EXCLUSION OF GULLS FROM RECREATIONAL BEACHES USING BORDER COLLIES AND MONITORING GULL HABITAT USE RELATIVE TO HUMAN INFRASTRUCTURE

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This is dedicated to my mother for her continued support throughout all of my endeavors and also to Ron Decker and all the teachers who cultivated my love for science over the years.

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BORDER COLLIES AS A MANAGEMENT TOOL FOR GULL EXCLUSION ON GREAT LAKES RECREATIONAL BEACHES

ABSTRACT

Recreational use of the Great Lakes is a vital component to the economies of coastal communities. Species of native gulls have increasingly become inhabitants of Great Lakes beaches and as a result, a growing problem. Of these species, the Ring-Billed Gull (*Larus delawarensis*) has shown a dramatic increase in numbers in the Great Lakes region, estimated at 10% per year since the early 1970's. With this observed increase in gulls over the past several decades a rise in gull-human interactions has also increased, which in turn leads to general nuisance issues as well as human health and safety issues. Ring-billed Gull feces have been found to carry bacteria such as *Escherichia coli, Salmonella* spp., and *Campylobacter* spp., which may contribute to the contamination of recreational waters. Trained working dogs have demonstrated their potential as a non-lethal management tool in human-wildlife conflicts concerning livestock depredation and disease transmission. Border collies were used to harass and exclude gulls from public beaches to investigate 1) the efficiency of this method and 2) a reduction in *E. coli* levels in beach sand and water. Using a cross-over, experimental design, we monitored and hazed gulls at four Lake Michigan beaches during summer 2012 and 2013. With the application of border collies, we found relative abundance of gulls was lower on dog-treated beaches ($W = 10$, $P = 0.06$) during treatment periods.

KEY WORDS dogs, gulls, beaches, exclusion, *E. coli*, wildlife damage management, non-lethal control, Michigan

INTRODUCTION

Recreational use of the Great Lakes is a substantial component to the economies of coastal communities (Vaccaro et al. 2009, Song et al. 2010). The summer season draws large numbers of people to recreational beaches for swimming, sun-bathing and other water related activities. This generates revenue for local businesses as well as permit sales for county and state agencies. Over time, species of native gulls have shown an increasing presence at Great Lakes beaches, and as a result growing human-wildlife conflicts have arisen.

The Ring-Billed Gull (*Larus delawarensis*) has shown a dramatic increase in numbers in the Great Lakes region, estimated at 10% per year since the early 1970's (Solman 1994). After disappearing nearly entirely from the Great Lakes by the early 1900's, Ring-Billed Gulls returned to about 27,000 nesting pairs in Lake Michigan and Lake Huron by 1960 and by the mid-1980's had reached over 700,000 nesting pairs (Figure 1) (Blokpoel and Tessier 1986; Greenlaw and Sheehan 2003; Norwood 2011). Ring-Billed Gulls are classified as a migratory bird species and are thus protected by federal law under the Migratory Bird Treaty Act of 1918. This has aided them in the largest breeding population increase of any waterbird in the Great Lakes region, as well as establishing them as the most abundant (Solman 1994; Morris et al. 2011; Norwood 2011).

