshire, and Hampden counties from October to April 2008-2012. The study area was comprised of a variety of small towns and medium cities, including Worcester, the second largest city in Massachusetts (population 181,000 in 2010). Large shopping centers, golf courses, residential areas and freshwater ponds are common. Major and minor highways traverse the area, and a variety of parks, state forests, and greenways exist, including small municipal parks. Urban sprawl and continued development has reduced the amount and type of natural habitat, but also increased the amount of new urban ecological niches. We captured ring-billed and herring gulls at 18 trapping locations, which were focused in urban or suburban areas around the cities of Worcester (42°15'N, 71°48'W) and Springfield (42° 6'N, 72°35'W) (Fig. 3.2). Trapping locations were chosen opportunistically to maximize capture success and included a variety of locations including parking lots, landfills, waste water treatment plants and inland beaches.

Methods

Satellite Tracking – We used a net launcher (Clark et al. in press) to capture ring-billed gulls, which were than fitted with solar powered 9.5 g (Microwave Telemetry, Columbia, MD; use of trade names does not constitute an endorsement by the U. S. Government) or 9.5 g (Northstar Science and Technology, King George, VA) ARGOS platform terminal transmitters (PTTs). Herring gulls were fitted with solar powered 22 g or 30 g GPS tags (Microwave Telemetry) or 11.5 g PTTs (Northstar Science and Technology). Transmitters represented <3 % of body mass of the birds. Transmitters were attached as backpacks with loops around the neck and body. The harness consisted of 6 mm wide tubular Teflon ribbon (Bally Ribbon Mills, Bally, PA), braided nylon fishing line as thread, cyanoacrylate adhesive, and a 2.5 cm x 2.5 cm leather breast piece. Attachment followed the procedure described by Snyder et al. (1989), but without the feather shield.

GPS equipped transmitters were programmed to transmit 6 times per day (mid-morning, noon, mid-afternoon, late afternoon, evening, and night); times shifted slightly seasonally to account for longer days. ARGOS PTTs were programmed to turn on and transmit for 8 hours each day, then turn off for 18 hours. This 26-hour duty cycle ensured that transmissions occurred throughout each 24-hour period.

PTTs used the ARGOS system to transmit locations from tagged birds via satellite. Each received transmission was assigned a Location Class (LC) based on the quality of the reception (ARGOS 2013). ARGOS classified locations into one of 7 classes (Z, B, A, 0, 1, 2, 3 in ascending order of accuracy). While ARGOS provided an associated accuracy assessment for LCs 0-3, we assessed transmitter accuracy (mean

distance between test location and true position) independently in the field before deployment. All transmitters were activated and placed on a flat roof for ≥2 weeks. All locations from these test transmitters were collected and compared to the actual location. GPS transmitter accuracy was ±18 m for the 22 g models and ±30 m for the 30 g models. For PTTs, we only used LC 1, 2, and 3. Transmitter accuracy for the 9.5 g Microwave models was ±1890 m (1), ±1217 m (2), and ±354 m (3). Accuracy for the 9.5 g Northstar was ±1572 m (1), ±587 m (2), and ±336 m (3). For 11.5 g transmitters, accuracy was ±1959 m (1), ±858 m (2), and ±218 m (3).

 Classification of seasonal roost sites — Data from gulls equipped with ARGOS PTTs were filtered so only LCs 1, 2, or 3 were retained. We defined roost sites as locations (point coordinates) that were received 0.5 hours after sunset and 0.5 hours before sunrise. We retained one location per night per individual. If more than one location was received for an individual during a night, then either the highest quality location was kept, or if multiple locations of the same class were received, one location was selected randomly and the rest were discarded.

 For each nighttime location (point coordinate), a circular buffer was generated in ArcGIS 10.0 with the nighttime location as the center and a radius equal to the calculated accuracies of each transmitter for each location class. For example, nighttime locations received from ring-billed gulls equipped with Microwave transmitters that were classified as a "3", were plotted with the received location in the center of a circle with a radius of 354 m (the calculated error for that transmitter type with that location class). In ArcGIS 10.0, each location point and its associated error circle was plotted over color aerial photographs. The roosting site for each location was identified based on the intersection

of each error circle with its underlying habitat feature. In most cases, the circle

intersected with only one biologically plausible roosting site (e.g., body of water). In

cases where the circle intersected multiple potential roosting sites (e.g., water body and

island), the location was classified as unknown. In addition, when the error circle

intersected a variety of habitats (e.g., an urban area), the site was broadly classified (e.g.,

urban) when possible, but a specific site was not identified. Each identified roosting site

was classified as either land or water. Roost sites were further classified for both land

(bridge, dock, island, pier, roof, or shoreline) and water (fresh, brackish, salt) locations.

For freshwater roosts, each site was identified as a lake (natural body of water), reservoir

(man-made), or river. Roosting sites from gulls equipped with GPS transmitters were

determined the same way but without an associated error circle.

Each roosting location was assigned to a specific season. Boundaries for these

seasonal breaks were determined by weather changes and gull activity patterns (e.g.,

breeding vs. non-breeding). Four seasons were used: Spring (March-May), Summer

(June-August), Fall (September-November), and Winter (December-February). We used

descriptive statistics to describe the seasonal roost site selection of herring and ring-billed

gulls.

Roost site selection modeling – For the modeling analysis, all roost locations were

further filtered to include only those that also had an associated daytime location that was

received ≥2 hours before sunset, i.e., during the same day when the roosting location was

recorded. This was done so that we could use distance to last daytime location as a

variable in our model (see statistical analysis section). Because PTTs transmitted in 8-

hour blocks only during periods when satellite communication was possible, not all

nighttime locations had a daytime location from the same day. In addition, in order to compare the characteristics of inland water sites used and not used for roosting, we restricted our data to freshwater locations in the Massachusetts study area.

For each individual roosting location, we described the used roosting site and 1 unused roost randomly selected (with replacement) from a pool of all available roosts within the study area. Random sites were selected using ArcGIS 10.0 and statewide hydrology data from MassGIS. Based on sizes of used roosts, we set a size of $\geq$12 ha for ring-billed and $\geq$50 ha for herring gulls in order to be eligible for selection. We considered all random sites within these size limits to be available to gulls. Within the study area, 148 and 460 potential roost sites were identified for herring and ring-billed gulls, respectively. For each roosting site, several variables were recorded for both the used roost and randomly selected unused roost, as follows: 1) the date of each location was recorded as well as the size in ha (Size) of each used and unused roost site; 2) the low temperature (Temp) for each date was recorded in degrees Celsius; 3) the distance between each gull's last daytime location (Daytime) to the center of the used and unused roost site was measured (m); 4) the distances (m) between used and unused roost sites and the nearest known foraging location (Food). These foraging sites were determined through a separate analysis (D. E. Clark, unpublished data) and included parking lots, agricultural fields, landfills, and waste water treatment plants. Finally, we considered the fifth variable to be the disturbance potential of each water body by estimating the maximum distance a gull could roost from the shoreline (Disturb). We calculated the maximum diameter of each used and unused roost site using the CONVEX_HULL feature of the Minimum Bounding Geometry Tool in ArcGIS 10.0. This tool calculated

the smallest possible polygon that enclosed each input feature (i.e., each used and unused roost) and calculated the maximum distance between 2 vertices. This distance was divided in half and represented the maximum distance a gull could roost from the shoreline of any given water body. Larger radii would represent lower potential disturbance from shoreline activities.

Statistical analysis – We pooled roosting locations over the 4 years of the study to determine which roost or site characteristics best distinguished used and unused roost sites. We evaluated our data for correlations to ensure no pairs of variables were highly correlated (Spearman's $r_s > 0.7$). Highly correlated variables most likely measured the same or similar roost characteristics. If strong correlations were found between variables, we retained the variable we determined to be the most biologically meaningful for later analysis. We tested the effects of these variables on roost site selection using the binomial family of Generalized Linear Models with the GLM2 and AICmodavg packages in R 2.15.1 (Marschner 2011, Mazerolle 2012, R Development Core Team 2012). Used inland roosts were coded as 1, and available unused roosts were coded as 0. We used an information-theoretic approach and Akaike's Information Criteria (AIC or AIC_c to correct for small sample sizes) to scrutinize the relative strength of *a priori* selected models. We calculated Akaike model weights and considered the model with the lowest AIC to be the most parsimonious model (Burnham and Anderson 2002).

We determined *a priori* which models to include in the analysis in order to limit the number of potential models to ones with biological support or interest. We used our own experience and judgment to select models. In addition to the global model, we included 7 other candidate models including 2 simple models that contained only one

variable. The first model considered only Size (ha) of each water body and was used to assess whether gulls simply selected the largest available body of water. Our second model contained only Food (distance to closet foraging site) in order to determine if gulls selected roosts based solely on proximity to foraging areas. We considered size to be an important variable and modeled Size with various interactions of the variables Food, Daytime (distance to last daytime location), and Disturb (maximum radius of each water body).

Results

Seasonal Roost Selection – Twenty-one ring-billed gulls were captured and fitted with satellite transmitters. Gulls transmitted an average of 12.6 months (range = 1-35). Thirteen gulls provided 1,292 nighttime roosting locations of class 1, 2, or 3. The remaining 8 gulls did not provide useable locations. Thirteen herring gulls were fitted with transmitters which transmitted an average of 14.2 months (range = 1-52). The 6 herring gulls equipped with GPS transmitters provided 1,328 nighttime roosting locations. Six herring gulls equipped with PTTs provided 970 locations of class 1, 2, or 3, and 1 herring gull provided no usable locations.

We were able to classify 1,205 of the 1292 (93%) ring-billed gull roosting locations. Ring-billed gulls provided roosting locations from all 4 seasons. Most locations were received in Winter ($n = 402$), followed by Fall ($n = 307$), Spring ($n = 287$), and Summer ($n = 209$). For herring gulls, we were able to classify 2242 of the 2298 (98%) locations. Most locations were received in Spring ($n = 842$), followed by Winter ($n = 561$), Summer ($n = 554$), and Fall ($n = 285$).

The majority of ring-billed gull roosting locations were classified as water (93%), and gulls used water roosts consistently across seasons (Fig. 3.3). Herring gulls also roosted on water (64%), but frequently roosted on land (34%), particularly during the spring and summer (Fig. 3.3). Most land roosts were classified as islands ($n = 502$), followed by piers ($n = 143$) and roofs ($n = 101$). Other land roosts used less frequently were bridges, docks, and coastal shorelines.

Ring-billed gulls were most often identified roosting on fresh water, while herring gulls were more likely to be found roosting on salt water in all seasons except Winter, when they used fresh water slightly more often (Fig. 3.4). When roosting on fresh water, both herring and ring-billed gulls used lakes, rivers, and reservoirs (Fig. 3.5). Ring-billed gulls used lakes (37%), reservoirs (32%), and rivers (31%) in about the same proportion, while herring gulls used lakes (47%) more often than rivers (29%) or reservoirs (25%).

Roost Site Selection in Massachusetts – Twelve of the 13 tagged herring gulls and 12 of the 21 tagged ring-billed gulls provided 364 and 333 inland Massachusetts water roosting locations, respectively. Ring-billed gulls roosted on 22 different water bodies, and herring gulls roosted on 34 different water bodies; however, only 14 roosts were used more than 5 times during the study, and 4 roosts accounted for 66% of the locations (Table 3.1).

For the modeling analysis, 10 ring-billed and 11 herring gulls provided 44 and 167 useable roost locations, respectively. Spearman tests showed strong correlation ($r_s = 0.98$) between Size and Disturbance variables for roosting ring-billed gulls. Therefore, we retained Size in our ring-billed models but eliminated Disturbance. No significant correlations existed among the rest of the variables. Our modeling suggested that both

herring and ring-billed gulls selected roost sites based on more than one main effect. Neither species chose roosts based solely on size or distance to foraging areas. For ring-billed gulls, the most supported of the *a priori* models included the interaction between size of a water body and distance from the last daytime location to the roosting location (Table 3.2). There was strong evidence ($w_i = 0.69$) for the selected model, and the model explained a majority of the variability in roost site selection (Table 3.2, % Dev.). There was strong evidence for the relative importance of Size and Daytime in explaining roost site selection. There was also support ($\Delta AIC_c = 1.79$) for the second most supported model. This model included the interaction of Size and Daytime, in addition to the variable Food.

Ring-billed gulls used roosts that were 17.7 times larger than random sites (Table 3.3). When considering other mean values of used roosts versus random sites, distances from last daytime location and foraging areas was 4.5 and 2.3 times less, respectively, for used sites versus random sites. Used roosts had a radius that was 4.1 times larger than random roosts.

For herring gulls, the most supported model included the interaction between size of a water body and distance from the last daytime location, in addition to the variables Food and Disturb (Table 3.4). There was very strong evidence ($w_i = 1.0$) for the selected model, and the model explained a large amount of the variability (Table 3.4, % Dev.). All other models had a $\Delta AIC > 10$ and were considered unlikely. Herring gulls used roosts that were 2.9 times larger than random sites and had radii that were 1.73 larger than random sites (Table 3.3). Distances from used roosts to foraging areas and last daytime location were 5.8 and 2.2 times smaller, respectively than random sites.

Discussion

Seasonal Roost Selection – Our data show that both ring-billed and herring gulls

demonstrated a consistent pattern of roost selection throughout the year.   Ring-billed

gulls chose water roosts almost exclusively, and a majority of those roosts were on fresh

water. While herring gulls also used water roosts throughout the year, they were

commonly found on land roosts as well. Other studies have identified herring gulls

roosting exclusively on fresh water (Schreiber 1967, Hickling 1973, Nugent 2009);

however, these studies only surveyed known roosting sites or potential freshwater lakes

and reservoirs for the presence of gulls. Because individual birds were not followed, it is

possible other roosting sites may have been used but went undocumented. Golightly et

al. (2005) followed radio-tagged western gulls (*Larus occidentalis*) in southern California

and reported 47% of all locations were in marine habitats, while 53% were inland. It is

unclear how many of these were roosting locations, but they did document roosting gulls

on inland lakes.

Our study indicates that ring-billed gulls are most likely to be found roosting on

fresh water, while herring gulls more commonly use salt water, except during winter. We

suggest that this difference is likely related to the variability in use of marine

environments by the two species. All of the tagged herring gulls we captured in

Massachusetts during winter migrated north and concentrated their movements during the

spring and summer (presumably nesting) on coastal marine islands in maritime Canadian

providences. As a result, almost all water roosting locations from late winter through late

summer were marine. In contrast, our tagged ring-billed gulls traveled to the Great Lakes

or St. Lawrence River during late spring and concentrated their movements (presumably to breed) around these freshwater locations.

In winter, ring-billed gulls used saltwater roosts more frequently than in other seasons, while herring gulls increased the amount of time spent roosting on fresh water. We suspect this is related to daytime foraging and changing environmental conditions. During winter, our tagged herring gulls were often located at inland foraging locations and regularly selected freshwater roosts in proximity to where they spent the day. Ring-billed gulls were also common inland foragers during the winter; however, our study birds spent more time on coastal habitats during late winter, most likely in response to decreasing availability of inland roosting sites during years when ice conditions developed.

While our data indicate that ring-billed gulls roosted on reservoirs, lakes, and rivers in about equal proportions in other parts of their range, this selection distribution was not evident while roosting in Massachusetts. Ring-billed gulls rarely roosted on rivers in Massachusetts, even though river roosts were available and often used by herring gulls. Casual observations of one of the known Massachusetts' river roosts suggested that herring gulls were actually roosting on small rocks and boulders within the river itself, which is consistent with a herring gull roost described by Schreiber (1967) in the Penobscot River, Maine. Because herring gulls regularly roosted on land, the structure of these river roosts probably attracted herring gulls but not ring-billed gulls, which rarely roosted on land.

While herring and ring-billed gulls used multiple freshwater roosts in Massachusetts, only a few roosts had more than 5 recorded locations during the length of

the study. Our data show that certain water bodies were favored by either herring or ring-billed gulls, while other roosts were used frequently by both species (Table 1). Some comparable sized roosts seemed to be preferred by one species. Unfortunately, no visual surveys were done at these roosts, and we were unable to determine if roosts were comprised of single species or were mixed. However, during weekly roost counts at Wachusett Reservoir, we regularly observed both herring gulls and ring-billed gulls within the same roost; however, ring-billed gulls were more abundant and comprised 80-90% of the roost. It is likely that certain water bodies may be preferred by one species, and this predilection may be related to historical use or proximity of species-specific foraging areas.

Roost Site Modeling – Our data show that herring and ring-billed gulls are responding to similar environmental variables when selecting an inland roost site in Massachusetts. Size alone is not an important determinant in roost site selection; however, the interaction between roost size and last daytime location was important in both species' habitat models. Our data suggest that gulls are selecting the largest available roost in closest proximity to their last daytime location. In our study area, Quabbin Reservoir is the largest potential roost and is 6 times bigger than the next largest roost (Wachusett Reservoir); however, gulls roosted on Wachusett Reservoir 22 times more often than Quabbin. We suggest this is related to the relative position of each reservoir in the landscape. Wachusett Reservoir is located about 12 km from the city of Worcester, which provides a variety of foraging options including parking lots, waste water treatment plants, fields, and landfills. In contrast, Springfield, which provides similar foraging opportunities, is about 32 km from Quabbin Reservoir. The landscape

immediately around Quabbin is dominated by forest, small towns, and residential areas and probably represents poorer quality urban gull habitat. Smaller roosts closer to Springfield (e.g., Connecticut River, Table 3.2) would attract more roosting gulls.

Distance to foraging areas was also an important variable in both species models. Random roosts were about 2.3 times farther from foraging areas than used roosts. It is likely that a gull's last daytime location is associated with opportunities to acquire food before travelling to a nighttime roosting location. In general, our study gulls were often located in urban and suburban areas during the day foraging on anthropogenic food sources (e.g. handouts, waste water treatment plants, suburban farms) (D. Clark, unpublished data). The location of water bodies in relation to gull foraging sites would influence the chances of it being used as a roosting site. Large water bodies far away from potential or existing food sources have a smaller chance of attracting roosting gulls than those water bodies located near or adjacent to food sources. It is likely that factors not measured in this study contributed to whether gulls selected a particular water body. Historical use as a roosting site is likely an important consideration. We know Wachusett Reservoir has been used as a gull roost for at least 50 years, and it is likely that other preferred roosts probably have a similar history, although we could not determine this. Gulls returning to Massachusetts each year are likely familiar with these roosting sites. Although we assessed the shoreline disturbance potential of each water body, on-water activity is probably another important factor we did not assess. Recreational boating (e.g., water skiing) may impact the formation of a roost if birds are repeatedly disturbed. While Wachusett Reservoir has no public boating, other preferred roosts in the study area did allow various types of boating.

Management Implications

In Massachusetts, inland gull populations fluctuate seasonally and reach their peak during late fall. Inland sources of natural food are severely limited during this time of year, and gull foraging is strongly influenced by the availability of anthropogenic food subsidies (e.g., handouts, waste water treatment plants) (D. Clark, unpublished data). Urban and suburban areas provide a range of foraging opportunities, and large lakes or reservoirs within close proximity to these foraging sites have the potential to attract roosting birds. Conflicts can arise when roosting gulls impact the water resources (i.e., drinking water, recreation) or the roost is located near airports causing increased aviation risks. Past efforts to relocate or remove roosting gulls have failed (Dewey and Lowney 1997), or worked conditionally (Gosler et al. 1995, Nugent 2009). Bird harassment efforts are often directed at the roosting birds in an attempt to discourage their presence or disrupt their roosting behavior. Most harassment programs have focused on the roost and not addressed why gulls are choosing a particular body of water. Our data suggest that where gulls choose to roost is strongly related to size of the roost site, where they are during the day and where potential food sources are located. Attempts to reduce the number of gulls or prevent a roost from forming may be challenging unless these foraging sites can be identified and eliminated. If the amount of available food in close proximity to impacted water bodies can be reduced, it may be possible to reduce the presence of gulls.

Table 3.1. Inland water roosting sites used by ring-billed ($n = 12$) and herring gulls ($n = 12$) in Massachusetts, 2008-2012. Only locations used at least 5 times by one species were included.

Water Body	Size (ha)	Radius (m)	No. times used		
			Ring-billed	Herring	Total
Connecticut River	531	254	1	48	49
Flint Pond	67	486	0	11	11
Foss Reservoir	63	434	7	0	7
Indian Lake	61	409	13	45	58
Lake Cochituate	58	391	32	1	33
Lake Quinsigamond	84	258	3	7	10
Merrimack River	642	288	0	11	11
Quabbin Reservoir	9895	1600	13	1	14
Quaboag Pond	221	925	25	2	27
Singletary Pond	143	721	2	46	48
Stiles Reservoir	128	424	0	8	8
Sudbury Reservoir	376	1205	21	8	29
Wachusett Reservoir	1564	2157	187	117	304
Webster Lake	506	1069	9	27	36

Table 3.2. Results of generalized linear models testing the effects of water body size, distance to foraging, distance from last daytime location, and temperature (°C) on roost site selection of ring-billed gulls in Massachusetts. The best model is in bold.

Model[a]	Log-likelihood	K[b]	AIC$_c$[c]	ΔAIC$_c$	Weight(w_i)	% Dev[d]
Size×Daytime	**-15.98**	**4**	**40.43**	**0.00**	**0.69**	**73.8**
Size×Daytime+Food	-15.75	5	42.22	1.79	0.28	74.2
Size+Daytime+Food	-19.93	4	48.34	7.90	0.01	67.3
Size+Food+Daytime+Temp	-18.81	5	48.34	7.91	0.01	69.2
Size×Food	-27.18	4	62.85	22.42	0.0	55.4
Size	-35.64	2	75.41	34.98	0.0	41.6
Food	-50.88	2	105.89	65.46	0.0	16.6

[a] Size: Area in Hectares; Food: Distance (m) of a water body to nearest foraging location; Daytime: Distance (m) from a bird's last daytime location to its nighttime roost.
[b] Parameters
[c] Second-order Akaike's Information Criteria (for small sample sizes)
[d] Percentage of deviance explained by the model: (Null deviance-Residual deviance)/Null deviance x 100

Table 3.3. Mean roost site characteristics and standard errors (SE) at used roosts of ring-billed (RB) and herring gulls (HG) and random water bodies in central Massachusetts, 2008-2012.

Habitat Variable	RB used	RB random	HG used	HG random
	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)
Size (ha)	885 (109.3)	50 (11.2)	635 (48.2)	218 (61.1)
Radius (m)	1410.5 (123.9)	348.0 (31.5)	933.7 (63.6)	538.9 (22.0)
Distance from last daytime location (m)	10324 (1306.9)	46349 (4232.7)	10077 (820.4)	57972 (2913.8)
Distance to nearest foraging location (m)	5613 (574.2)	13035 (1647.6)	6179 (604.7)	13811 (956.4)

Table 3.4. Results of generalized linear models testing the effects of water body size, disturbance buffer, distance to foraging, distance from last daytime location, and temperature (°C) on roost site selection of herring gulls in Massachusetts. The best model is in bold.

Model[a]	Log-likelihood	K[b]	AIC	ΔAIC	Weight(ω_i)	% Dev[c]
Size×Daytime+Food+Disturb	**-80.32**	**6**	**172.64**	**0.00**	**1.0**	**65.1**
Size×Daytime	-88.27	4	184.53	11.90	0.0	61.6
Size×Disturb+Food+Daytime	-93.40	6	198.81	26.17	0.0	59.5
Size+Disturb+Daytime+Food+Temp	-96.64	6	205.27	32.64	0.0	58.0
Size×Food	-185.89	4	379.79	207.15	0.0	19.2
Food	-207.31	2	418.63	245.99	0.0	9.9
Size	-207.74	2	419.48	246.84	0.0	9.7
Size×Disturb	-207.46	4	422.92	250.29	0.0	9.8

a Size: Area in Hectares; Disturb: Maximum distance (m) from the center of a water body to its shoreline; Food: Distance (m) of a water body to nearest foraging location; Daytime: Distance (m) from a bird's last daytime location to its nighttime roost.
b Parameters
c Percentage of deviance explained by the model: (Null deviance-Residual deviance)/Null deviance x 100

Figure 3.1. Average (±SE) number of gulls roosting on Wachusett Reservoir, Massachusetts, September-April, 2006-2012.
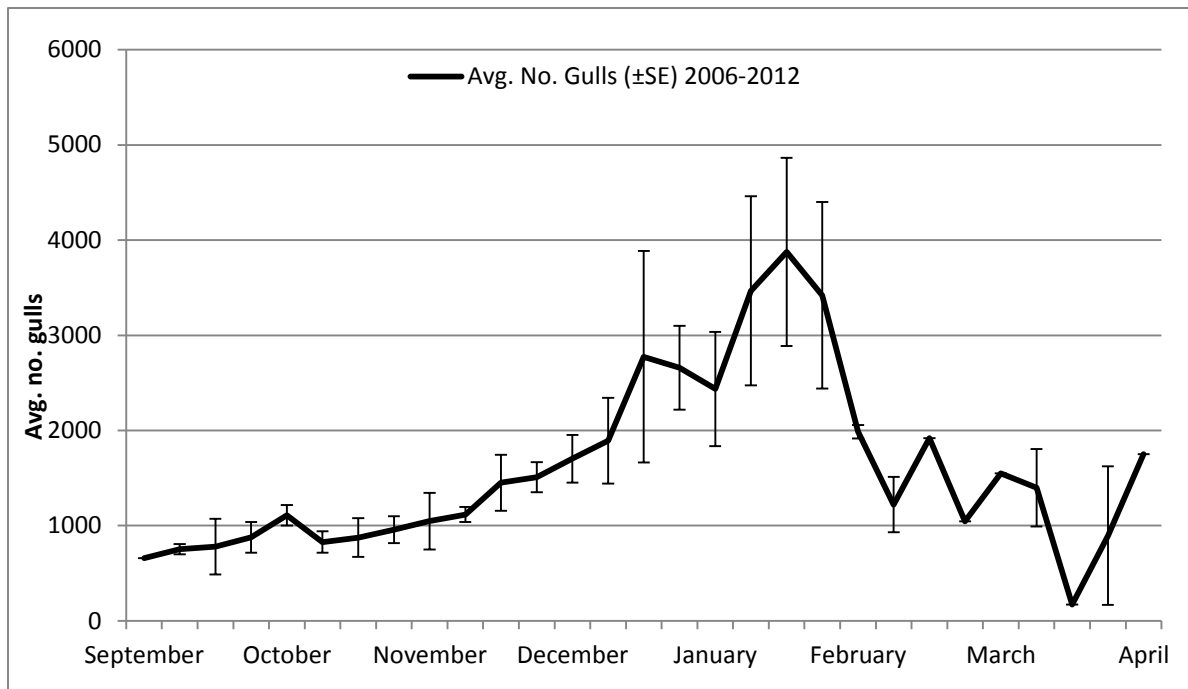
Figure 3.2. Gull capture locations (●) and general study area in relation to Quabbin and Wachusett Reservoirs and Springfield and Worcester (▲), Massachusetts.
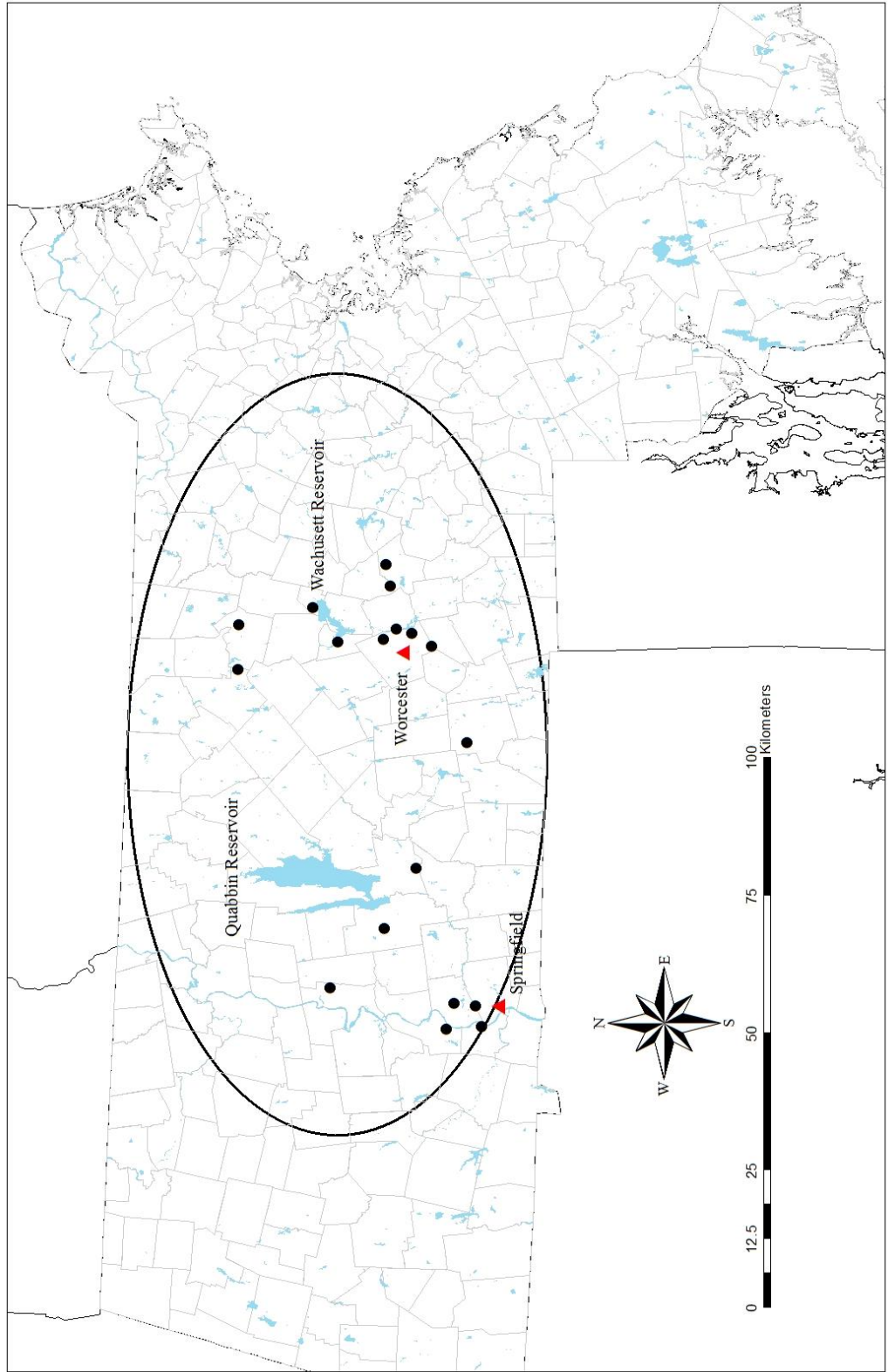
Figure 3.3. Number of ring-billed (A) and herring gulls (B) roosting on land, water or unknown during Spring (March-May), Summer (June-August), Fall (September-November), and Winter (December-February), 2008-2012.

A
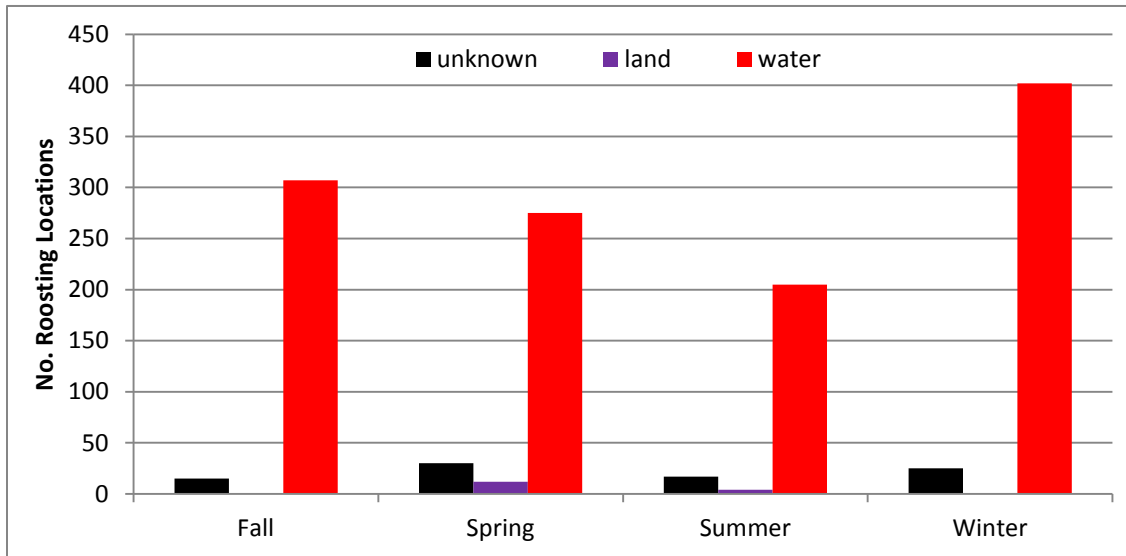
B
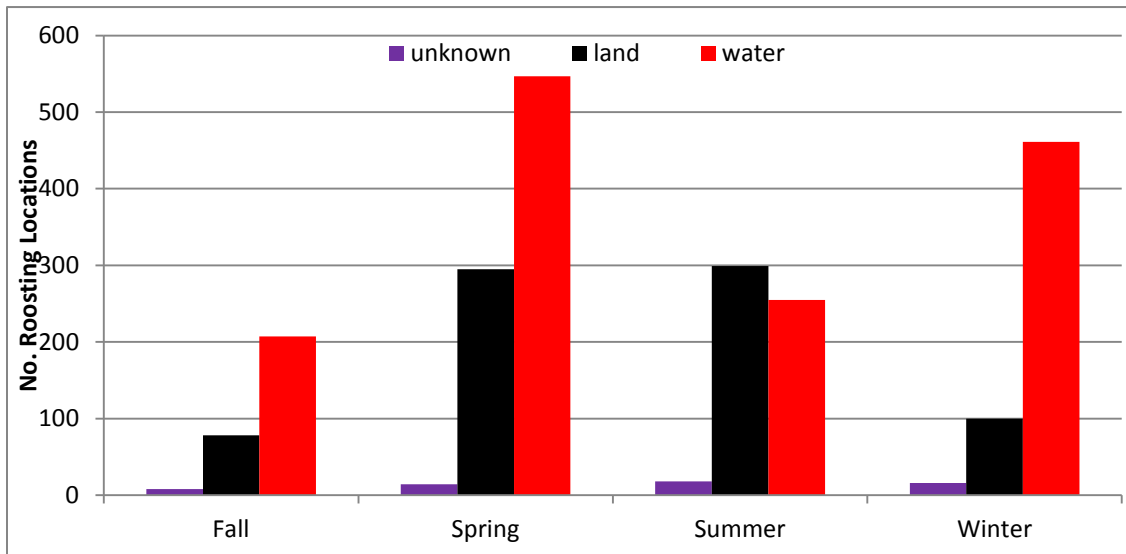
Figure 3.4. Number of ring-billed (A) and herring gulls (B) roosting in fresh, salt, or brackish water during Spring (March-May), Summer (June-August), Fall (September-November), and Winter (December-February), 2008-2012.

A
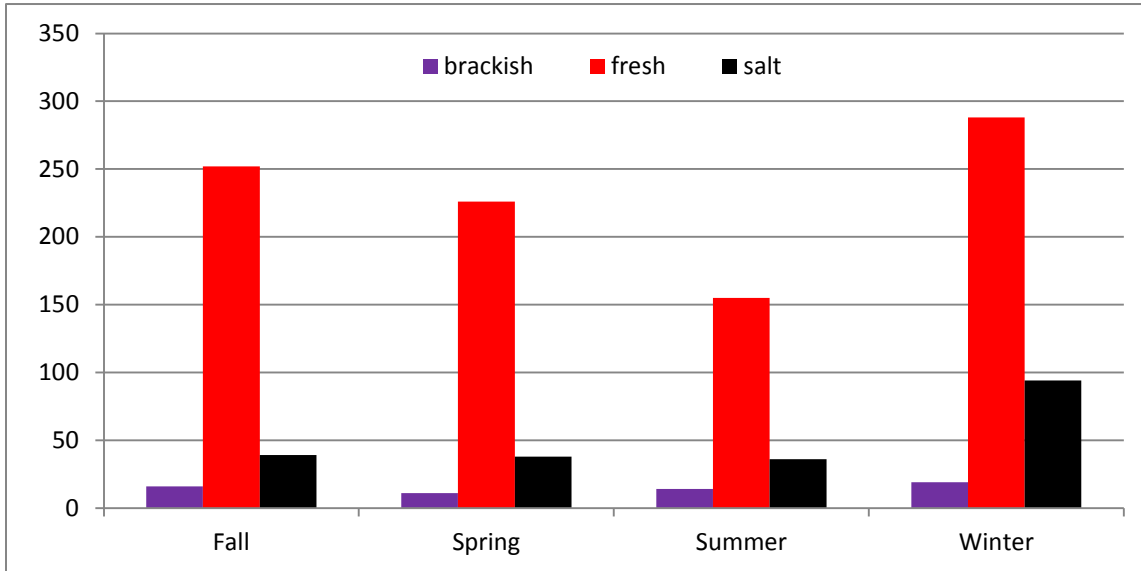
B
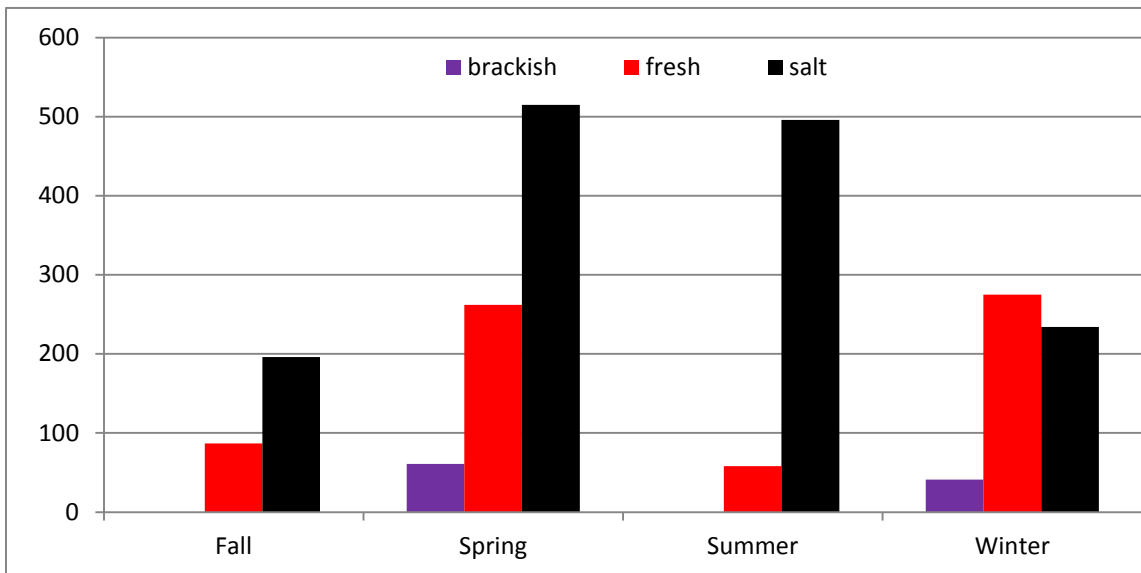
Figure 3.5. Percentage of inland water roosting sites for ring-billed and herring gulls that were located on lakes, reservoirs, or rivers.
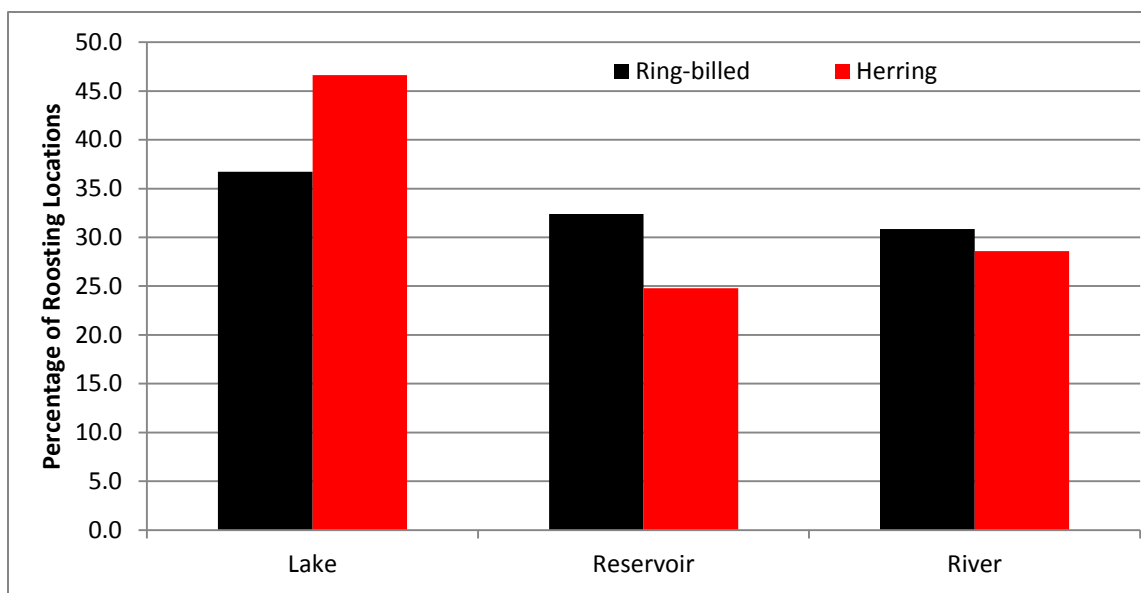
CHAPTER 4

ASSESSING GULL ABUNDANCE AND FOOD AVAILABILITY IN URBAN PARKING LOTS: CAN EDUCATION REDUCE THE AMOUNT OF HUMAN-PROVISIONED FOOD?