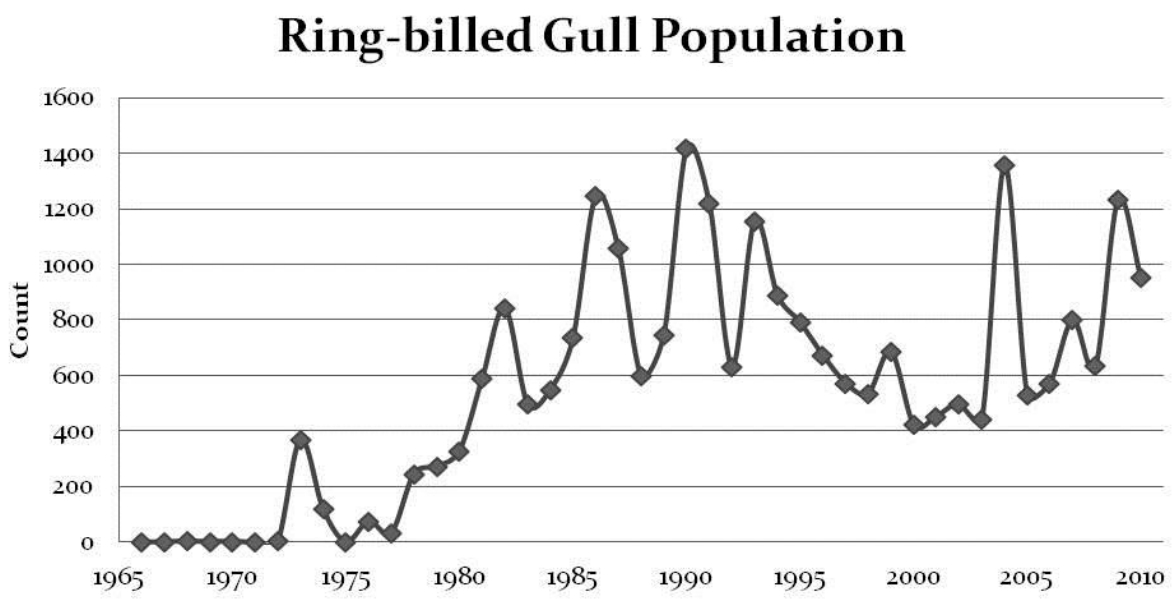

Figure 1. Ring-Billed Gull population trend as recorded in the USGS Michigan Breeding Bird Survey.

With this increase in gulls over the past several decades comes a rise in gull-human interactions and conflicts, which in turn leads to general nuisance issues as well as potential human health and safety concerns (Hartmann et al. 2009). These effects can be most readily observed at recreational beaches where high numbers of gulls and people are found together. Gulls are generally not very aesthetically pleasing and their frequent defecation can lead to property damage, reduced recreational enjoyment and even health risks due to accumulation of fecal matter (Hartmann et al. 2009). Ring-Billed Gull fecal matter has been found to carry bacteria such as *Escherichia coli (E. coli)*, *Salmonella* spp., and *Campylobacter* spp., which may contribute to the contamination of recreational waters (Lévesque et al. 2000). The potential human health hazards posed by recreating at contaminated beaches can lead to swim bans and beach closings. These closings have the potential to result in significant economic losses to Great Lakes coastal communities. Rabinovici et al. (2004) estimated a Lake Michigan beach closing could lead to a net economic loss of up to $35,000 per day. Song et al. (2010) estimated a

seasonal closure in one beach site may result in an economic loss of $130,000 to $24 million, while closing all Lake Michigan sites could be as high as $1 billion. This further illustrates the substantial economic importance of the Great Lakes public beaches.

Implementing a gull deterrent that effectively reduces the number of gulls using a beach may mitigate health hazards and potential economic loss associated with beach closings. There are many lethal and non-lethal methods proposed for deterring gulls. Lethal methods include removal of individuals through active culling, as well as egg oiling techniques that prevent the hatching and survival of offspring. Reiter et al. (1999) found that the U.S. public favors non-lethal management methods, compared to lethal control, when dealing with wildlife-human conflicts. Non-lethal methods to deter nuisance bird species include harassment and exclusion techniques. Harassment methods use noise making devices (e.g., propane cannons, air horns, sirens and pyrotechnics) and repellents (e.g., lasers and strobe lights; Blackwell et al. 2002, Gilsdorf et al. 2002). Exclusion techniques include using overhead monofilament wire fencing, scarecrows and chemical repellents (Blokpoel and Tessier 1984, Gilsdorf et al. 2002). However most of these methods are not feasible, or are otherwise undesirable on a public beach.

Properly raised and trained dogs have already proven to be an effective non-lethal management tool in human-wildlife conflicts concerning livestock depredation and disease transmission (Andelt 1992; Vercauteren et al. 2008, 2014; Gehring et al. 2010*a, b*). Conflicts caused by Canada Geese (*Branta canadensis*) on golf courses and airport runways have been safely alleviated using dogs as a harassment tool (Castelli and Sleggs 2000). Burger et al. (2007) found disturbances in the form of cars, planes, people and dogs had effects on gull and other shorebird behavior at beaches, but did not examine continuous exposure to these disturbances. In addition to being a highly intelligent species of dog, border collies possess an excellent herding

instinct. This behavior is important for wildlife harassment as it encourages the dog to chase and displace animals without attacking or harming them (Koski and Kinzelman 2010). Koski and Kinzelman (2010) used border collies for waterfowl and gull harassment on beaches, but noted that continuous treatment was necessary to maintain desired exclusion levels. Dorfman and Rosselot (2011) suggested border collies were effective tools for improving beach quality at one beach in Chicago, IL; however, this effectiveness was not quantified. Border collies have been used in recent years for gull harassment on Chicago beaches with mixed success, often reducing gull numbers, but seeing gull numbers increase shortly following canid harassment (Hartman et al. 2009, 2012). Converse et al. (2012) conducted a study in Racine, WI which indicated up to a 98% reduction in gull visitation at beaches using border collies for canid harassment.

While dogs have proven themselves as useful tools in reducing wildlife conflicts, the effectiveness of dogs for avian exclusion has not been well documented. The amount of published experimental data specifically pertaining to dogs for avian management is very limited. More research is required to establish the effectiveness of dogs as an efficient, non-lethal management tool for human-avian conflicts. The goal of this study was to evaluate the effectiveness of trained border collies as a tool for gull removal on recreational beaches. Varying intensities of exclusion efforts were explored in order to further determine the minimum effective application of canid harassment. The reduction of beach *E. coli*, and therefore an increase in beach quality, was the desired result of gull exclusion efforts.

METHODS

Study Area

Beach sites used in this study were located along Lake Michigan in Ottawa County of Michigan's western Lower Peninsula (Figure 2).

Figure 2. Beach sites used throughout 2012 and 2013 study years. A: North Beach Park, B: Grand Haven Beach Association, C: Izzo's Private Beach, D: Grand Haven City Beach, E: Rosy Mound Park Beach, F: Kirk Park Beach.

Ottawa County features approximately 40 km of Lake Michigan coastline with numerous state, county and township park beaches dotted along the shore. Beach sites used included a mixture of public and private properties across two sampling years during summer 2012 and summer 2013. Four sites were used during each field season. Potential sites were selected based on availability and being at least 500 m away from other sites. Public beach sites consisted of properties owned and operated by the Ottawa County Parks and Recreation Commission with the exception of the Grand Haven City Beach, which is owned and operated by the city of Grand Haven. State Park properties were not used as they would not allow dogs on beach areas or off leash at any time,

which may limit the areas for application of this method. The 2012 summer field season sites included North Beach County Park (560688 E, 4770277 N, 16 T), Grand Haven Beach Association (560862 E, 4769379 N, 16 T), Rosy Mound County Park (562453 E, 4763267 N, 16 T) and Kirk County Park (563687 E, 4755172 N, 16 T). The 2013 sites included North Beach County Park (560688 E, 4770277 N, 16 T), Izzo's private beach (560924 E, 4769049 N, 16 T), Grand Haven City Beach (561443 E, 4766754 N, 16 T) and Kirk County Park (563687 E, 4755172 N, 16 T).