Abstract

Feeding birds is a common activity throughout the world, yet very little is known about the extent of feeding gulls in urban areas. We monitored 5 treatment and 3 control parking lots in central Massachusetts, USA during September-April 2011-2013 to document the number of gulls present, the frequency of human-gull feeding interactions, and the effectiveness of education in reducing human-provisioned food. In treatment lots, educational signs were erected, and gull feeders were approached and asked to stop feeding. Control lots were monitored, but feeders were not approached. Gulls were counted in all parking lots every 20 minutes. Ring-billed gulls accounted for 98% of all sightings. There were fewer feedings ($P = 0.007$) during some monitoring sessions but significantly more gulls ($P = 0.008$) in treatment lots during most monitoring sessions. There were fewer feedings after control lots were transformed into treatment lots ($P = 0.01$), but no difference in gull numbers in the lots before and after education ($P = 0.16$). Education appears to have some influence in reducing gull feedings, but our efforts were not able to reduce the number of feeders or the amount of food enough to influence the number of gulls using parking lots.

Introduction

Feeding birds is a common human-wildlife interaction in the Western world.

Recent estimates for the United States indicated that almost 53 million people fed

wildlife around their homes in 2011 (U.S. Department of the Interior, 2011). Of the 53

million feeders, most (95%) fed birds, while about 15 million (28%) fed other wildlife,

such as deer and bear (U.S. Department of the Interior, 2011). In addition, about 5.4

million people fed wildlife away from home an average of 11 days (U.S. Department of

the Interior, 2011). Providing supplemental food to birds has been associated with

reproduction earlier in the breeding season, longer breeding periods, and increased

production of young (Jones & Reynolds, 2007). Feeding birds is generally encouraged

by several prominent organizations (e.g., Cornell Laboratory of Ornithology's Project

Feeder Watch), and supplying food to wildlife may provide some specific limited

benefits (e.g., aid recovery of endangered species). Conversely, feeding birds has also

been implicated in altered behavior patterns, malnourishment, the spread of diseases,

dependency, and habituation (Orams, 2002, Rollinson, O'Leary, & Jones, 2003). As a

result, many state and federal wildlife agencies and professional wildlife organizations

discourage the practice (O'Leary & Jones, 2006, The Wildlife Society, 2006).

Given its popularity in the United States, feeding birds likely brings pleasure to its

participants, but the reasons people feed may be more complicated. Jones and Reynolds

(2008) summarized a study done in Brisbane, Australia, where bird feeders indicated that

in addition to giving them pleasure, feeding also served as "environmental atonement".

Feeders felt they were providing food in reparation for human environmental impacts or

habitat destruction. Further, many feeders said they fed out of a human concern for the

animals (i.e., the birds were cold, hungry, etc.) and felt the animals benefited from being fed (Jones & Reynolds, 2008). Given the complexity of the underlying psychological reasons behind the activity, it is likely that some participants have very strong convictions about feeding.

Ring-billed gulls (*Larus delawarensis*) are a common inland species in northeastern North America and are quick to identify and exploit readily available sources of food. Populations of ring-billed and herring gulls (*L. argentatus*) have increased substantially in the last 50 years in both Europe and the United States, and this increase is often attributed to several factors, including the exploitation of anthropogenic food resources, particularly landfills (Horton, Brough, & Rochard, 1983, Belant, 1997). Gulls use of landfills has been studied frequently, resulting in a common paradigm that gulls rely extensively on landfills during both the breeding and non-breeding season for their sustenance (Horton et al., 1983, Sol, Arcos, & Senar, 1995, Brousseau, Lefebvre, & Giroux, 1996, Belant, Ickes, & Seamans, 1998, Duhem, Vidal, Legrand, & Tatoni, 2003). However, the exploitation or dependence of gulls on human-provisioned food (e.g., handouts) has received considerably less attention.

In Massachusetts, ring-billed and herring gulls are year-round residents but inland populations increase dramatically during the fall and winter. Anecdotal observations and a pilot study conducted during 2010-2011 suggested that gulls were being provided a substantial amount of anthropogenic food through direct provisioning throughout the greater Worcester, Massachusetts area. In turn, locally fed gulls were travelling to Wachusett Reservoir to roost each night. Wachusett serves as the treated, but unfiltered,

water supply for 2.2 million consumers in greater Boston, and roosting gulls were causing serious water quality problems (Metropolitan District Commission, 1992).

Our objectives were to assess the relative abundance of inland wintering gulls at various parking lots where feeding occurred, quantify the amount of food being fed to gulls, and try to reduce the amount of provisioned food through education and outreach. We used an experimental framework, incorporating randomly selected treatment parking lots (human feeders approached) and control lots (observation only), coupled with before-after tests, to determine the effectiveness of educational signage and public interaction in limiting or preventing public gull feeding.

Study Area

This study was conducted in central Massachusetts during September-April 2011-2013. As part of a larger ecological study of ring-billed gulls, we used wing-tag re-sightings, satellite telemetry, and field observations to identify foraging sites in urban parking lots in and around Worcester (42°15'N, 71°48'W) (D. E. Clark, unpublished data). Eight parking lots were selected as sites where the public regularly fed gulls (Fig. 4.1). These lots were located 12-21 km from Wachusett Reservoir and ranged in size from 1.4-8.7 ha of open area (e.g., parking spaces). They contained a variable number of retail stores and were all located in urban or suburban settings surrounded by roads, residential areas, and other development. Most (7 of 8) of the parking lots had at least one fast food restaurant, and all lots had a similar layout (e.g., light poles, large areas of empty parking spaces).

Methods

Experimental design

Parking lots.—One of the parking lots was used in a pilot study (2010-2011) to assess public feeding of gulls and was kept as a treatment lot. Four of the remaining 7 identified parking lots were randomly selected as treatment lots, and the remaining 3 were assigned as control lots. We approached the owners of all treatment lots to describe our program and get permission to install signage and approach individuals. All owners cooperated with the study. Treatment lots were posted with educational signage to discourage feeding; all lots received 3-12 small (46 cm x 61 cm) DO NOT FEED signs that were attached directly to light poles about 3.5 m off the ground. Small signs were positioned at strategic locations around each lot (i.e., where feeding had been observed); sign density was determined by the size of the lot and limitations by the property owners. Two towns (Worcester and Leominster) within the study area had specific regulations against feeding wildlife (including gulls). In these towns, the small signs included language that feeding gulls was illegal and cited the specific regulation (Fig. 4.2a). Signs posted in other towns did not include this language, but were otherwise identical (Fig. 4.2b). In addition, 4 of the 5 treatment lots received a large (1.2 m x 1.5 m) educational sign that was anchored to 3 m posts on the perimeter of the lot for maximum visibility; one lot's owner did not grant permission for the large sign (Fig. 4.3). The large sign provided a similar message as the small sign; however, it did not discuss the legality of feeding and included larger text and a specific photo instead of a graphic. All signs were posted about 2 months prior to the study. The three remaining parking lots served as controls, and no signage was installed.

Public interaction.—Parking lots were monitored during 4 sessions: (1) 26 September – 22 October 2011; (2) 1 January – 20 January 2012; (3) 7 November – 2 December 2012; and (4) 3 December 2012 – 27 March 2013. During monitoring sessions 1 and 2, each day was divided into 4 shifts: early morning (0600-0900), late morning (0900-1130), early afternoon (1130-1400), and late afternoon (1400-1630). Each shift was about 3 hours long. Parking lots were allocated randomly to each day/time shift and assigned to a single monitor, except for a large (8.7 ha) parking lot where 2 monitors were assigned. Fifteen different monitors received training and participated during the first 2 monitoring sessions. During the third monitoring session, parking lots were randomly chosen to be monitored, and monitoring events lasted 2-9 hours. During the fourth monitoring session, control lots were reassigned as treatment parking lots to test the effectiveness of education in a before-after approach. Educational signage was erected and feeding was discouraged in these former control lots.   During the third and fourth session, monitoring was conducted by 2 monitors.

During all monitoring sessions, personnel assigned to treatment lots were instructed to closely observe the lot and identify all potential feeding events. If a feeding event was identified or suspected (i.e., swarm of gulls, mobbing behavior), monitors quickly made their way to the location of the feeding in a marked state vehicle and recorded the gender of the feeder and their license plate number. All feeders were approached on foot by the monitor. Once approached, the monitor identified themselves, handed the feeder an informational brochure, and then described the negative implications of feeding gulls. All feeders were asked if they had seen the DO NOT FEED signs and if they would stop feeding gulls in the future. Monitors also answered

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any questions. The type of food being offered was specifically noted when possible (bread, French fries, popcorn, etc.) and an approximate amount was determined by assigning the feeding to one of 3 qualitative categories: Minor (a few pieces of food, typically associated with the feeder offering gulls some of their own meal), Moderate (more than a few pieces of food, typically associated with food being brought specifically to the parking lot for gulls), and Major (a substantial amount of food, usually multiple loaves of bread, boxes of cereal, etc. that were specifically brought to the parking lot for gulls). When possible, monitors removed as much of the food as possible and noted the percentage removed. Other available food not associated with a feeding (e.g., garbage) was identified and removed when possible. Monitors assigned to control lots observed and recorded all feeding events, but did not approach any feeders.

Gull counts – Complete gull counts were conducted in all parking lots at the beginning of every shift and about every 20 minutes thereafter. Gulls were identified to species (i.e., ring-billed, herring, or great black-back (*Larus marinus*)) using 8x40 or 10x50 binoculars when necessary. In addition, all marked (i.e., wing-tagged or leg banded) gulls were noted during counts, and individuals were identified when possible. During early morning and late afternoon shifts, the time gulls first arrived in parking lots was recorded as well as the time when all gulls had left the lot for the day. Finally, during some shifts, the general cardinal direction of arrival (after sunrise) and departure (before sunset) were noted for gulls first entering or finally leaving parking lots.

Data Analysis

We conducted an analysis of variance (ANOVA) to test for differences in gull numbers and gull feedings between treatment and control parking lots (R Statistical

Software, R Core Team 2012). The dependent variables were mean number of gulls, mean number of total feedings per hour, and mean number of major feedings per hour recorded in each parking lot during each session. Independent variables were treatments (education vs. no education), session (1-3), and parking lot (1-8). We used treatment-by-session, treatment-by-lot, and session-by-lot interactions to examine differences in numbers of gulls and feedings between parking lots with and without education. We used descriptive statistics (mean ± SE) to illustrate differences in gull numbers and feedings between education and no education parking lots.

To test for differences before and after the three control lots became treatment lots, we used ANOVA to compare average number of gulls and feedings in these three lots during the control period and after we began educating the public.

Results

Over 4,200 individual gull counts were conducted in the 8 parking lots during the 4 sessions. Most (98%) gulls observed and counted in parking lots were ring-billed gulls, while about 1.4% were herring gulls, and only 0.06% were great black-back gulls. On average, less than 30 gulls were observed in parking lots during each count, although the maximum number of gulls observed was as high as 250 (Fig. 4.4). We were able to document 44 and 63 first arrival and last departure times, respectively, for gulls entering and leaving parking lots. Gulls tended to leave parking lots an hour or less before sunset, and in only one case were any gulls present after sunset (Fig. 4.5). Gulls tended to arrive in parking lots early in the morning. Most arrivals were 10-15 minutes before sunrise, although some lots didn't have any gulls until shortly after sunrise (Fig. 4.6).

We recorded 1062 observations of tagged gulls in study parking lots between 2008-2013 (before and during the feeding study). Almost 300 different individual gulls were identified, and most of these were adults (Fig. 4.7). Of the identified adults, there was a relatively even distribution between males and females (Fig. 4.7). Some marked gulls were seen repeatedly in parking lots (both study lots and others), often over successive years. The number of resightings for any particular individual ranged from a single sighting to 60 (Fig. 4.8).

We spent 1,278 hours in parking lots and observed 611 gull-food interactions. Most (n = 555) of the interactions were feedings, and the rest (n = 56) were gulls scavenging parking lot garbage. The gender of the feeders couldn't be identified 36% of the time. Of the identified feeders, more were men (35%) than woman (26%), and a small percentage (3%) were men and women feeding together. Feeders were approached 34% (n = 187) of the time. Monitors were unable to approach 66% (n = 368) of the feeders for a variety of reasons. The reason was noted 151 times, and the most common explanation was the feeder left the parking lot too quickly, in many cases before the gull food was consumed (Fig. 4.9). Feeders were commonly observed dumping food while driving through the lot; they never stopped to observe the birds or the feeding.

Of the feeders asked, a majority (78%) indicated they had not seen the DO NOT FEED signs. Only 8% (n = 14) of the feeders said they saw the signs. When asked if they would stop feeding gulls in the future, 141 feeders (75%) indicated they would stop feeding, while 46 (25%) said no or were non-committal.

Feeders offered a variety of food to gulls (Table 4.1), although bread, baked products, and French fries constituted the majority of feedings. Bread, baked goods, and

cereal were the most common food items offered in large quantities. While we were unable to specifically quantify major feedings, most constituted >5 loaves of bread or >3 boxes of cereal. Monitors were able to remove all the food from 19% (n = 107) and some of the food from 6% (n = 36) of the feedings. None of the food was removed from 74% (n = 409) of the feedings because in most cases, the gulls ate the food too quickly. Monitors identified 231 different individuals feeding gulls from their vehicles and another 30 individuals feeding gulls while walking through a lot. Of the 231 individuals identified through their vehicle license plate numbers, 11 were seen feeding on more than one occasion.

There was no difference in the number of major feedings (i.e., when large quantities of food were offered) between treatment and control lots (P = 0.20) or among lots (P = 0.84) during Session 1 (Fig. 4.10). There were fewer (P = 0.01) total feedings in Treatment lots during Session 1 compared to Control lots. There were fewer (P = 0.008) gulls seen in treatment lots than in control lots during Session 1 (Fig. 4.11).   During Session 2, there were fewer (P = 0.007) major feedings in treatment lots, but no significant (P = 0.123) differences in total feedings between lots. More gulls (P = 0.008) were seen in Treatment lots during Session 2. There were no differences in either major (P = 0.794) or total (P = 0.170) feedings between Treatment and Control lots during Session 3. There were more gulls (P = 0.005) seen in Treatment lots than Control lots during Session 3.

There was a significant decrease in the number of total feedings in parking lot 7 before and after education was implemented (P = 0.01, Fig. 4.12a). There was a marginally significant difference in the number of total feedings between all lots before

and after education (P = 0.055). There was no significant difference in the number of gulls seen in these parking lots before and after educational efforts (P = 0.155, Fig. 4.12b).

Discussion

To our knowledge, this is the first study to quantify the abundance of gulls and gull feedings in urban parking lots in North America. Our results suggest that feeding gulls is a common activity during winter, done by casual visitors as well as dedicated feeders making specific visits to parking lots to provide large quantities of food. In turn, this activity attracts large numbers of gulls to these parking lots. While we documented 3 species of gulls, lots were dominated by ring-billed gulls. We only selected 8 parking lots for inclusion in the study however, we documented gull feedings at upwards of 20 more lots in central and eastern Massachusetts. Further, we received resightings of our tagged gulls from parking lots throughout the eastern United States and Canada, suggesting that this activity is common and widespread.

Providing supplemental food to gulls may have a variety of ecological impacts. Gulls are diet generalists; they can change diets throughout the year, and individual diet preference is not fixed (Pierotti & Annett, 1990). A variety of research has reported on the prevalence of human-derived food in the diet of gulls and suggested that the availability of anthropogenic food can improve reproductive success or winter survival (Horton et al., 1983, Pons & Migot, 1995, Weiser & Powell, 2010). Adult male silver gulls (*Larus novaehollandiae*) specializing on anthropogenic food in Hobart, Australia, were significantly heavier than males captured in non-urban areas where human-derived

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food was not available (Auman, Meathrel, & Richardson, 2008). Auman et al. (2008)

suggested that the urban birds were in better condition than the non-urban birds.

In contrast, Pierotti and Annett (1990) proposed that reproductive performance

was a better measure of individual fitness than caloric intake. They studied the breeding

ecology of herring gulls in Newfoundland where individuals specialized in either

anthropogenic (garbage) or natural foods.   While garbage had the highest caloric value

per meal and also the most fat and protein per gram, the eggs of these specialized gulls

were most likely to be infertile or not develop. Pierotti and Annett (1990) suggested that

contaminants in the food and insoluble calcium were potentially responsible and

challenged the idea that gulls benefit from human-derived food. Further, western gulls

(*Larus occidentalis*) feeding primarily on human refuse showed reduced egg hatching

and fledging success and a shorter lifespan (Pierotti & Annett, 2001). Western gull

chicks experimentally fed an exclusive human-derived diet experienced abnormal

development or death (Pierotti & Annett, 2001).

Most of the individual gulls we were able to identify in parking lots were adults,

though juveniles and sub-adults were common. Our results suggest there is no difference

in parking lot use between adult males and females (i.e., resightings of marked gulls of

known sex). During our study, gulls arrived at parking lots within minutes of sunrise,

suggesting that these gulls had traveled directly from their nighttime roost to the lot.

Further, gulls tended to stay in parking lots until just before sunset before flying off to

roost for the night. It is unclear whether these gulls were foraging exclusively on human-

derived food and whether this diet may lead to short or long-term health effects.

However, given the arrival and departure times, the frequency of sightings of many

different individual tagged gulls in parking lots (both within and outside central Massachusetts), and the number of sightings of some individuals (i.e., some gulls were seen >40 times in parking lots over multiple years), it seems likely that human-provisioned food in urban parking lots may be a relatively important component of the diet of ring-billed gulls during winter.

While the ecological impacts of human-derived food are contested, there is clear evidence that gulls feeding on anthropogenic food can have societal impacts. Anthropogenic food sources concentrated in or near urban areas can attract large groups of gulls leading to property damage (Haag-Wackernagel, 1995, Belant, 1997), aircraft hazards (Gosler, Kenward, & Horton, 1995, Dewey & Lowney, 1997), or increased risk of disease transmission and surface water contamination (Benton, Khan, Monaghan, Richards, & Shedden, 1983, Nugent & Dillingham, 2009). While a variety of food was provided to gulls, bread was the most common food offered. This is consistent with feeding studies of other species including ducks in Australia (Chapman & Jones, 2009), magpies (*Gymnorhina tibicen*) and butcherbirds (*Cracticus spp.*) in Australia (Rollinson et al., 2003), and black currawongs (*Strepera fuliginosus*) in Tasmania (Mallick & Driessen, 2003). Bread is likely a common offering because it is relatively inexpensive, easy to obtain, and readily accepted by gulls and other wildlife.

It is evident from our results that just posting educational signs is ineffective in preventing feedings in these lots because the vast majority of feeders never noticed the sign, even though in several cases they were standing directly in front of one. In contrast, Mallick and Driessen (2003) reported about 70% of visitors to a national park in Tasmania had seen their "Keep Wildlife Wild" anti-feeding sign, although the sign did

not change any pre-existing opinions about feeding. Ballantyne and Hughes (2006) tested different language in bird feeding signs and concluded that signs with clear reasons why not to feed that are designed to convince people that feeding is detrimental to the birds' health and survival are the most persuasive. While our small signs included specific reasons, they did not appeal to the health of the bird, although our large sign did include this message. It is likely our signs were not directly in the cone of vision of drivers or got lost in a multitude of existing urban signage and blended into the "urban noise" (Morris, Hinshaw, Mace, & Weinstein, 2001).