Study Design

Beach sites were 200 m in width and had to be a minimum of 500 m away from another beach site in order to minimize any effects from adjacent beaches. Distances between beaches ranged from approximately 750 m to 15,300 m apart. Distances between beach boundaries were determined using a combination of satellite imagery and handheld GPS receivers. Sites were grouped into adjacent pairs with one beach arbitrarily assigned a control and the other defined as a treatment. Each field season began in mid-May and ended mid-August for roughly a 3-month sampling period. Field seasons were separated into two trial periods that consisted of 38 days each with a 10 day rest period in between trials. Upon the completion of trial period one a cross-over design was used where all control beaches became treatment beaches and vice versa (Figure 3; Vercauteren et al. 2008).

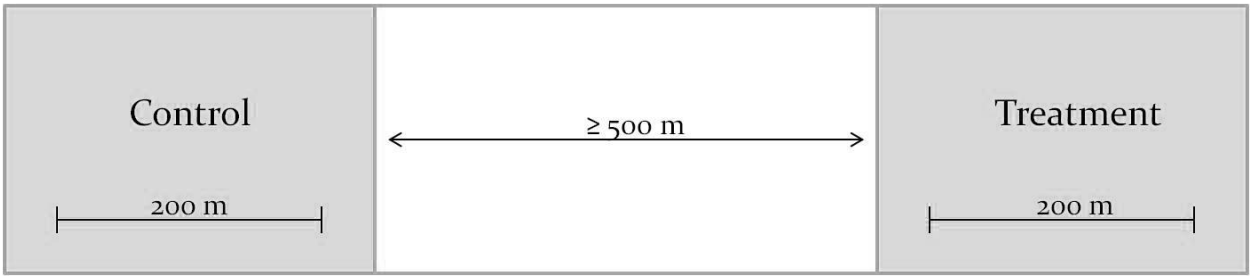

Figure 3. Study design including beach size, pairing and distance from other sites. A crossover design switched treatment and control beaches during separate trial periods.

This design was used due to having only two dogs available each field season and to eliminate bias that may have resulted from differences in terrain or gull visitation between beaches. Using this method each field season produced four control beaches and four treatments beaches. Gull counts were conducted on all beaches throughout all trial periods. During 2012 beaches were monitored seven days per week from 8am to 6pm. The intensity of treatments was reduced from 10 h to eight h for the second field season. The reduction of intensity better highlighted the efficiency of the dogs relative to time spent on beaches. This also allowed for targeting times of the day when dogs could be most effective at excluding gulls while avoiding any conflict with beach visitors as well as a better use of personnel resources. During the 2013 season beaches were monitored five days per week for four h following sunrise and four h prior to sunset. All observation sessions consisted of gull counts at 15-min intervals. Only gulls physically on the beach were counted; this did not include gulls offshore, sitting on swim buoys or flying over the beach during count intervals.

All count data was compiled in a Microsoft® Excel (Microsoft, Redmond, WA) database for data manipulation. Statistical analyses were performed using program R-2.14.1 (R Foundation for Statistical Computing, Vienna, Austria). I converted gull counts to an index (i.e., total gulls per unit effort) by totaling gull counts over an entire 38 day trial period and dividing by number of 15-min count intervals that occurred on the beach over that period of time. I used Wilcoxon signed-rank tests to compare gull use on dog-treated beaches to control beaches without gull harassment. An alpha value of 0.10 was used to determine statistical significance; with only two dogs and limited treatment periods this helped ensure the detection of effects the dog may have had on gull numbers, in light of any stochasticity in dog performance. Wilcoxon

signed-rank tests were also used to compare the reduction in beach *E. coli* levels as a result of gull exclusion.

Four different border collies were leased (Fly Away Farm & Kennels, Chadbourn, NC) for gull harassment, two during each field season. All dogs were female and ranged in age from 18 months to seven yrs. Dogs used were bred from herding stock and trained specifically for avian harassment, most often having worked excluding geese from military airbase runways. Costs for leasing two border collies were $500 per dog, per month, or $3,000 per field season. This included delivery of the dogs and handler training. For the 2013 season an additional delivery fee of $750 per dog was added. These figures do not include miscellaneous costs such as dog food, leashes, harnesses, transportation crates, veterinary care, etc. All dogs were delivered with instruction manuals and handlers received hands-on training from Fly Away Farm & Kennels employees prior to starting treatment periods. Dog feces on beach sites resulting from the border collies were immediately picked up, bagged, and disposed of in waste receptacles by the dog handler. Dogs were deployed on treatment beaches for gull harassment accompanied at all times by a dog handler. Control beaches had no gull harassment, but were still monitored by an observer. My research was approved by the Institutional Animal Care and Use Committee at Central Michigan University (IACUC #12-14).