We were surprised by the behavior of the feeders, and we recognized at least 3 groups: (1) feed-and-watch, (2) short-watch, and (3) dump-and-run feeders. Most studies suggest that people enjoy feeding wildlife because it gives them pleasure, a sense of satisfaction, and an avenue to interact with wildlife (Howard & Jones, 2004, Jones & Reynolds, 2007), and the feeders in groups 1 and 2 spent at least some time watching the gulls eat. However, the large number of dump-and-run feeders who dumped food in parking lots without stopping their vehicles, or only stopping briefly to unload food, would suggest that a direct visual reinforcement (i.e., the gulls consuming the food that was left for them) was unnecessary. It is plausible that these feeders stopped and witnessed previous feedings and were reassured that the food would be consumed by gulls and therefore didn't need to witness every feeding event. It is also possible that these feeders were motivated to feed for other reasons and specifically interacting with wildlife was not their primary motivation.

Our educational efforts showed limited and variable effectiveness in reducing the number of feedings or the number of gulls in these parking lots. Even when there were

significantly fewer feedings in treatment lots, the number of gulls in some cases was higher than control lots. It is likely that either our efforts weren't able to reduce the amount of available food enough to influence gull numbers or our educational campaign wasn't conducted long enough to reach most of the feeders. Based on our satellite and wing-tag data (D. E. Clark, unpublished data), it is clear that individual gulls return to the same parking lots in successive winters, suggesting that gulls returning to treatment lots in central Massachusetts probably encountered enough food to stay since we were only able to remove a small percentage of the available food. It is plausible that if enough food could be eliminated, increased competition for the remaining food may provoke some gulls to leave these parking lots in search of more abundant food.

Anecdotal conversations with feeders suggested that most were ignorant of where gulls went when they left a parking lot and were unaware of the implications of their actions (i.e., feeding gulls attracts more gulls which roost on water supply reservoirs). In addition, most feeders indicated that they fed gulls out of concern for the birds, which is consistent with other feeding studies (Mallick & Driessen, 2003, Ballantyne & Hughes, 2006). When educated, most of the feeders we encountered verbally agreed to stop feeding. Unfortunately, our approach only allowed us to interact with a minority of the feeders and only remove a small percentage of the provisioned food. It is likely a broader educational approach may be more effective. In Basel, Switzerland, a large informational campaign was initiated to discourage feeding of pigeons (*Columba livia*) (Haag-Wackernagel, 1995). Pamphlets and posters were placed around the city, and the campaign message was spread through television, radio, newspapers, and magazines.

Within two years, their reduction goals were met; however, the educational effort was also coupled with a trap and kill program.

Our efforts to foster a behavioral change in feeders (i.e., stop feeding) relied on an information-intensive campaign that assumed feeders would stop feeding gulls once they became educated on the topic. However, research in social marketing suggests that enhanced knowledge has little or no impact on behavior, and most failed attempts to elicit behavioral changes underestimate the difficulty of changing behavior (McKenzie-Mohr, 2000). Future efforts to reduce the number of gull feeders in central Massachusetts should focus on using community-based social marketing techniques to elicit change. Social marketing emphasizes that any program begins with an understanding of the barriers that people perceive exist from engaging (or stopping) in an activity and highlights the importance of delivering programs that target specific segments of the public (gull feeders) and works to overcome barriers of this group (see McKenzie-Mohr & Smith, 1999 for a discussion on social marketing). Continued efforts should focus on individuals dedicated to gull feeding and identifying what barriers exist from stopping their behavior. Further, an effective social marketing strategy should be developed and then pilot tested before being broadly implemented. Any program should be evaluated through some direct measure (e.g., the number of feedings, number of gulls, etc.).

<center>Management Implications</center>

Feeding gulls is a common activity at parking lots in central Massachusetts, and humans provide a substantial amount of food to wintering gulls. This subsidized feeding can attract and concentrate ring-billed gulls, leading to potential water quality concerns when gulls leave parking lots to roost on close by water supply reservoirs. In addition,

the concentration of birds can lead to potential public health concerns from an increased risk of disease transmission. Our data suggest that limiting or eliminating human provisioned food is challenging, and prohibitive/educational signage alone will not change people's behavior. Our ground-based educational program had limited success in preventing feedings or reducing the number of gulls utilizing parking lots. We would recommend a broader educational campaign using social marketing techniques that specifically targeted people who provide food to gulls.

Table 4.1. Types and amounts of food fed to gulls in parking lots in central

Massachusetts.

	Amount of Food Provided[a]			
Food Item	Minor	Moderate	Major	Total
Bread	77	39	40	156
French fries	118	21	4	143
Lunch items (sandwich, etc.)	37	10	3	50
Unknown	44	3	0	47
Baked goods (pretzel, bagel)	15	4	6	25
Crackers	15	4	2	17
Chips	9	4	4	17
Cereal	1	8	8	17
Leftovers (rice, spaghetti)	4	9	4	17
Other (candy, nuts, cheese)	16	1	0	17
Fruit	15	0	0	15
Popcorn	5	4	4	13
Pet food	0	3	7	10
Pizza	6	1	2	9

[a] Minor: a handful or less; Moderate: more than a handful; Major: >3 loaves of bread, >3

boxes cereal, etc.
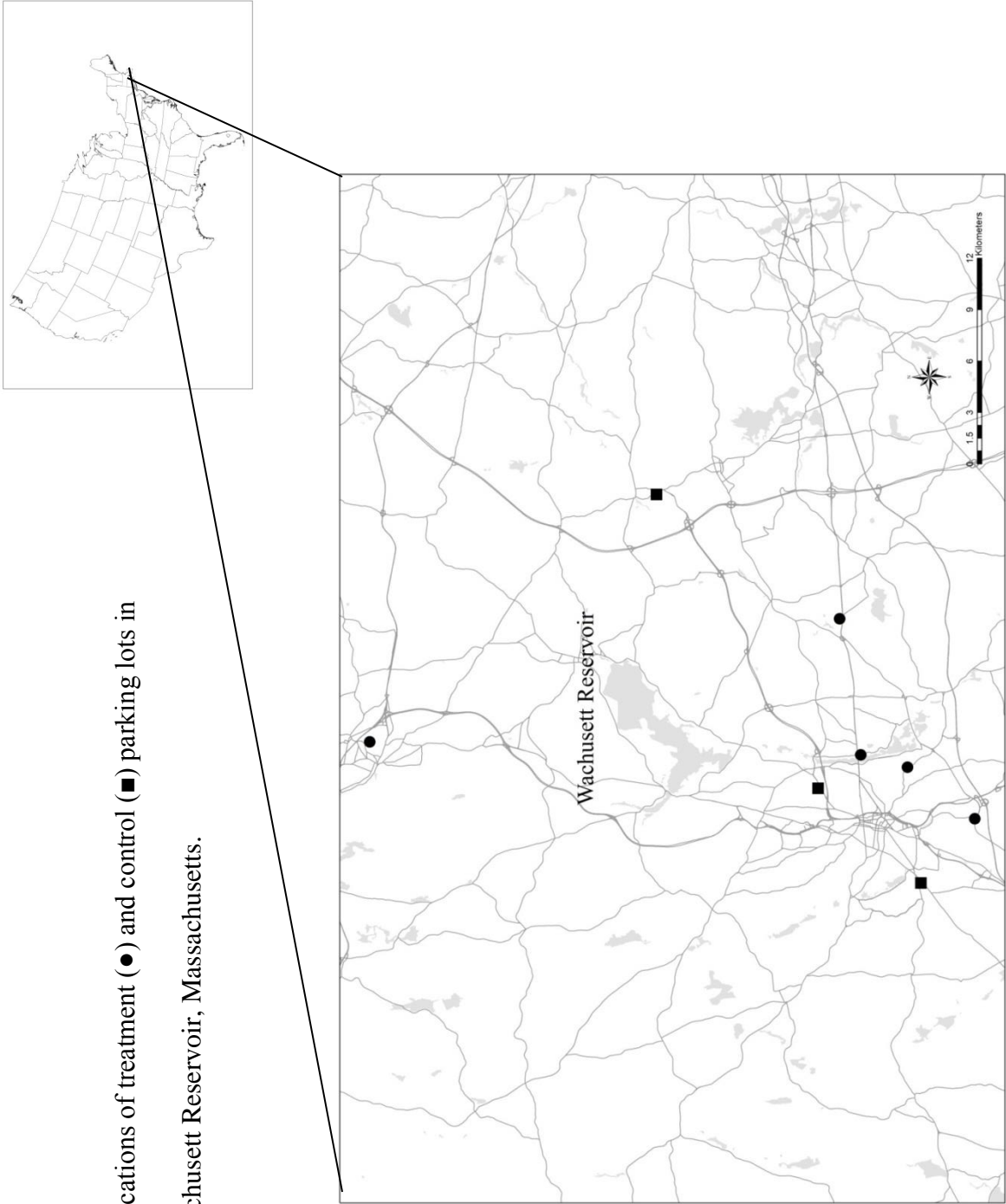
Figure 4.1. Locations of treatment (●) and control (■) parking lots in relation to Wachusett Reservoir, Massachusetts.

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Figure 4.2. A. Small education sign used to discourage feeding in cities where the activity was prohibited; **B.** Educational sign used in cities where feeding was not prohibited in central Massachusetts.

Figure 4.3. Large educational sign used to discourage feeding in parking lots in central Massachusetts.

Figure 4.4. Average (±SE) and maximum number of gulls seen during each parking lot monitoring session during 3 periods of the day: Early (sunrise-11:00 am), Mid (11:00 am-1:00 pm), and Late (1:00 pm-sunset).
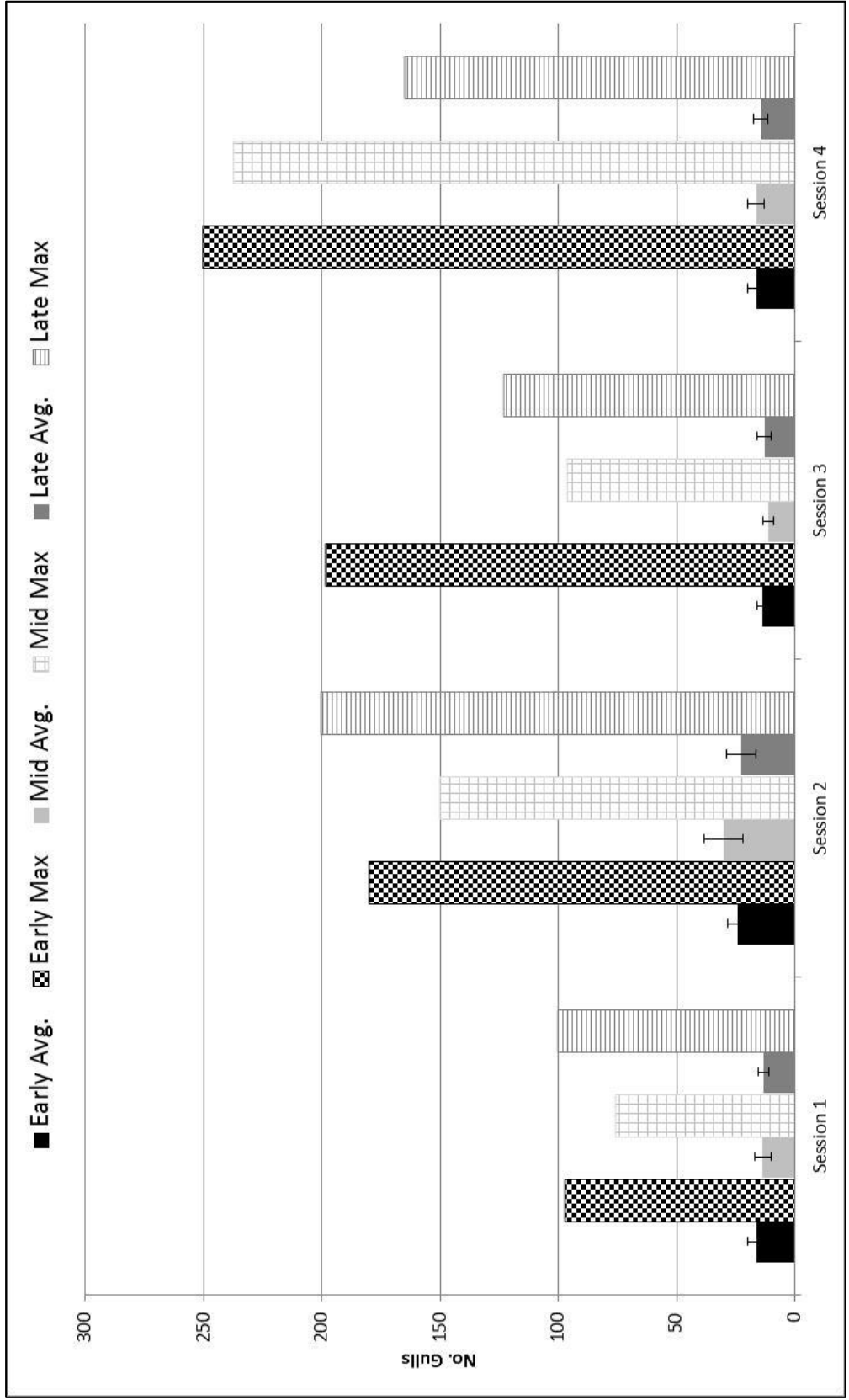
Figure 4.5. Number of minutes before or after sunset ring-billed gulls left parking lots in central Massachusetts, 2012-2013.
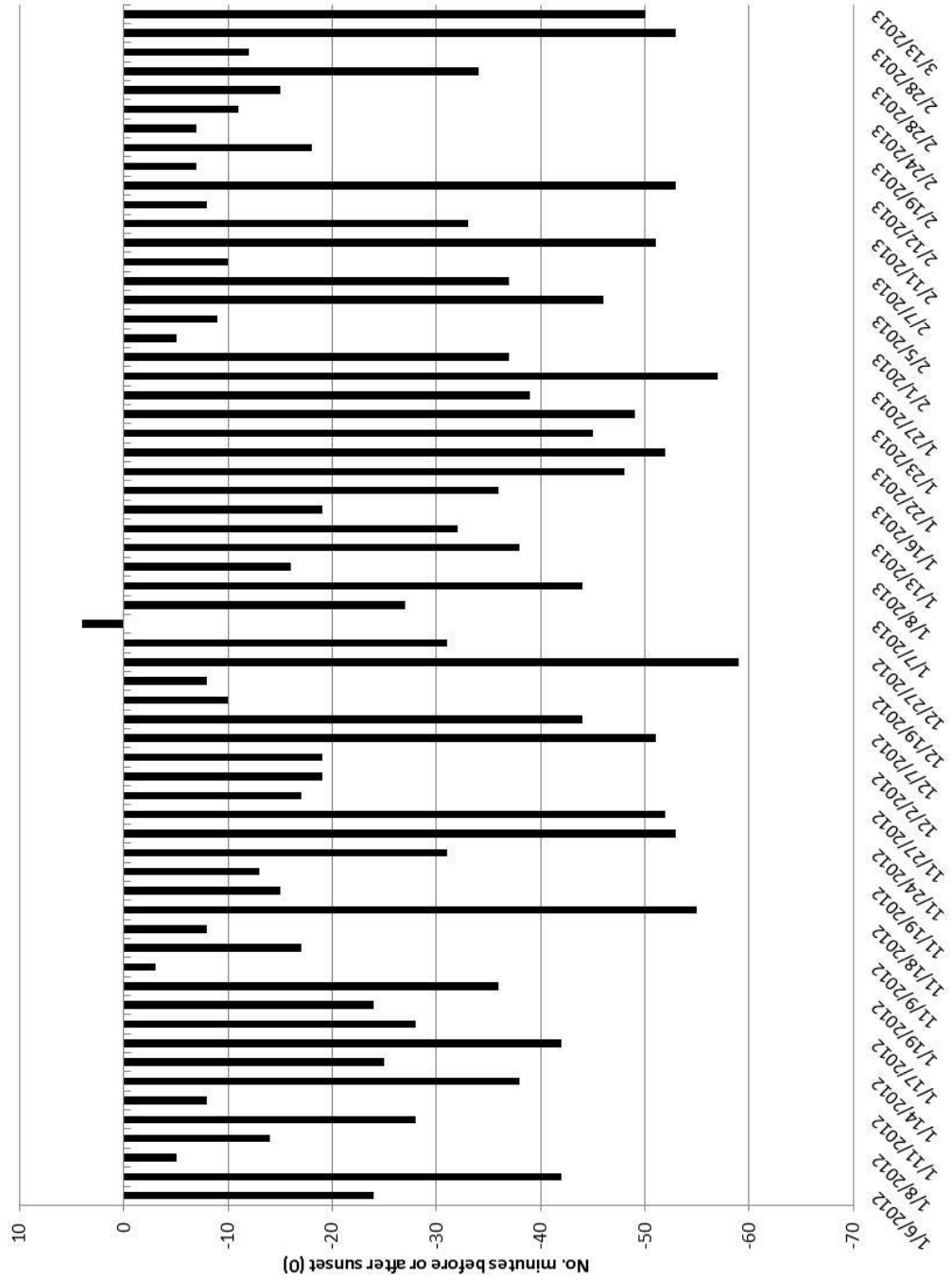
Figure 4.6. Number of minutes before or after sunrise ring-billed gulls arrived in parking lots in central Massachusetts, 2012-2013.
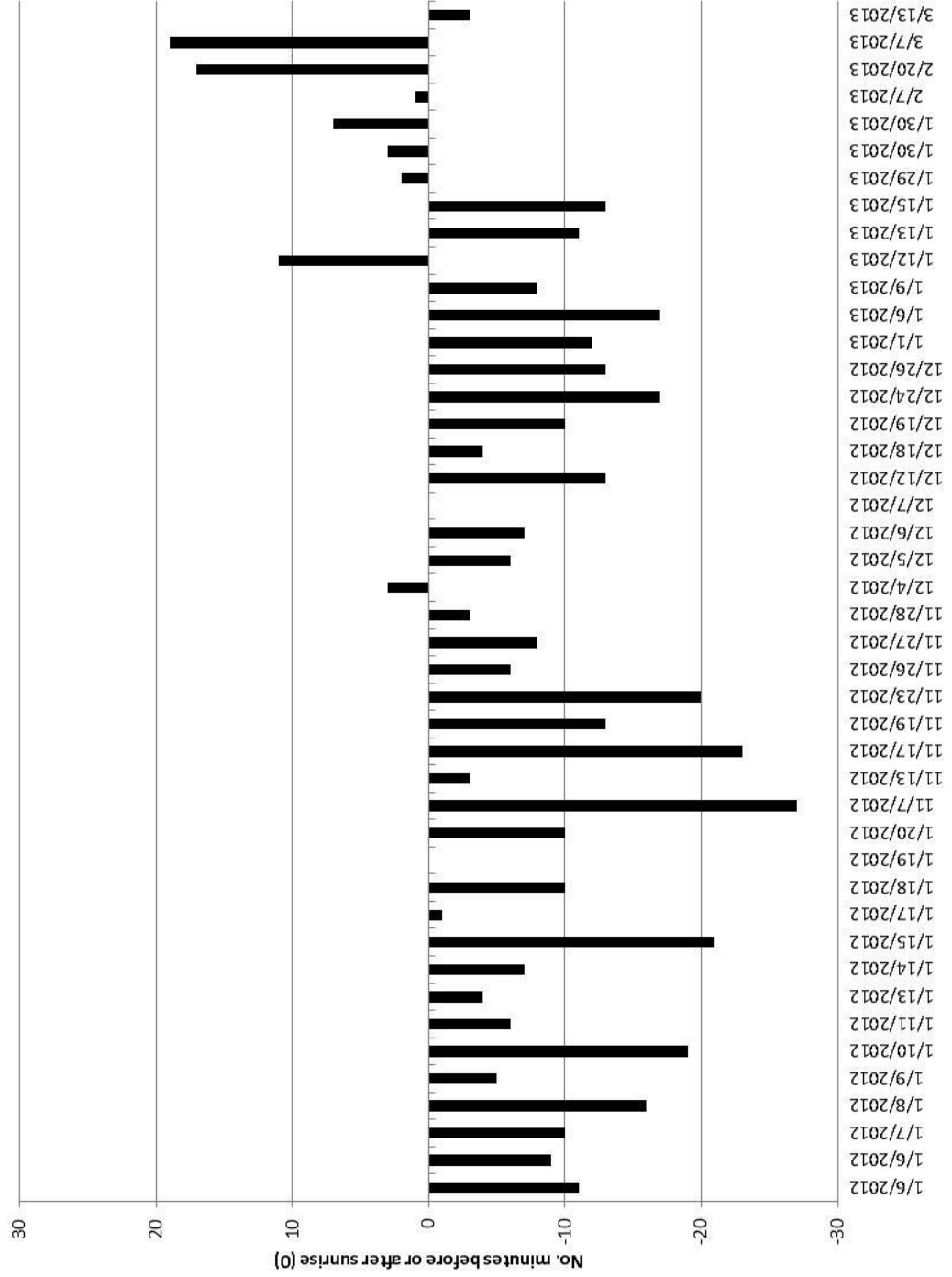
Figure 4.7. Percentage of adult (male, female, and unknown), sub-adult, and juvenile ring-billed gulls observed in treatment and control lots in central MA, 2008-2013.
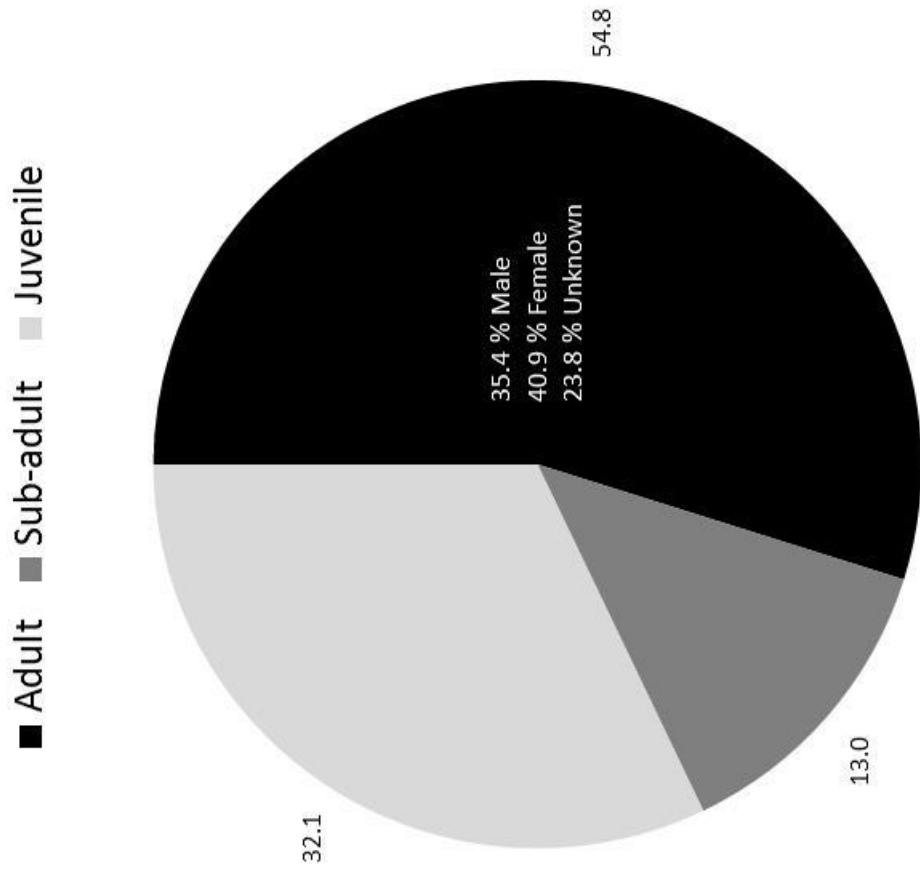
Figure 4.8. Number of times individually marked (wing-tags and/or leg bands) gulls were resighted in parking lots in central Massachusetts. 2008-2013.
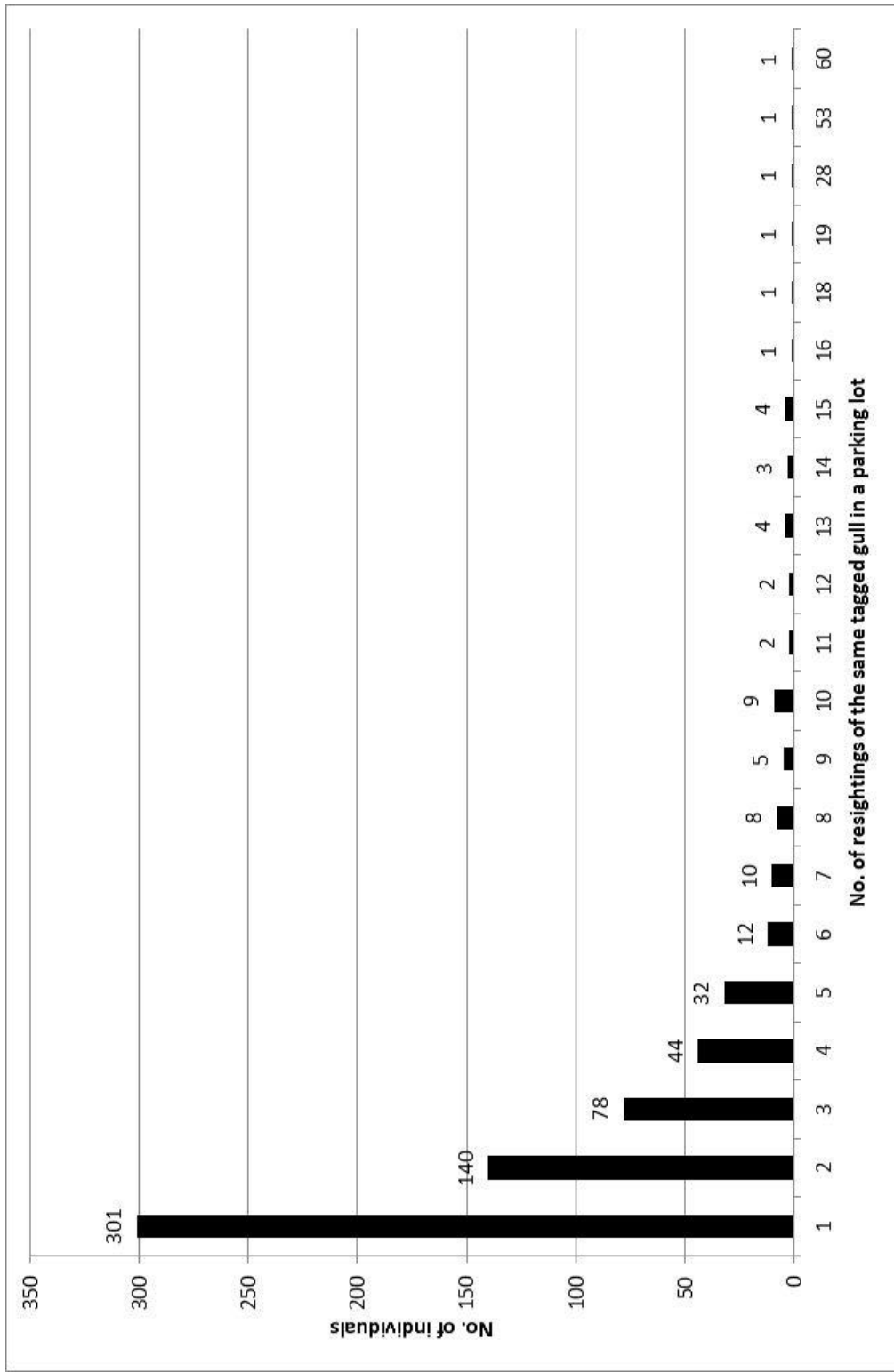
Figure 4.9. Summary of reasons why gull feeder couldn't be approached in parking lots in central MA, 2011-2013.

Drive-by feeding (saw feeder)

Feeder gone upon arrival (didn't see feeder)

Language barrier

Unknown

Approached feeder but they left

Feeder identified, couldn't get there in time

Feeder on foot; entered store

Feeder refused to speak

36

58

2

8

18

10

12

3
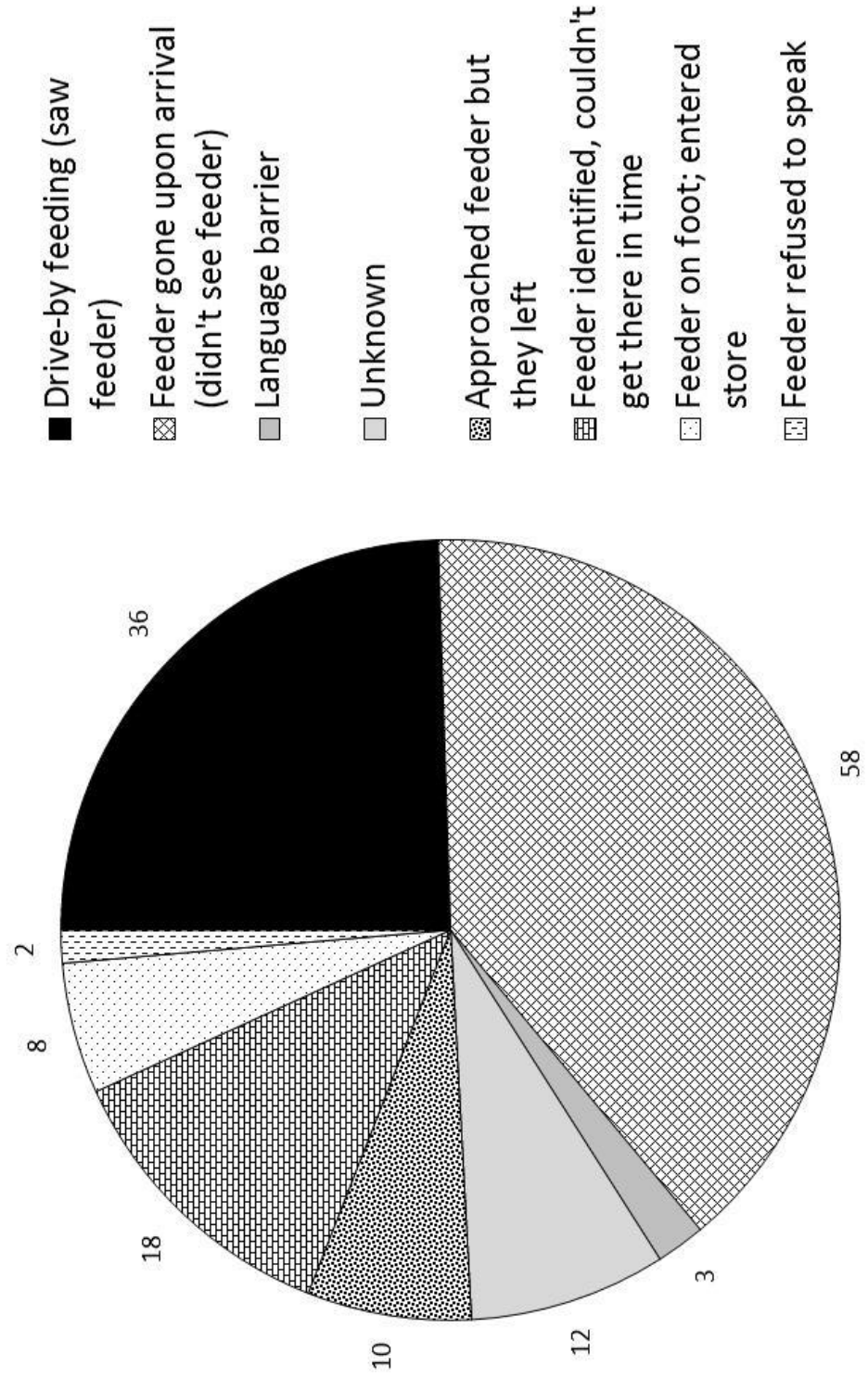
Figure 4.10. Mean number of feedings/hour (Total and Major) (±SE) seen in treatment and control

parking lots during 3 Sessions (Session 1: 26 September – 22 October 2011; Session 2: 1 January –

20 January 2012; and Session 3: 7 November – 2 December 2012).
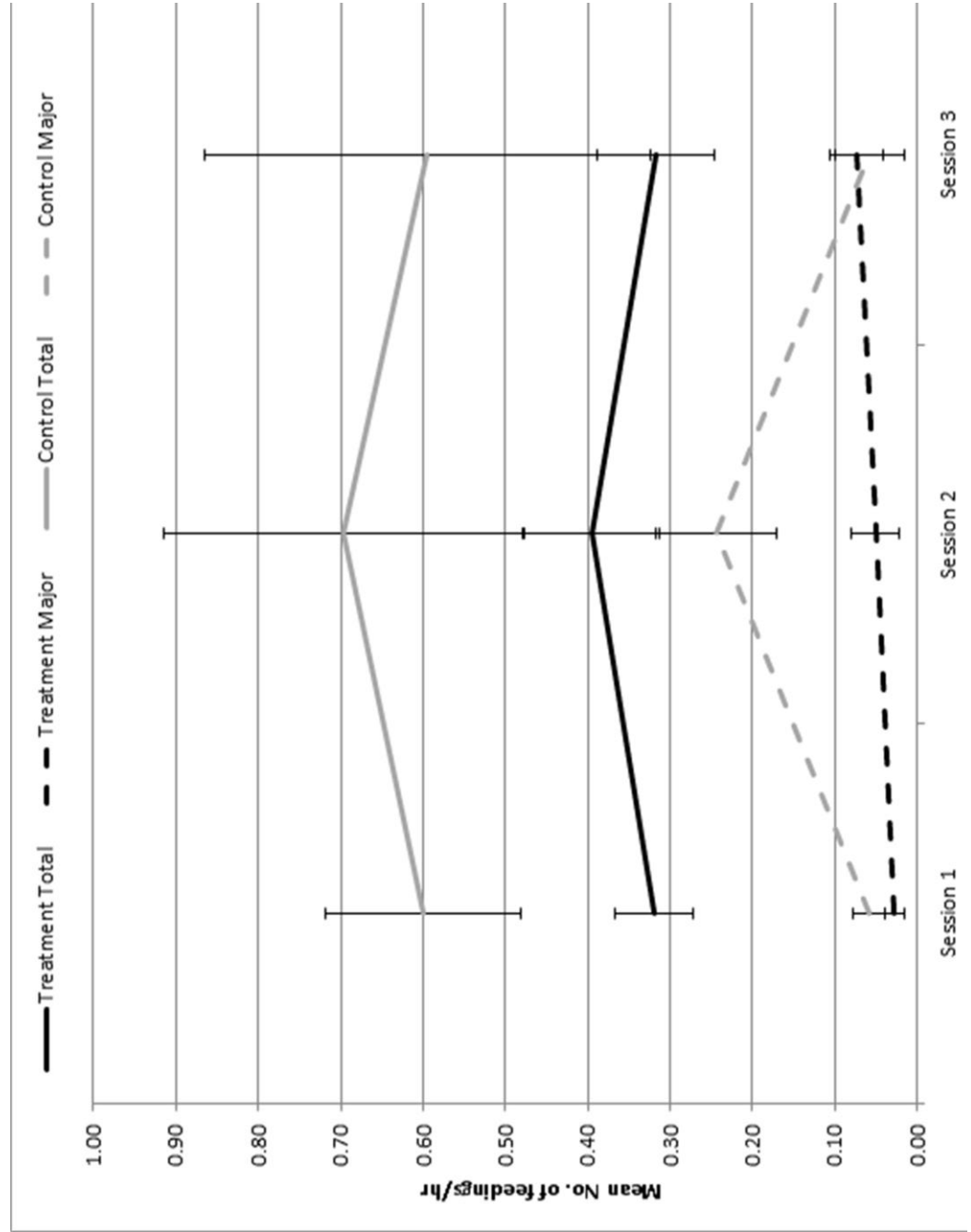
Figure 4.11. Mean number of gulls (±SE) seen in treatment and control parking lots during 3 Sessions (Session 1: 26 September – 22 October 2011; Session 2: 1 January – 20 January 2012; and Session 3: 7 November – 2 December 2012).
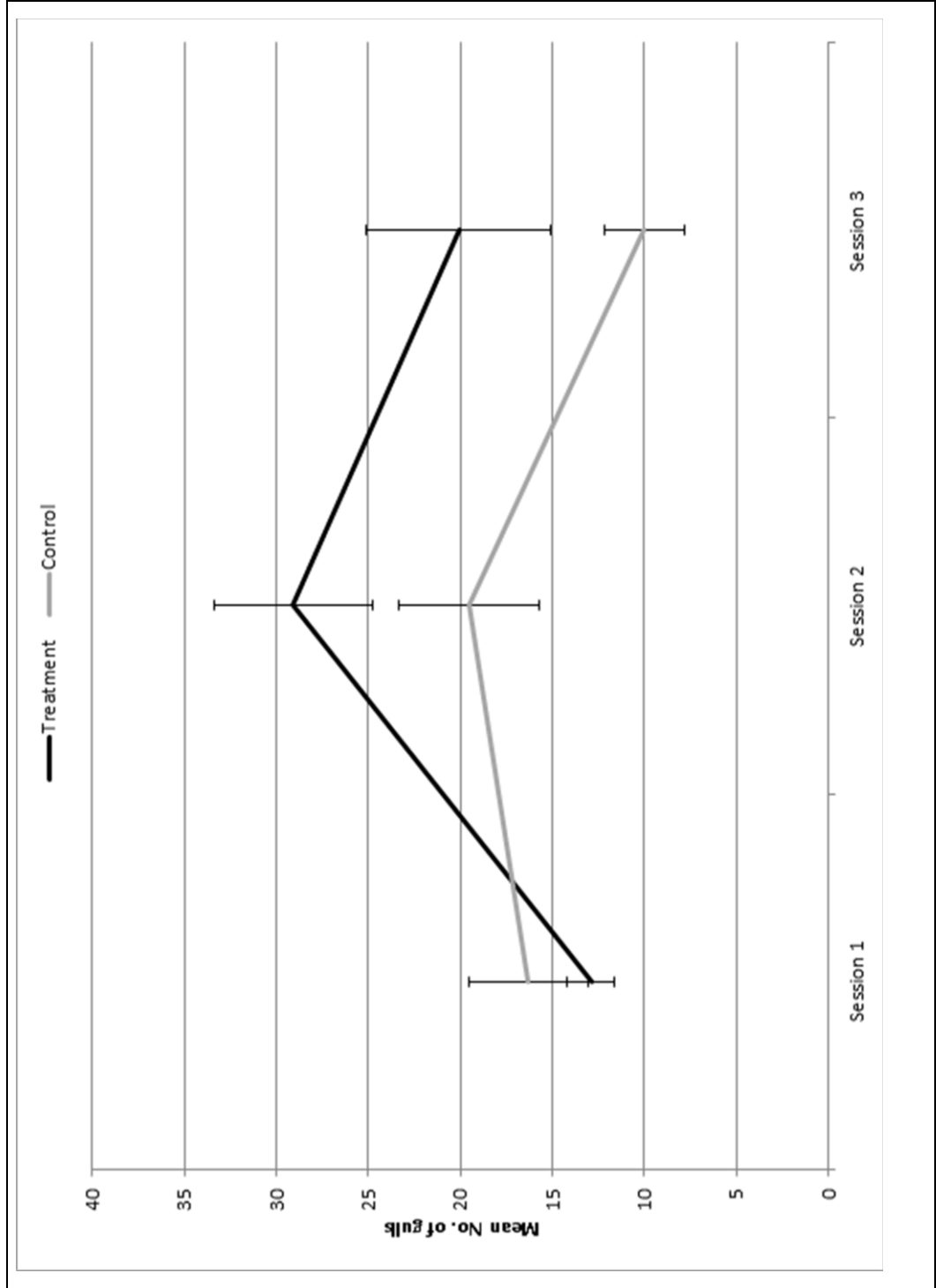
Figure 4.12. **A.** Mean number of gulls (±SE) seen in control lots before and after educational efforts; **B.** Mean number of feedings/hour before and after (Before: ■ After: ▨) educational efforts.