RESULTS

Gull Counts

The 2012 sampling season saw a high of 8,163 gulls counted on North Beach Park and a low of 722 gulls observed on Rosy Mound Park throughout the four 38 day control sampling periods. Over the four 38 day treatment periods a high of 5,241 gulls were counted on North Beach Park and a low of 56 gulls observed on Grand Haven Beach Association. After the 2012

field season higher gull numbers were observed during the morning and evening hours when compared to mid-day hours (Figure 4**)**. This prompted the shift and reduction in treatment intensity for the 2013 season in order to better target gulls for exclusion. During the 2013 season total gull counts ranged from 13,680 observed on North Beach Park to 2,423 on Grand Haven City Beach throughout 38 day control periods. The 38 day treatment periods saw a high of 1,161 gulls on Izzo Beach and a low of 11 gulls on Kirk Park.

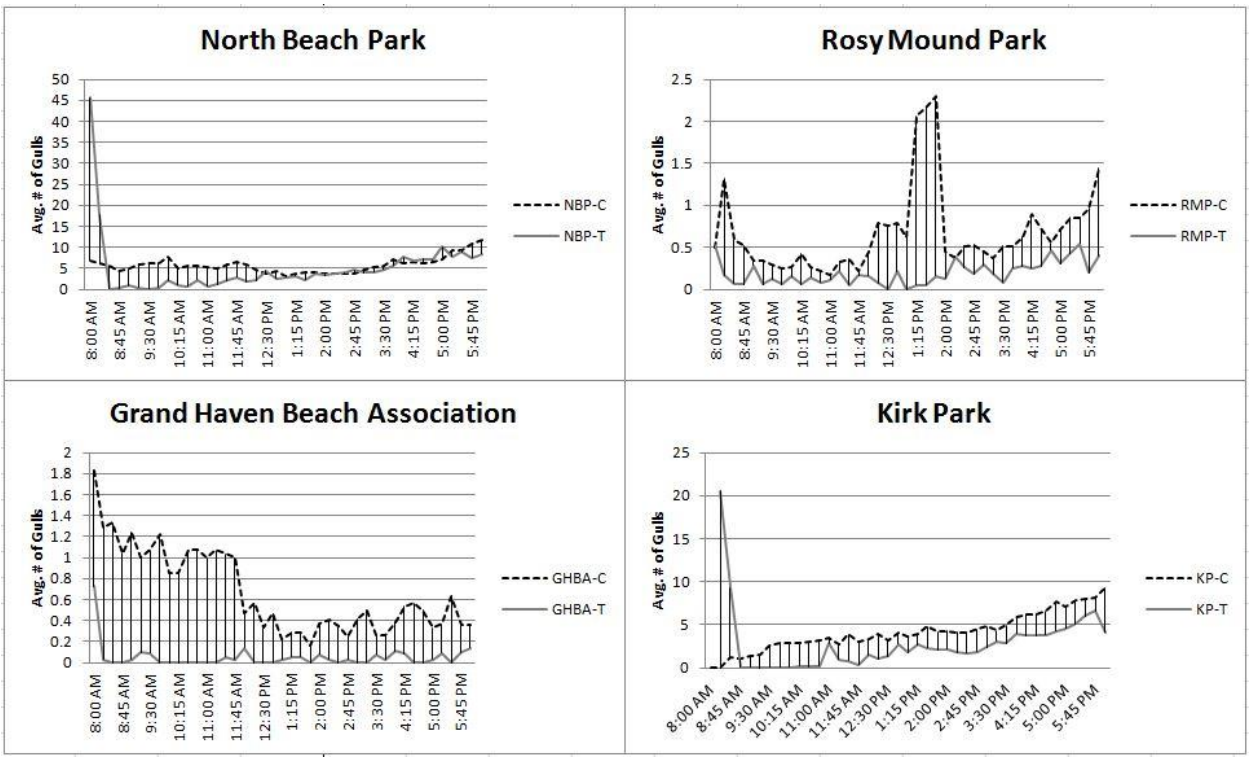

Figure 4. Average number of gulls on beaches during each count interval throughout summer 2012. Solid: Treatment, Dashed: Control.

Dog Effectiveness

During 2012 control sites North Beach Park, Grand Haven Beach Association, Rosy Mound Park and Kirk Park had 5.90, 0.70, 0.70 and 4.57 gulls per unit effort, respectively. During the treatment trial period North Beach Park, Grand Haven Beach Association, Rosy Mound Park and Kirk Park had gulls per unit effort values of 5.14, 0.04, 0.22 and 2.46

respectively (Figure 5). Percent reduction in gulls per unit effort as a result of harassment efforts ranged from 13% (North Beach Park) to 94% (Grand Haven Beach Association). Fewer gulls were present on dog-treated beaches compared to control beaches (W = 10, P = 0.062).

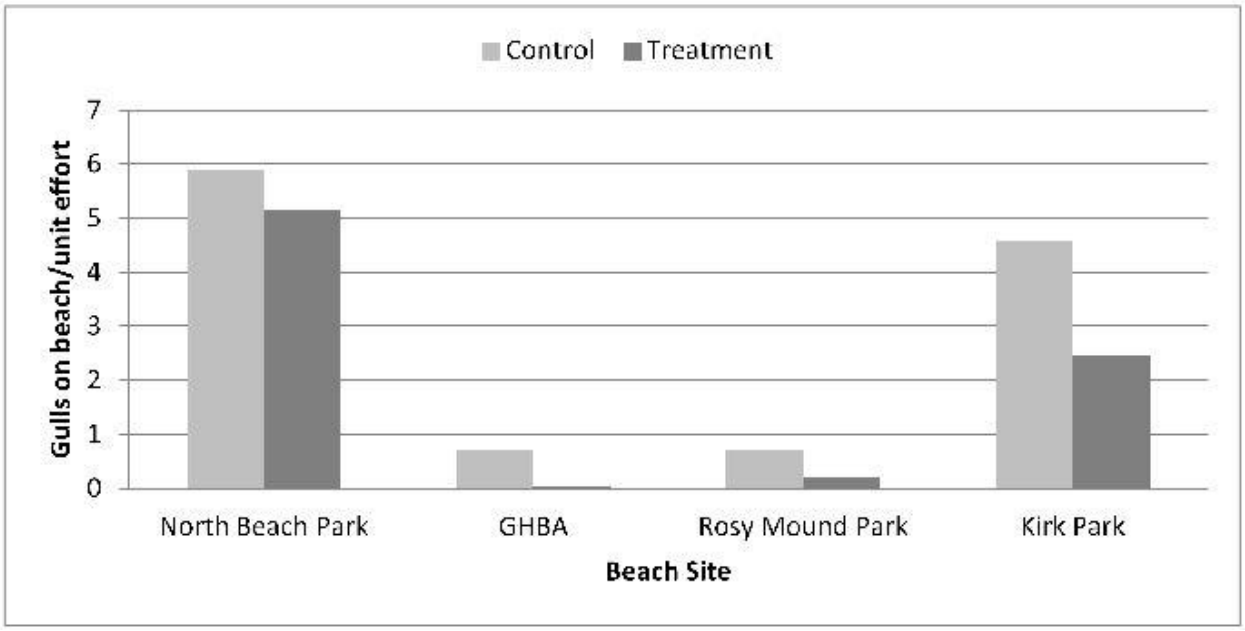

Figure 5. Gulls counted on beaches per unit effort during summer 2012.