A
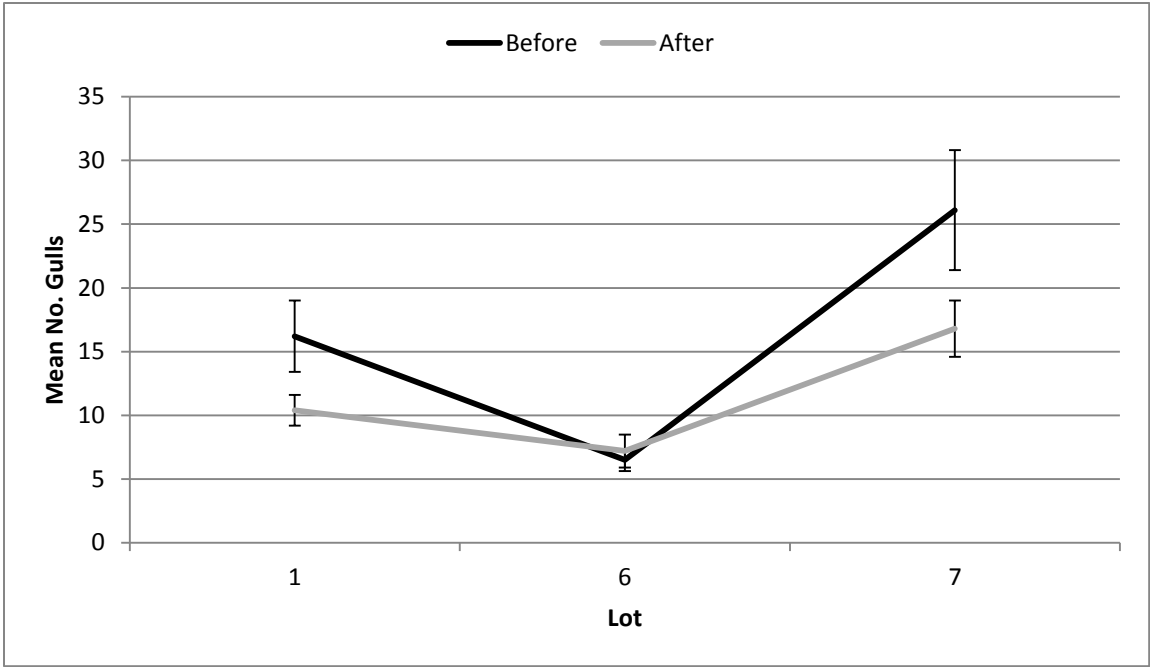
B
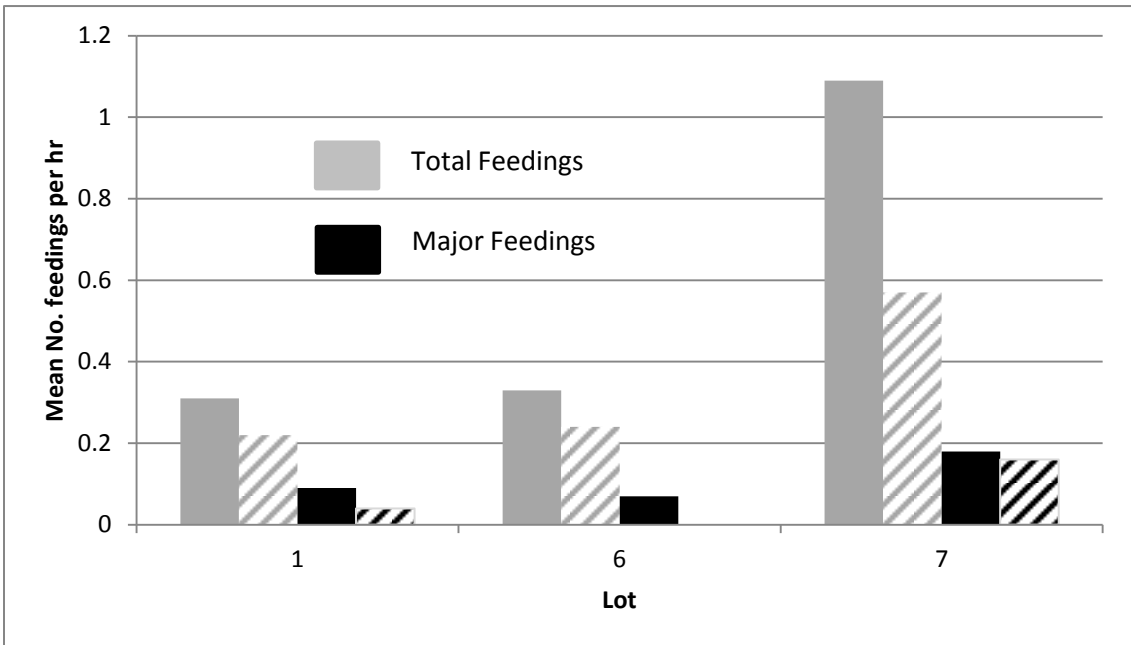
CHAPTER 5

USE OF STAINLESS STEEL WIRES EXCLUDE RING-BILLED GULLS FROM A MUNICIPAL WASTE WATER TREATMENT PLANT

Abstract

There is growing concern about the prevalence of pathogens and antibiotic-resistant bacteria in the environment and the role wildlife plays in their transmission and dissemination. Gulls feeding at waste water treatment plants may provide a route for transmission of pathogens and bacteria to public water supplies or other critical areas. We identified gulls routinely feeding at a waste water treatment plant in Millbury, MA, USA and tested the effectiveness of overhead stainless steel wires in excluding gulls from the plant. The number of gulls in certain structures was compared before and after wiring and during an experimental approach using simultaneous treatments and controls. Stainless steel wires spaced at 0.9-3.3 m (3-10 ft.) effectively prevented gulls from using treatment structures ($P < 0.0001$) and were effective for >24 months. Material costs to wire all structures were about $5,700, and labor costs were $4,020. Overhead stainless steel wires can provide a long-term, cost efficient method of excluding ring-billed gulls from waste water treatment plants.

Introduction

Ring-billed gulls (*Larus delawarensis*) are common inland birds in the northeastern United States and Canada as populations have increased dramatically since the 1970s (Greenlaw and Sheehan 2003). Ring-billed gulls will utilize a variety of inland freshwater lakes and ponds, including water supply reservoirs (Nugent and Dillingham 2009). As opportunistic foragers, ring-billed gulls are often associated with

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anthropogenic food sources such as landfill and poultry farm refuse, household garbage, food scraps, and handouts (Blokpoel and Tessier 1984, Belant et al. 1995, Brousseau et al. 1996, Belant et al. 1998). In addition, several European studies have reported gulls feeding at coastal sewage outfalls (Fenlon 1981, Ferns and Mudge 2000) or sewage plants (Fenlon 1983). However, we are unaware of any studies specifically linking ring-billed gulls to municipal waste water treatment plants in the United States or efforts to exclude them.

Gulls feeding at waste water treatment plants can potentially become infected or contaminated with a variety of pathogens. Over 50% of feces collected from gulls feeding at a sewage plant in Scotland tested positive for S*almonella* (Fenlon 1983). Butterfield et al. (1983) tested fecal samples from herring gulls (*Larus argentatus*) feeding at untreated sewage outfalls in northeast England for S*almonella* and found 2.1-8.4% of the samples were infected. Ferns and Mudge (2000) studied black-headed gulls (*Larus ridibundus*) in South Wales and southern England, also feeding at sewage outfalls, and documented a 6.3% *Salmonella* infection rate. They concluded that gulls could represent a transmission route of pathogens from sewers to lakes and reservoirs. In addition, *Campylobacter* spp. was identified in 13.7% and 36.2% of gull feces collected in Northern Ireland and Sweden, respectively (Moore et al. 2002, Broman et al. 2002). Moore et al. (2002) speculated that gulls feeding on human fecal material at sewage treatment works were a likely route for infection.

Other pathogens such as total coliforms, *Escherichia coli*, and multiple antibiotic-resistant bacteria are common in both raw water and secondary effluent at waste water treatment plants (Kamel et al. 2010, Huang et al. 2012, Hendricks and Pool 2012). In the

northeastern United States, Alroy and Ellis (2011) tested herring gull feces and human wastewater for antimicrobial-resistant *Escherichia coli* and detected *E. coli* isolates in 59.2% and 17.5% of wastewater and fecal samples, respectively. In addition, gulls may carry a diversity of antibiotic resistant bacteria. Martiny et al. (2011) tested herring gull feces for a variety of antibiotic resistant genes and detected both common and undescribed genes. They suggested that gulls may serve as a vector between human-dominated habitats and the environment.

Ring-billed gulls feeding regularly at municipal waste water treatment plants can have potentially serious public health implications, particularly when gulls fly to parks, playing fields, pastures, public beaches, or water supply reservoirs after feeding at a plant. As part of a larger ecological study of ring-billed gulls, we documented birds using waste water treatment plants and also visiting public parking lots, water supply reservoirs, and parks (D. Clark, unpublished data). Gulls have been observed or reported feeding at 15 treatment plants throughout the northeastern United States and Canada (D. Clark unpublished data). While a variety of deterrent techniques have been used to exclude birds from critical areas with variable success, including chemical repellents (Cummings et al. 1995), harassment (Nugent and Dillingham 2009), effigies (Stickley et al. 1995), lethal removal or culling (Green 2008), and fencing or netting (Maxson et al. 1996, Blokpoel et al. 1997), these techniques are often cost prohibitive at larger scales or are publicly unpalatable. Nonlethal control methods that are cost-effective and provide the best long-term solution are most desirable, but to our knowledge none of the potential solutions have been tested experimentally to document their effectiveness.

We used an experimental framework, incorporating wired (treatment) and control (unwired) structures at a waste water treatment facility, coupled with before-after tests, to determine the ability of overhead wires to exclude gulls. We present a cost-effective deterrent technique that uses stainless steel overhead wires to exclude ring-billed gulls from a large space within a densely populated area. In addition, we describe the installation design of the wiring system and provide estimates of its associated costs.

Study Area

This study was conducted at the Upper Blackstone Waste Water Treatment facility (42°12'43.76"N, 71°47'17.57"W) in Millbury, Massachusetts, USA (Fig. 5.1). The facility has been in operation since 1976 and was designed to treat an average of 190 million liters per day (mld) (56 million gallons per day) of raw influent. During 2011, flow averaged 115 mld (33.1 mgd). The facility treats all waste water from 7 towns and cities and partial waste from an additional 4 towns. In addition, private septic service tank trucks empty their collected waste into the system.

The 12.8 ha (31 acre) facility uses biological nutrient removal in a 4-stage process to treat raw influent, which involves primary treatment, bio-reaction, settling, and chlorine treatment (Fig. 5.1). Influent enters the system through a large open concrete channel where screens and grit chambers remove large rocks and sand from the water. The influent then passes through an open channel and enters the primary treatment stage, where water is circulated through one of 7, 55 x 12 m (180 x 39 ft.) primary clarifiers, where suspended solids and organic material settles out. The water then enters an aerated bio-reactor tank where activated sludge removes pollutants. Water then flows into 1 of 8 37-m (121 ft.) diameter round secondary settling tanks. Water from the secondary tanks

passes through a 30 x 30 m (98 x 98 ft.) chlorine contact tank and is dechlorinated before entering the Blackstone River as treated effluent. All stages of the treatment facility are above ground, uncovered, and accessible to birds.

Methods

Experimental design – We installed wires to test the effectiveness of excluding gulls from 4 of the 5 structures that made up the treatment facility: (1) the entry chute, (2) primary treatment tanks, (3) secondary treatment tanks, and (4) chlorine contact tank (Fig. 5.1). The bio-reactor tanks were not wired because our observations before the study did not detect gulls inside these structures, which were filled with highly turbulent, dark water. For 1, 2, and 4 above, we used a before-after study design (Green 1979) where we observed and recorded the approximate number of gulls in each of these structures before and then after complete wiring. For 3 above (secondary treatment tanks), we used an experimental approach with simultaneous treatments and controls, where 4 of the 8 structures were wired and 4 were not wired. To assign treatments and controls, we randomly selected a first tank, wired it, and then alternatively assigned the remaining 7 tanks as unwired (controls) or wired (treatment) to obtain 4 wired and 4 unwired tanks. At the completion of the secondary treatment tank experiment, the 4 unwired tanks were wired, and the number of gulls in each structure was monitored in a before-after framework. Before-after designs can be problematic because any change could be attributed to another source (e.g., all gulls leaving the area), but this design can be useful when used as a supplement to experiments that are conducted at the same time; in our case, the implementation of treatments and controls at the secondary treatment tanks.

Wire installation – We used single-strand stainless steel piano wire about 1 mm (0.05 in) in diameter with a 136 kg (300 pound) tensile strength (Precision Brand No. 29041, Downers Grove, IL; mention of trade names does not constitute an endorsement from the federal government). We chose piano wire because of its durability, UV resistance, and ease of handling. Several of the structures at the plant were bounded by aluminum railings which were incorporated into the installation design. However, to avoid corrosion between the aluminum railing and steel wire, a small piece of vinyl coated polyester fabric (BondCote, 7.5 oz, Style G80494, Pulaski, VA) was wrapped around the top of the vertical railings and held in place with a 44.4-69.9 mm (1.75-2.75 inches) stainless steel hose clamp (Ideal, model 67365, Smyrna, TN). Fabric and hose clamps were placed every 2.2-3.3 m (7-11 ft.) along the railings. The wire was placed on top of the fabric, and the hose clamp kept the wire from slipping down. On structures without aluminum railings, we used 9.5 mm x 102 or 152 mm (0.375 inch x 4 or 6 inch) stainless steel eyebolts (Lehigh #7135, Billerica, MA) anchored in 12.7 mm (0.5 inch) holes drilled into the concrete walls. Eyebolts were spaced every 1.8 m (6 ft.) along the outside of structures.

We wired the entry chute during September 2010 (Fig. 5.2a, b). Wires were installed diagonally across the channel so the maximum spacing between wires was about 2 m (6.5 ft.). Wiring of the primary settling tanks began in November 2010 (Fig. 5.3a), and the chlorine contact tank was wired in May 2011 (Fig. 5.2e). Both structures had line spacing of 1.8 m (6 ft.) installed diagonally. Wiring of the secondary tanks began in June 2011 (Fig 5.3b). Wire was run from the outer railings to the center walkway and/or

catwalk in a radial design (Fig. 5.3b). Spacing between wires varied around the tanks, but never exceeded 3.3 m (10 ft.).

Gull observations – Before any wires were installed, opportunistic visits (during 2008-2010) were made to the treatment plant to observe and note gull numbers in each treatment structure. In addition, visits were made during the wiring installation phase and after all wiring had been completed. During each visit, 1-3 observers drove slowly through the plant and noted the approximate number of gulls in or on each treatment structure. In addition, the number of gulls on site but not associated with a treatment structure was noted. Visits lasted less than an hour. Additionally, on-site personnel visited wired structures daily as part of their routine maintenance and noted any gulls in wired tanks.

During the experimental study, observations of the wired and unwired secondary tanks were made by a single observer over 9 days during October 2011. To determine if the number of gulls varied throughout the day, each day was divided into 4 3-hour shifts. Days and shifts were chosen randomly, and each shift was completed 3 times. During each shift, the number of gulls in each of the 8 secondary tanks was recorded every 20 minutes. In addition, the number of gulls on site, but not in a secondary tank (i.e., on a roof, grass, flying) was also recorded. Finally, any gulls seen in other treatment structures (entry chute, primary tanks, chlorine tank) were also noted.

In order to determine differences in gull abundance between tank treatments and at different times of the day, we conducted an analysis of variance (ANOVA) to test for differences in gull numbers between wired and unwired tanks (R Statistical Software, R Core Team, 2012). The dependent variable was the mean number of gulls recorded in

wired and unwired tanks during each day/shift combination. The independent variables were treatments (wired and unwired), days (1-9), and shifts (1-4). We used treatment-by-day, treatment-by-shift, and day-by-shift interactions to examine differences in gull use between tank treatments following wiring and also to determine differences in gull abundance at different times of the day. We used descriptive statistics (mean ± SE) to illustrate differences in gull numbers between wired and unwired tanks and on-site.

Results

Gull use of tanks – We visited the site 7 times from 2008-2010 before any wires were installed and 10 times during the wire installation phase. Before wiring, gulls could be seen in all stages of the treatment plant except the aerators (Fig. 5.4). During wiring, gulls were regularly seen in unwired structures, but not in wired structures (Fig. 5.4). Eight visits were made to the treatment plant after all structures had been wired. No gulls were seen in any of the wired structures during these visits; however, a small number of gulls were seen flying into the unwired aerators, presumably to feed.

During the experimental study, the difference in the number of gulls using wired and unwired tanks was highly significant ($P < 0.0001$); no gulls were seen in any of the wired secondary treatment tanks during the experiment's 36 hours of observations over 9 days (Fig. 5.5). A relatively low but variable number of gulls were seen in each of the unwired secondary tanks, and gulls readily flew in and out. A large number of gulls (>50) were seen at the water treatment plant not in association with any treatment structure (Fig. 5.5). Most of these gulls were sitting on the roofs of plant buildings, on the ground, or flying. No gulls were detected in any of the other wired structures (entry chute, primary tanks, or chlorine tank).

The number of gulls present at the site varied throughout the day. Although more gulls were seen in the unwired tanks and on site during the second and third shifts (9:30 am - 3:30 pm) than during the first (sunrise - 9:30 am) and fourth (3:30 pm - sunset) shifts, there were no significant differences between shifts ($P = 0.28$). The number of gulls at the treatment plant varied from day to day, however there were no significant differences between days ($P = 0.17$).

Following the study in late October 2011, observations by on-site workers indicated that several juvenile gulls were present in the chlorine contact tank. In response, additional eye bolts and 113 kg (250 pound) braided nylon fishing line (Spiderwire) (in place of stainless steel) were installed in November 2011 so that the spacing between wires was reduced from 1.8 m (6 ft.) to 0.9 m (3 ft.). We chose the nylon line to evaluate its potential as a substitute for steel wire. Multiple random visits were made to the treatment facility after all structures (except the bio-reactor) were wired (Fig. 5.4). During these visits, no gulls were seen in any of the wired structures. However, on one occasion a small number (<10) of gulls were seen flying into the unwired bio-reactor tanks, dipping their bills into the water. In addition, a variable number of gulls were usually observed on the site perched on roofs or on the ground.

Cost – Materials to wire the entire treatment facility cost about $5,700 (Table 5.1). A majority (74%) of the costs were associated with the stainless steel wire. The secondary treatment tanks were the most expensive structures to cover. Labor costs were about $4,000 based on an hourly wage of $15.00 and took 3-4 laborers about 268 hours to complete.

Discussion

Overhead lines or wires have been used in a variety of situations to exclude an assortment of birds including great cormorants (*Phalocrocorax carbo sinensis*), Canada geese (*Branta canadensis*), American crows (*Corvus brachyrhyncos*), herring gulls, great black-back gulls (*Larus marinus*), and ring-billed gulls (see Pochop et al. 1990 for a review). Ring-billed gulls have been successfully repelled from nesting areas with monofilament line (Blokpoel and Tessier 1983) and partially repelled from public places with wire and stainless steel fishing line (Blokpoel and Tessier 1984) and landfills with wire (Forsythe and Austin 1984, McLaren et al. 1984). A range of spacing (60 cm – 6 m) (23.5 inches - 20 ft.), patterns (parallel, grids), and heights (60 cm – 10 m) (23.5 inches – 32.75 ft.) were used.

 In previous studies, researchers either compared gull numbers before and after overhead lines were installed at each site (Forsythe and Austin 1984, McLaren et al. 1984) or observed the number of gulls after wires were installed (Blokpoel 1984); they did not use an experimental framework with simultaneous treatments and controls to compare use between wired and unwired sites. In addition, these studies were conducted >25 years ago under dissimilar environmental circumstances when presumably population levels and food resources were different. Studies that attempted to exclude gulls from food resources reported substantial reductions in the number of birds accessing the feeding site, but acknowledged a variable number of gulls still penetrated the wires to feed (Blokpoel 1984, Forsythe and Austin 1984, McLaren et al. 1984).

Our use of stainless steel wires showed complete effectiveness in reducing the number of ring-billed gulls utilizing waste water treatment facility structures. Once wires

were installed over a structure, gull use declined to zero and remained that way throughout the duration of the experiment and beyond. During our experiment, gulls avoided the wired secondary tanks completely and made no attempts to enter. Their activities were concentrated in unwired tanks. Other studies have reported varying levels of success in excluding gulls. Maxson et al. (1996) reported different responses of ring-billed gulls depending on the situation. Elevated colored nylon string spaced at 2 m (6 ft.) effectively prevented gulls from nesting in new or small colonies with no history of successful breeding but string spacing as close as 1.2 m (4 ft.) had little effect deterring nesting gulls at larger, denser colonies with historic breeding success. Blokpoel et al. (1997) used monofilament lines spaced at 70 cm (28 inches) to exclude nesting ring-billed gulls from Ice Island, Ontario, Canada. The lines substantially reduced the number of gulls, but they reported that gulls still occasionally nested inside the exclosure, and if the exclosure was removed too early in the nesting season, the gulls quickly returned.

It is unclear what mechanism provokes the avoidance response in gulls. Blokpoel and Tessier (1984) speculated that flying gulls focus their eyes on the ground and unexpectedly encounter wires or lines as they approach for a landing. This would suggest that the avoidance mechanism is a learned behavior after a gull flies into a line. However, Amling (1980) reported gulls avoided a wired reservoir without ever attempting to fly through the lines. While the specific mechanism for avoiding wired places is unknown, ring-billed gulls do not appear to become habituated to overhead lines (Blokpoel and Tessier 1984).

Attempts to exclude ring-billed gulls from food sources have been relatively successful, but not completely effective. Blokpoel and Tessier (1984) used stainless steel

wires and monofilament line to install a grid over public places where gulls were being fed. Gull use after installation was reduced substantially; however, some gulls did feed under the wires near the edges. Efforts to exclude ring-billed gulls from landfills have been successful when the line spacing was 6 m (20 ft.) but unsuccessful when spacing was 12 m (40 ft.) (Pochop 1990).

Observations at the primary settling tanks immediately after wiring documented gulls "testing" the wired tanks. A small number of gulls (1-5) would fly back and forth over the wired tanks and then drop down towards the tank. As they approached the wire, most gulls would veer off quickly and erratically. In a few instances, direct contact was made with the wire by a gull, which resulted in panicked flapping and erratic movements, often accompanied by vocalization. Over time, fewer and fewer gulls were seen investigating the tanks or attempting to enter. At no time were any gulls seen standing or feeding under the wires. Interestingly, several (< 10) juvenile gulls were observed in the final chlorine contact tank after the experiment ended in late October 2011, although this tank had the same wire spacing as the primary settling tanks and most likely much less available food. From May 2011 until October 2011, no gulls had been seen in this tank. It is unclear what prompted their sudden entry, but it appeared to be limited to a small number of juvenile gulls. The reduction in wire spacing in November 2011 prevented further entries.

During one visit to the site after wiring had been completed, we observed gulls (<10) flying in and out of the bio-reactor tank, which we did not wire. No gulls had been observed in this tank during all previous visits. This tank is filled with dark brown, highly turbulent water. No gull attempted to land in the water, but their behavior

suggested they were pursuing food items as they flew close to the water and dipped in their bills. Given that wires prevented gull access to the rest of the site, it is possible these gulls were attempting to feed in the only remaining unwired structure. However, given the turbulence and lack of water clarity, it is unlikely that this structure would provide a reliable source of food.

In our study, gulls did not habituate to the wires >24 months after installation, which is consistent with other studies (Amling 1980, Blokpoel and Tessier 1984). While we chose to use stainless steel wires, other materials have also effectively excluded gulls, including monofilament line and nylon string. However, given that monofilament line breaks down in sunlight, and nylon string may wear over time, the initially higher costs of stainless steel were justified over the lifespan of the material. In addition, we have used monofilament line in other situations and found that ducks can become tangled in the line, causing injury or death.

Line spacing can be a critical component in attempting to exclude gulls. We were conservative with our line spacing (0.9-3.3 m) (3-10 ft.), which resulted in complete exclusion. However, other studies have used much wider spacing with success in different situations, including 6 m (20 ft.) spacing at landfills and 5 m (16 ft.) spacing at public places (Pochop 1990). It is possible that a wider spacing in this study may have been just as effective in some of the structures, however, the relatively minor additional costs to install closer wires was justified, particularly on a site of this size. In addition, given that a small number of gulls entered the chlorine contact tank under the original spacing of 1.8 m (6 ft.), wider spacing may have allowed more entries or attempts. Wire

spacing should be as conservative as possible, but larger projects may necessitate wider

spacing to be cost effective.

While overhead wires can provide successful gull exclusion at waste water

treatment plants, they do not exclude all species. During our study, mallard ducks (*Anas*

platyrhynchos) readily flew in and out of the chlorine and secondary tanks (Fig 5.2e),

either avoiding the overhead wires or hitting them with their wings on the way in or out.

Collisions with the wire did not seem to injure the birds or deter them from future entries

or exits. We did not witness any other bird/wire interactions. While a small number of

Canada geese and turkeys (*Meleagris gallopavo*) were present at the study site, they did

not attempt to enter any of the wired structures.

Because wires will likely be installed over existing treatment structures, we

recommend consulting with on-site engineering and operational staff prior to any

installations. While none of the wires in our design posed any walking hazards, they

would be encountered during routine maintenance activities. Through the planning

phase, we were able to leave large enough gaps in areas that were routinely accessed. If

necessary, small pieces of flagging could be attached to wires to remind staff of their

presence.

<center>Management Implications</center>

There is growing concern about the role of gulls as carriers and potential

transmitters of multi-drug resistant bacteria, particularly *E. coli* (Poeta et al. 2008,

Simões, et al. 2010, Poirel 2012). Evidence suggests that these bacteria can be present in

both raw wastewater and treated effluent at sewage treatment plants (Huang et al. 2012,

Hendricks and Pool 2012). Further, it has been documented that ring-billed gulls feeding

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at waste water treatment plants in central Massachusetts also use water supply reservoirs and public places (D. Clark, unpublished data). Possible transmission of diseases or pollution of drinking water supply reservoirs by ring-billed gulls is a serious potential public health risk. Excluding gulls from waste water treatment plants would reduce the likelihood of gulls being exposed to various pathogens. It is possible that gulls could be excluded from waste water treatment plants using other methods, including harassment, shooting, or a broad population control program. However, these alternatives can be costly, require long-term commitments of personnel, or may be publicly unpalatable. Overhead stainless steel wires can provide an effective exclusion method that is relatively inexpensive, long-term, site-specific, and publicly acceptable.

Table 5.1. Material costs (in dollars) associated with installing stainless steel wire over various structures to exclude gulls at a municipal waste water treatment plant.

Structure	Materials (No. of each used)				Total	Cost per square foot
	Eyebolts	Wires	Hose Clamps	Concrete Anchors		
Entry Chute	$ 82.66 (25)	$ 115.65 (71)	$ 49.00 (50)	$ 5.75 (20)	$ 253.06	$17.84
Primary Tanks (n = 7)	$ 532.00 (152)	$ 1447.30 (353)	$ 74.48 (76)	$ 34.96 (152)	$ 2088.74	$24.80
Secondary Tanks (n = 8)	N/A	$ 2400 (469)	$ 490.00 (500)	N/A	$ 2890.00	$42.16
Chlorine Tank (n = 1)	$ 203.46 (57)	$ 290.00 (29)	N/A	$ 13.11 (57)	$ 506.57	$19.93
Total	$ 818.12	$ 4252.95	$ 613.48	$ 53.82	$5738.37	

Figure 5.1. An aerial view of the Upper Blackstone Waste Water Treatment Facility, Millbury, Massachusetts, showing the locations of each treatment structure.

Figure 5.2. Various structures associated with the Upper Blackstone Waste Water Treatment Facility after wire installation to prevent intrusion by gulls: A: entry chute with railing; B: entry chute without railing; C: primary settling tanks; D: secondary settling tanks; E: chlorine tank (note mallard ducks in the tank under the wires).

A

B

C

D

E
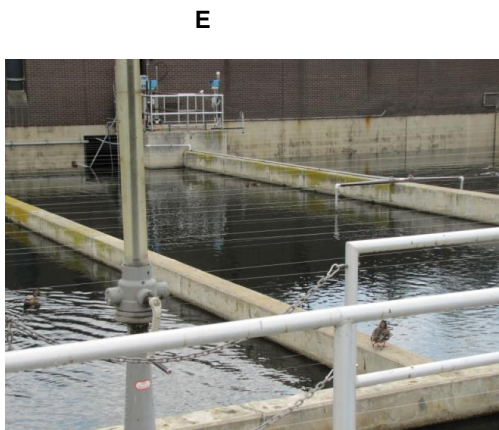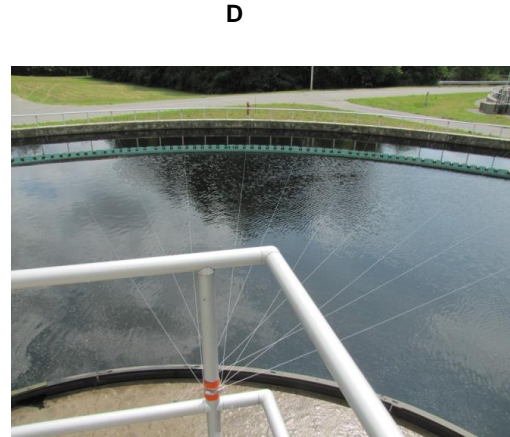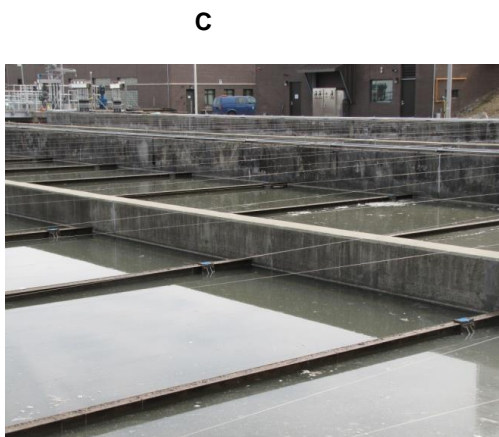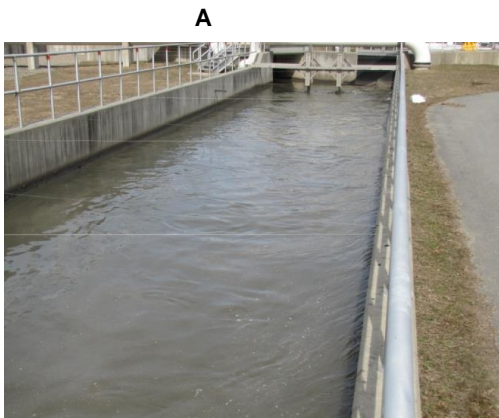
Figure 5.3. A: Wiring diagram of primary settling tanks showing locations of each tank and positioning of eyebolts and wire at a waste water treatment facility. For easier viewing, most eyebolts and wires are not shown, but the pattern would be repeated on each tank. Drawing not to scale. B: Wiring diagram of secondary settling tanks showing position of catwalk, outer railing, and wires. Drawing not to scale.
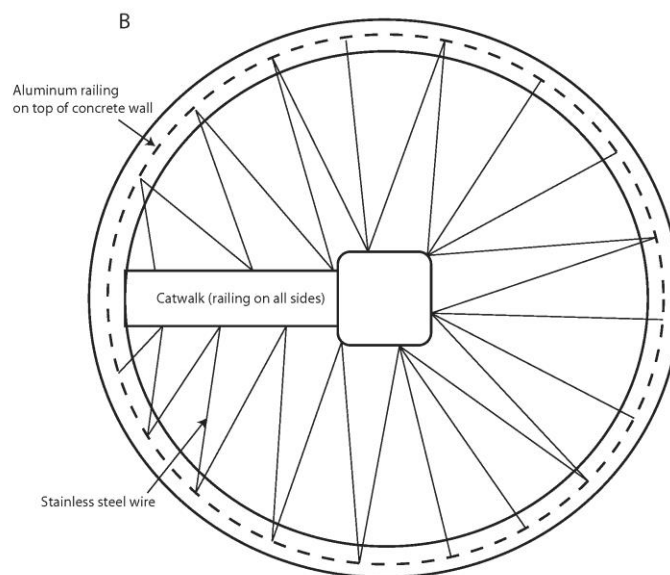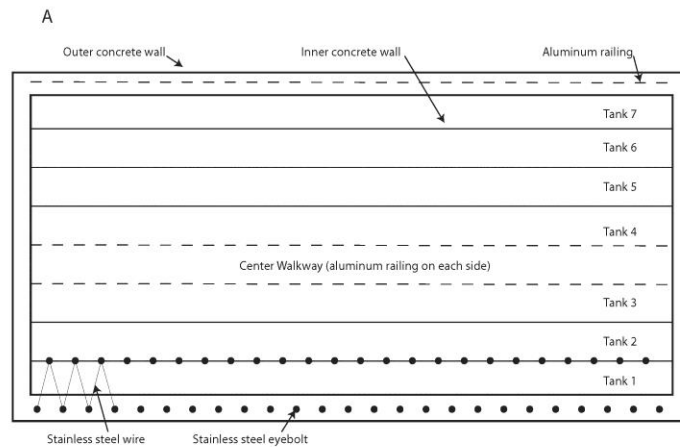
Figure 5.4. Approximate number of gulls seen in water treatment structures prior to, during, and after overhead wire installation at the Upper Blackstone Waste Water Treatment Facility. The category On Site refers to the number of gulls present at the treatment facility not in association with any water treatment structure
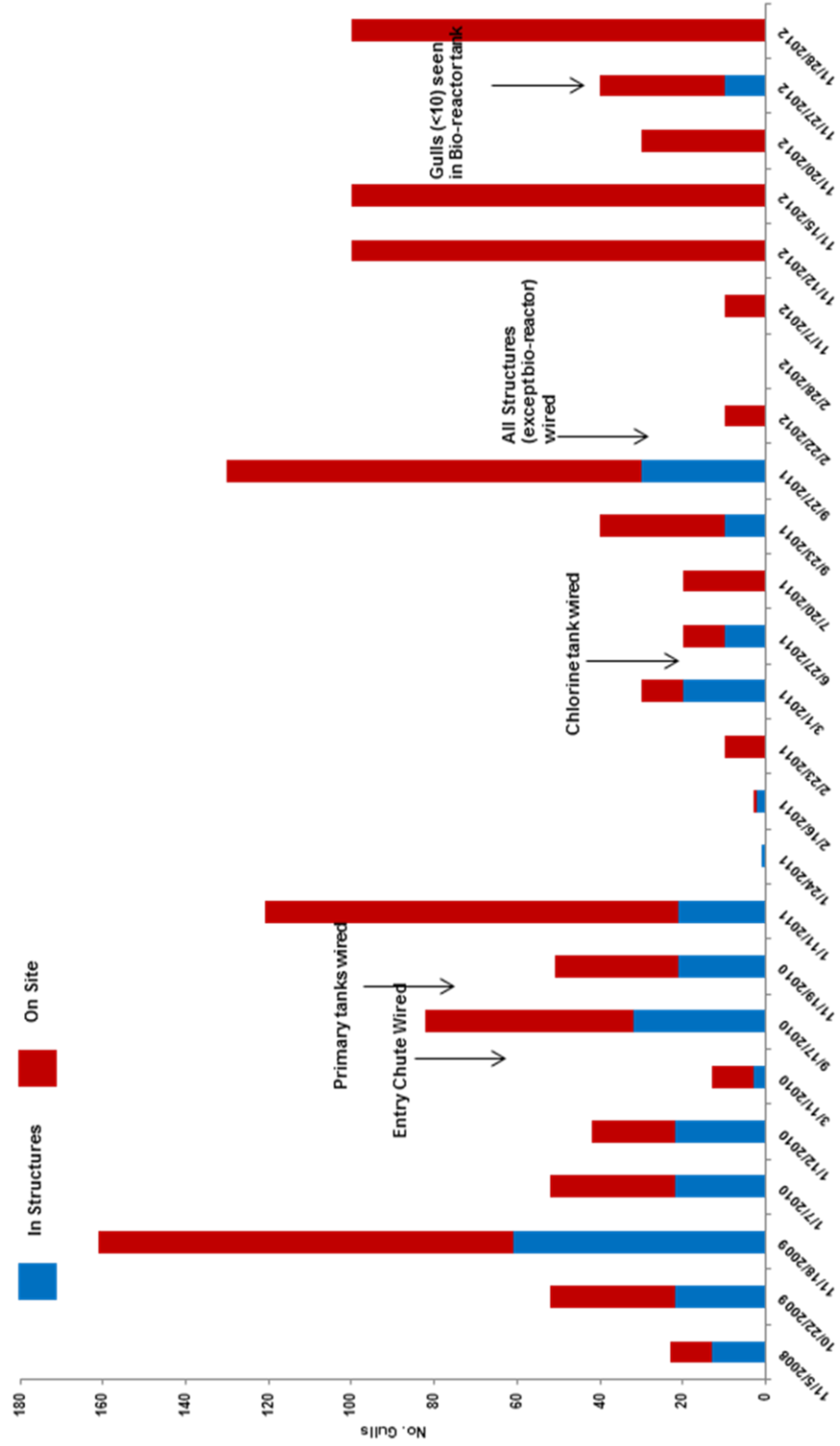
Figure 5.5. Mean (± SE) number of gulls seen in wired and unwired tanks and on site (at facility not in association with a treatment structure) at the Upper Blackstone Waste Water Treatment Plant, 2-22 October 2011.
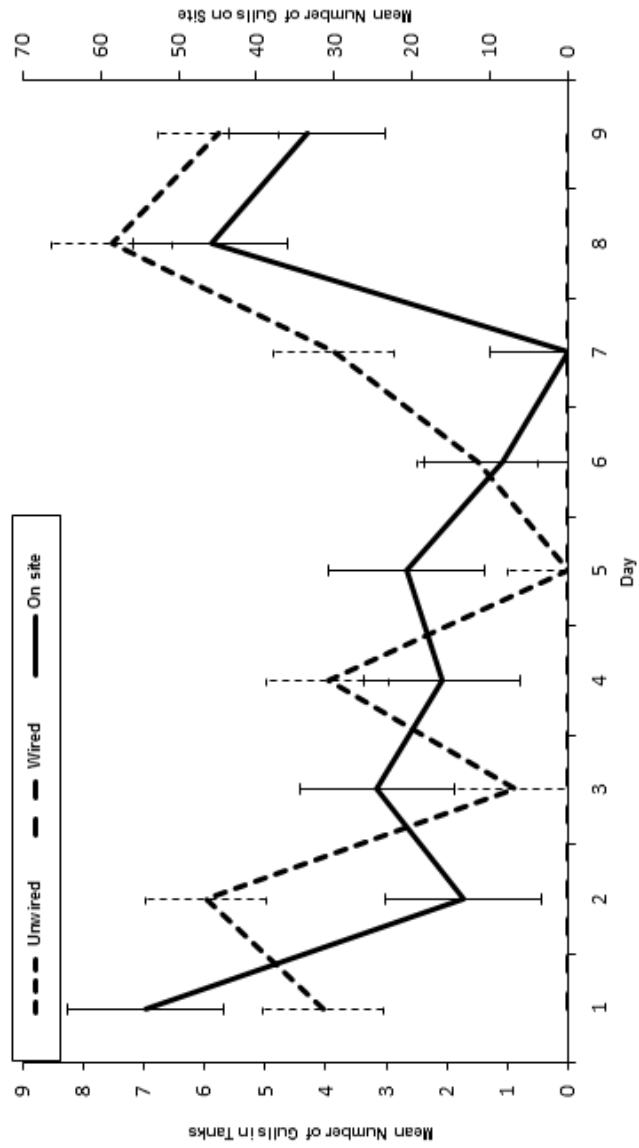
CHAPTER 6

A VERSATILE TECHNIQUE FOR CAPTURING URBAN GULLS

Abstract

Capturing birds is a common part of many avian studies but often requires large investments of time and resources. We developed a novel technique for capturing gulls during the non-breeding season using a net launcher that was effective and efficient. The technique can be used in a variety of habitats and situations, including urban areas. Using this technique, we captured 1,326 gulls in 125 capture events from 2008-2012. On average, 10 ring-billed gulls (*Larus delawarensis*) (range = 1-37) were captured per trapping event. Capture rate was influenced by the type of bait used and also the time of the year (highest in fall, lowest in winter). Our capture technique could be adapted to catch a variety of urban or suburban birds and mammals that are attracted to bait.

Introduction

In many avian studies, accomplishing specific objectives, such as collecting blood samples, taking biological measurements, attaching transmitters, or banding, requires the capture and handling of individual birds. A variety of techniques have been used to capture various species of gulls, including the Wilhelmshaven gull trap, canon nets, pull nets, or by hand (Horton et al. 1983, Bub 1991, Belant et al. 1998). In addition, walk-in or nest traps, drop-traps, funnel traps, or hand capture of flightless young are often used to capture gulls during the breeding season (Mills and Ryder 1979, Smith et al. 1992, Seamans et al. 2010, Alroy and Ellis 2011). However, while these techniques may prove effective in certain situations, they are limited in their versatility or efficiency. Various

components of pull nets typically need to be anchored to the ground, preventing their use on concrete, blacktop, or frozen soil (Hickling et al. 1989, Ferris and Bonner 2005). Canon or rocket nets can be dangerous and need large spaces to be deployed safely (Bub 1991). In addition, state or federal permits may be required to buy the charges or discharge the net (Prisock et al. 2012; J. Cardoza, pers. comm.). Walk-in, nest, or funnel traps are limited to situations where the breeding behavior of gulls confines them to specific locations, and gulls must be captured individually.