The 2013 field season continued to show a reduction in gull numbers between control and treatment trial periods. During control trials, North Beach Park, Grand Haven City Beach, Izzo's Beach and Kirk Park had gulls per unit effort numbers of 49.97, 4.95, 4.21 and 22.13, respectively. When dogs harassed gulls on these beaches, gull abundance declined to 1.02, 2.70, 1.57 and 0.04 for North Beach Park, Grand Haven City Beach, Izzo's Beach and Kirk Park, respectively (Figure 6). Percent reduction in gulls from control beaches to dog treatment beaches ranged from 45% to 99%. The number of gulls on dog-treatment beaches was lower than those on control beaches (W = 10, P = 0.062).

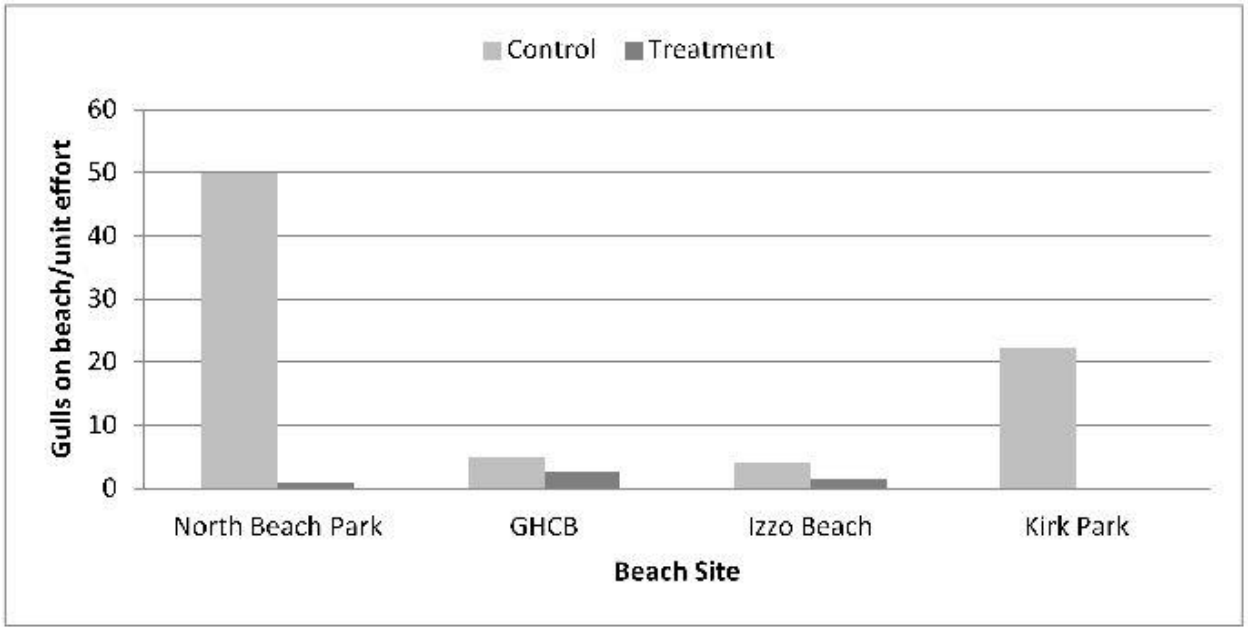

Figure 6. Gulls counted on beaches per unit effort during summer 2013.