Capturing gulls during the non-breeding season can add additional challenges because gulls are not constrained to nesting colonies where trapping efforts can be focused. Wintering gulls can be found in a variety of habitats, may be wary of traps, and can roost in different locations on successive nights (Clark, pers. obs.). Furthermore, capture methods during the non-breeding season must be effective in a variety of extreme weather conditions, including cold and wind, and also allow for the quick and efficient removal of captured birds.

During the past few decades, more wildlife research is being conducted in urban and suburban environments, and gulls are common and important members of many of these ecological communities. Wildlife captures in urban or developed areas can be particularly challenging as public relations and public safety become critical considerations. Wildlife capture techniques in urbanized areas must consider the welfare of both the public and the wildlife resource while still trying to maximize efficiency and effectiveness.

We present a novel and versatile capture technique that can be used to catch non-breeding gulls in a variety of habitats, including urban and suburban areas. This method

was developed as part of an ecological study of suburban gulls during the non-breeding season. During our early attempts to capture gulls we used walk-in traps and a Steele's pull net with minimal success (Ferris 2005). We also used a rocket net on 2 occasions with some success but the logistics, supplies, and operation proved too limiting. Because of these difficulties, we developed a capture technique using a net launcher. While other studies have referenced using a net launcher to capture birds, none of these studies provided any specific information (Craighead and Bedrosian 2008, Prosser et al. 2009, Herring et al. 2010). We found no previous studies that detailed how to capture urban gulls during the non-breeding season.

Study Area

The ecological study of ring-billed (*Larus delawarensis*), herring (*Larus argentatus*), and great black-backed (*Larus marinus*) gulls took place in Massachusetts in Worcester, Suffolk, Franklin, Hampshire, and Hampden counties from 2008-2012. Forty-two trapping locations were used to capture gulls and were focused in urban or suburban areas around the cities of Worcester (42°15'N, 71°48'W), Boston (42°21'N, 71° 3'W), and Springfield (42° 6'N, 72°35'W), Massachusetts (Fig. 6.1).

Methods

Trapping Procedure – We used a Coda net launcher (Coda Enterprises, Mesa, AZ; use of trade names does not constitute an endorsement by the U. S. Government), which is powered by a blank 0.308 caliber cartridge, to capture gulls. The net launcher was classified as a tool and not a firearm by the United States Federal Bureau of Alcohol, Tobacco, Firearms and Explosives and therefore did not require any special permits to possess or use. The launcher (Model 86-6000) was 86-cm long, 45.5-cm wide, and 40-

cm high and weighed about 22 kg (Fig. 6.2A). A fiberglass basket was attached to the front of the launcher where a 6.7 m^2 net was placed. On the leading edge of the net, two 13-cm weights (300 g each) were attached to each corner of the net with 160-cm ropes. Two additional 13-cm weights were attached along the net's leading edge with 80-cm ropes so all four weights were evenly spaced. These weights were inserted into the four barrels of the launcher. On the opposite corners of the net, two drag weights (907 g each) were attached with 292-cm ropes. We attached a third 2.7 kg drag weight to the center of the net with a 226-cm rope. The launcher was triggered by an electronic detonator that was attached to the launcher with a 61-m wire; it could also be fired from >60 m using the radio controlled remote trigger. While a variety of mesh sizes can be used, we used a 7.6-cm mesh. The launcher cost $4,290 US.

For all captures, we used 1 of 2 set-ups. The majority of captures were done by placing the net launcher under the side of a 4-wheel drive pick-up truck (Fig. 6.2B). Upon arrival to the trapping site, the net launcher was placed on the ground (typically the pavement of a parking lot) just past the driver or passenger's side door of the truck and pushed partially under the truck so the ends of the four barrels were almost flush with the door but still allowed clearance for firing. When possible, the launcher was positioned so the sun and any wind were behind the launcher. This provided some solar concealment and helped reduce the chances that cross-winds would blow the net sideways. The two corner drag weights were anchored to the front and rear tire wells of the truck. The center drag weight was placed on the ground under the lip of the launcher's basket. The trigger wire was attached to the launcher and extended to reach into the cab of the truck. A cartridge (blue tip) was loaded in the chamber, and a pile of bait was placed 3 - 4.5-m

in front of the launcher. The launcher was detonated from inside the truck's cab. Total set-up time was <5 minutes.

In situations where a truck couldn't be used (i.e., reservoir shoreline) or when the gulls were wary of the truck set-up, we used an alternative set-up that was independent of the truck and people and could be adapted to a variety of situations. In this set-up, the launcher was placed directly on the ground and partially concealed or camouflaged. In natural settings, the launcher was placed near vegetation, under a bush, etc. (Fig. 6.3A). In urban settings, the launcher was placed next to existing structures (e.g., light poles), placed at the base of large snow piles, or set next to items commonly found in urban areas (e.g., shopping carts, trash cans, etc.) (Fig. 6.3B, C). The launcher was not completely concealed and could be seen. The two corner anchor ropes were secured to sandbags or attached directly to available items. The trigger wire was attached to the launcher and then unwound 15-30 m away from the launcher. The launcher was detonated by a single researcher standing about 30 m away. As in the other set-up, a large pile of bait was placed 3 - 4.5-m in front of the launcher. Total set-up time was <5 minutes.

Captured birds were secured in the net to prevent escape and socks were placed over their heads to keep them calm and prevent biting. Birds were removed from the net and placed in poultry cages to await processing. In most cases, a single bird could be removed from the net in less than a minute.

Analyses – To assess the efficiency of our capture method in various situations we recorded the number of birds captured per trapping event. A trapping event was defined as discharging the net launcher when at least one gull was feeding from the pile of bait. In addition, we recorded several categorical variables (location, season, and bait) that

may have influenced capture rate. Location included parking lot, waste water treatment plant, saltwater beach, field, and freshwater shorelines; seasons were early fall (September/October), fall (November/December), winter (January/February), and early spring (March/April); and bait used was bread, crackers, bread and crackers, bread and other (chips, popcorn, etc.), crackers and other, or French fries. Finally, we recorded temperature during the capture event as a continuous variable measured in degrees Celsius.

We tested the effect of trapping location, season, bait, and temperature on the capture rate using Generalized Linear Models with the AICcmodavg package in R 2.15.1 (Mazerolle 2012, R Development Core Team 2012). We modeled our capture data using the Poisson distribution. To test for overdispersion of the data, we calculated the variance inflation factor ($\hat{c}$) (Burnham and Anderson 2002). There was evidence of overdispersion ($\hat{c}$=3.97, 123 df), so the quasi-likelihood method, QAICc, was used (Anderson et al. 1994). The AICcmodavg package created model selection tables using the QAICc criterion for supplied models. The package also provided confidence sets for the best model. The importance weight for each of the four variables was also calculated to determine their relative importance in predicting capture rate (Burnham and Anderson 2002).

We determined *a priori* which models to include in analysis in order to reduce the number of potential models to those with some biological support and interest. Model selection was based on our own experience and judgment. We selected a set of 5 models, including the global model. We expected Temperature to be an important variable; lower temperatures would potentially increase the response of gulls to our bait pile

because of higher metabolic demands in colder weather. In addition, we felt the interactions between Temperature x Season and Temperature x Bait may also be important as changing temperatures may make bait types more or less attractive.

Results

From 2008-2012, we captured 1,326 gulls (1,193 ring-billed, 130 herring, and 3 great black-backed) in 125 capture events. Of the 1,193 ring-billed gulls, 748 were adults, 145 were sub-adults, and 300 were juveniles. Of the 130 herring gulls captured, 92 were adults, 9 were sub-adults, and 29 were juveniles. Two of the 3 great black-backed gulls captured were sub-adults, and the third was a juvenile. On average, 9.5 ring-billed (range = 1-37), 1.0 herring (range = 0-21), and 0.02 great black-backed gulls (range = 0-1) were captured per trapping event. Most trapping events occurred during fall (n = 57) and winter (n = 29), followed by early fall (n = 20) and early spring (n = 19). Most capture events took place in parking lots (n = 88), followed by freshwater shorelines (n = 18), waste water treatment plants (n = 11), saltwater shorelines (n = 5), and fields (n = 3).

The model containing Season+Bait best explained capture rate (Table 6.1). The Season+Bait model was 54 times more plausible to explain capture rate than the second best model, Season+Bait+Location. The variables Season and Bait were 100 times more likely to explain capture rate than Temperature. Capture rate (mean ± SE) was greatest during the Fall (11.12 ± 0.85, n = 57) and lowest during the Winter (9.9 ± 1.09, n = 29) (Table 6.2). While French fries by themselves yielded the largest capture rate (16.0), that bait type was only used once. For bait type used multiple times, capture rate was greatest

when Bread+Other (12.5 ± 1.4, n = 22) or Bread+Crackers (11.9 ± 1.0, n = 51) were used.

Discussion

Urban populations of some gull species have increased dramatically in the last 20 years and some continue to rise (Auman et al. 2008, Duhem et al. 2008, Weiser and Powell 2010). Increasing gull populations are usually associated with anthropogenic food subsidies as gulls have adapted to urbanized environments to exploit food sources such as landfills, garbage cans or dumpsters, or directly provisioned food at restaurants or parking lots (Belant 1997, Belant et al. 1998, Auman et al. 2008, D. Clark, unpub. data). As populations have increased, there is growing concern about the ecological or public health consequences of gulls in urbanized areas, including impacts to drinking or recreational water bodies (Fogarty et al. 2003, Nugent and Dillingham 2009). These concerns could lead to additional research focused on understanding the interactions between urbanized gulls and humans.

Wildlife research in urban and suburban settings can be challenging because of the density of people or increased public scrutiny. Urban capture techniques must consider public safety the top priority. In addition, the safe and efficient capture and handling of wildlife is also critical when the public is present and sensitive to animal welfare. Well developed and tested capture methods are needed so biologists can quickly accomplish their goals, avoid negative public interactions, and ensure the safety of the public and the target animal.

The net launcher capture technique was very successful and highly efficient at capturing gulls in a variety of urban and suburban locations during the non-breeding

season. There was strong evidence (w_i=0.98) for the selected model and the relative importance of Bait and Season; however, the models we chose explained very little of the variability in capture rate (Table 6.1, % Dev.). Other factors we did not consider most likely influenced capture rate. We did not record wind speed during trapping events but observed that gulls were much more wary and unsettled on days when there was a strong breeze and were less likely to settle on the bait pile in large numbers. Gull behavior was probably also important. Gulls that reacted quickly and aggressively to a bait pile triggered a competitive response from other gulls, typically resulting in more gulls feeding from the bait and being focused on feeding by intra-specific competition. In contrast, there were instances in which gulls exhibited a weak response to bait; in these cases, it is likely gulls had already been fed by the public at the capture site before our arrival. In general, early morning (peak hunger) attempts to capture gulls seemed to elicit a better response.

Injuries and mortality are risks associated with any type of trapping, but injuries from the net launcher were rare. Less than 10 (<1%) birds were injured in 125 trapping events and all injuries were related to gulls being struck by one of the net weights. Most injuries were broken wings and resulted in the gull being euthanized. Firing the net launcher when all birds were on the ground and focused on the bait pile minimized this risk.

The net launcher was relatively expensive compared to other traps or techniques; however, in our case, the initial investment was justified, given the effectiveness of the method. The cost for a single funnel trap or noose mat is about $66.00 and $155.00, respectively (Hall and Cavitt 2012), but these costs are for a single trap, and most studies

would require multiple traps. In addition to requiring multiple traps, many techniques require longer set-up times or trapping periods to catch adequate numbers. Heath and Frederick (2003) trapped white ibises (*Eudocimus albus*) using rocket nets and mist nets. They reported set-up times of 35 and 26 minutes, respectively, and reported trapping <2 ibises per day. The net launcher was extremely efficient at catching gulls. Almost all our trapping events were set up in <5 minutes, and in many cases, we captured birds within minutes of setting up. In addition, the net launcher was portable, could be carried and set up by a single researcher, and could be detonated remotely.

One other study described using the Coda net launcher to capture birds but with different results. Prisock et al. (2012) reported catching 137 birds in 23 capture attempts using the Coda net launcher, but none of the target species were gulls. In their study, they used 3 different net sizes, all of which were larger than our net. When using a net size comparable to ours (6-m x 9-m), Prisock et al. (2012) reported capturing one Canada goose (*Branta canadensis*) in 5 capture attempts, while 36 geese, a white ibis, and a great blue heron (*Ardea herodias*) escaped. In addition, they reported pre-baiting trapping stations for >2 days to acclimate the birds to the net launcher. It is likely subtle differences in capture technique or target species contributed to the different capture rates. It was unclear how Prisock et al. (2012) anchored their net, but we found that securing the two anchor weights to unmovable objects and attaching a third center drag weight caused the net to drop quickly over the baited birds, increasing both the likelihood of catching birds and also the number caught. We never pre-baited our capture sites but instead were able to take advantage of the natural tendency for gulls to respond quickly to bait.

Our technique could be applied to other birds or even mammals that are attracted to bait. We incidentally captured American crows (*Corvus brachyrhynchos*), mallards (*Anas platyrhynchos*), and rock doves (*Columba livia*) and could have captured Canada geese. The net launcher can be safely used in highly urbanized areas with people present. We found most people were not disturbed when the launcher was fired, and very few people reacted to our presence. Based on these findings, the net launcher is an important tool that can be used to capture a variety of avian species, allowing researchers to efficiently use their time and resources.

Management Implications

Wildlife research involving the capture of individual animals is often a balance between the time and effort spent during capture and the need to ensure an adequate representative sample size. Time spent locating and capturing birds can be greatly enhanced when researchers utilize existing methods and techniques. However, techniques must be adequately described and available before they can be readily used or adapted.

While a variety of studies have referenced using a CODA net launcher to capture a diversity of birds, these studies did not provide any specific information or references on exactly how birds were captured. Readers were left with the implied belief that the technique used to capture the birds was widely known and easily applied. We believe our study gives researchers the advantage of understanding, using, or adapting a tested method for capturing gulls (or other birds) during the non-breeding season in urban and suburban settings (among other locations). We feel the detailed methods provided here

will prove useful in a variety of situations and provide readily accessible instructions on how a net launcher can be set up and used to efficiently capture birds.

Table 6.1. Results of generalized linear models testing the effects of season, bait, location, and temperature (°C) on capture rate of gulls. The best model is in bold.

Model[a]	Log-likelihood	K[b]	$QAIC_c$[c]	$\Delta QAIC_c$	Weight(ω_i)	% Dev[d]
Season+Bait	**-473.98**	**10**	**260.71**	**0.00**	**0.98**	**2.77**
Season+Bait+Location	-470.16	14	268.67	7.96	0.02	4.43
Season+Bait+Location+Temp	-469.89	15	271.12	10.41	0.01	4.55
Season×Temp+Bait+Location	-460.71	18	274.55	13.84	0.00	8.55
Bait×Temp+Season+Location	-458.13	19	276.03	15.32	0.00	9.67

[a] Season: Early Fall (September-October), Fall (November-December), Winter (January-February), Early Spring (March-April); Bait: Bread, Bread+Other, Crackers, Crackers+Other, French fries; Location: Parking lots, Fresh water, Fields, Waste water plants, Salt water.

[b] Parameter includes intercept and ĉ.

[c] Values based on the inflation factor of the global model (ĉ=3.97).

Table 6.2. Average (±SE, n) number of gulls captured per trapping event by season (Early Fall: September-October, Fall: November-December, Winter: January-February, Early Spring: March-April) and bait type in Massachusetts, 2008-2012.

Bait	Season (N)				
	Early Fall (20)	Fall (57)	Winter (29)	Early Spring (19)	Total
Bread, Cracker	8.4 (2.5, 5)	11.3 (1.2, 24)	10.3 (2.0, 13)	11.9 (3.6, 9)	10.9 (1.0, 51)
Bread, Other[a]	10.7 (3.4, 3)	10.8 (1.7, 17)	12.5 (2.5, 2)	-	10.9 (1.4, 22)
Cracker	10.9 (1.4, 10)	11.7 (2.3, 7)	9.8 (2.2, 8)	11.6 (1.4, 5)	10.9 (0.9, 30)
Cracker, Other	9.0 (-, 1)	11.5 (0.5, 2)	8.5 (1.0, 4)	7.7 (3.2, 3)	8.9 (1.0, 10)
Bread	-	10.6 (3.2, 7)	8.0 (3.0, 2)	4.5 (2.5, 2)	9.0 (2.2, 11)
French Fries	16.0 (-, 1)	-	-	-	16.0 (-, 1)
Total	10.4 (1.1)	11.1 (0.84)	9.9 (1.1)	10.4 (1.8)	

[a] Other could include popcorn, suet, French fries, potato chips, or dog food.

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Figure 6.1. Locations (■ Field; ● Fresh water; ▲Parking lot; ☐ Salt water; + Water treatment plant) used to capture gulls in Massachusetts, 2008-2012.
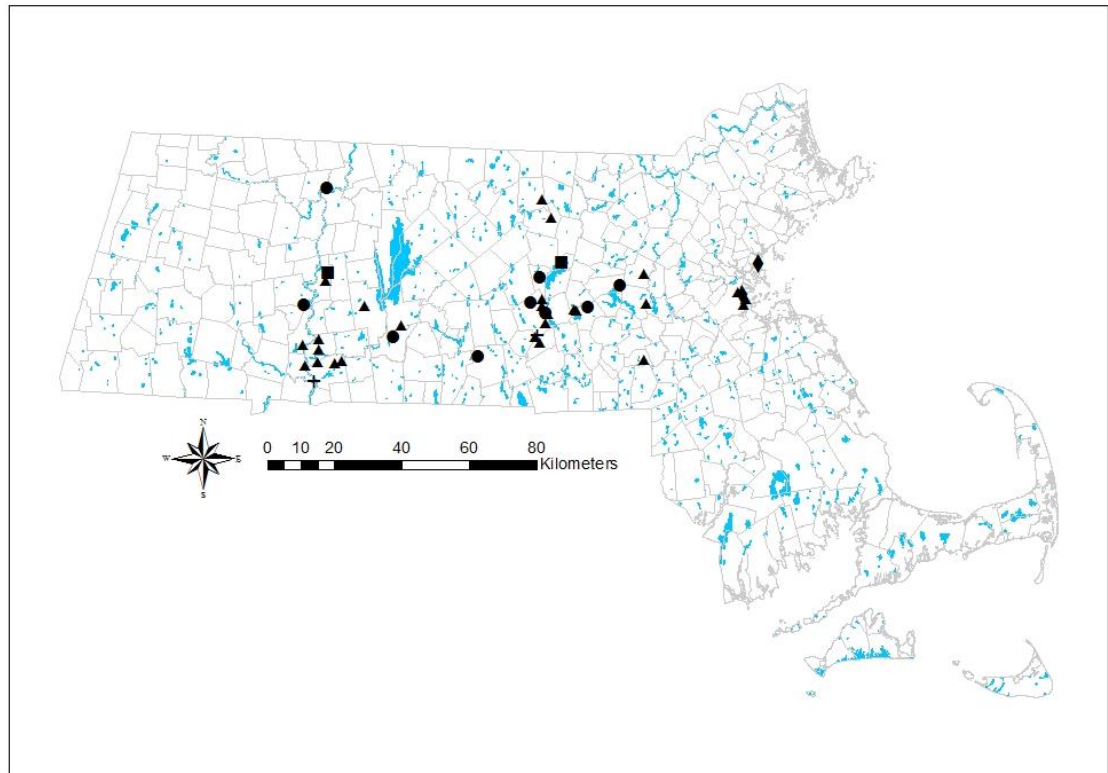
Figure 6.2. A. The Coda net launcher. B: A typical capture set-up in an urban

parking lot. The net launcher was placed under the side of the truck and a pile of

bait was placed in front. The launcher was detonated from inside the truck cab.

Figure 6.3. A: Capture set-up along a reservoir shoreline. The net launcher was placed near a bush and partially concealed. B: Capture set-up at a waste water treatment plant. The net launcher was placed under a guardrail. C: Photo of net launcher being launched.

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