During the first half of summer field seasons the exclusion of gulls using border collies resulted in a reduction of *E. coli* counts observed in sand when compared to control beaches (Control median = 146.5, n = 22; Treatment median = 43.9, n = 24; W = 661.5, P = 0.002). Following the cross-over of dogs however, the reduction in *E. coli* counts did not hold on treatment vs. control beaches (Control median = 334.5, n = 24; Treatment median = 672.1, n = 26; W = 743.5, P = 0.120). The cost of operations for achieving a reduction in *E. coli* during early summer months and an overall reduction in gull numbers was $3,000 for dog leasing ($1,500/dog), approximately $500 in dog equipment, food and medical care, and labor for dog handlers at $8-10/hour. For one summer of continuous gull exclusion on one beach the total cost would be approximately $6,750 to $8,150, depending on labor costs. Continuous gull exclusion on a beach throughout an entire summer season was not tested in this study; therefore *E. coli* counts during the second half of the summer during continuous treatment could vary. It is likely

that while continued *E. coli* loading by gulls would be minimal, *E. coli* already in the sand would continue growing and reproducing.

DISCUSSION

Few studies have been done to address the effects of dogs on gull exclusion at recreational beaches. Converse et al. (2012) conducted a study that focused on the improvement of water quality, as indicated by *E. coli* reductions, in response to bird harassment using dogs. They found that one week of canid harassment resulted in a 98% reduction ($P < 0.001$) in average bird numbers, of which 94-99% were gulls. As a result of a 50% gull population reduction they saw a 29% decrease in *E. coli* counts (Converse et al. 2012). While theirs is currently the only study focusing on gull harassment using dogs and resulting *E. coli* reductions, it focuses more on water quality improvement and very little is mentioned on the effectiveness of dogs for gull removal.

In the current study border collies have proven to be an effective tool for managing gulls on public beaches with a reduction in gull numbers of up to 94% in the first year and 99% during the second. The reduction in gulls may vary depending on beach characteristics, human gull encouragement and individual dog effectiveness. During the 2013 field season gull numbers were reduced 5% further while employing a less intense harassment effort. Border collies can be efficient at gull removal following a regular eight h/day harassment schedule and targeting gulls during peak times at early morning and late evening hours. While gull numbers were greatly reduced in the presence of a dog providing active harassment, it is unclear what the response of gulls would be immediately after a dog leaves the beach. Some sources indicate that gull numbers quickly return to previous levels after harassment from border collies (Hartman et al. 2009, 2012; Koski and Kinzelman 2010).

When considering border collies as a management tool for gulls it is important to weigh the costs and benefits of implementing such a program. While effective, leasing or purchasing border collies can be expensive along with the costs of properly housing and caring for the dog. The costs of hiring a handler to work with the dog at all times must also be considered. With this in mind managers should first determine the severity of their gull problem and decide if there are cheaper removal or harassment methods available. If there are a large number of persistent gulls on the property it may be necessary to employ dogs for harassment purposes.

Throughout both years of the study people were often observed feeding gulls despite signs posted stating "do not feed seagulls." Feeding a gull results in immediate increases in gull numbers, as one gull at a food source quickly attracts many more. It is highly recommended that beach managers adopt a more serious approach to preventing gull feeding on their beaches. Providing adequate means for beach goers to dispose of trash and food, as well as further education and informational signs on the impacts of gulls on beach quality, and the effects of feeding gulls, may help to reduce these behaviors at beaches, and in turn, gull presence.

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CHAPTER II

GULL HABITAT SELECTION RELATIVE TO HUMAN INFRASTRUCTURE

ABSTRACT

Recreational use of the Great Lakes is a vital component to the economies of coastal communities. Species of native gulls have increasingly become inhabitants of Great Lakes beaches and as a result, a growing problem. Of these species, the Ring-billed Gull (*Larus delawarensis*) has shown a dramatic increase in numbers in the Great Lakes region, estimated at 10% per year since the early 1970's. With this observed increase in gulls over the past several decades a rise in gull-human interactions has also increased; which in turn leads to general nuisance issues as well as human health and safety issues. Ring-billed Gull feces have been found to carry bacteria such as *Escherichia coli, Salmonella* spp., and *Campylobacter* spp., which may contribute to the contamination of recreational waters. It is known that gulls utilize human infrastructure (e.g. landfills), however it is uncertain how this relates to gulls on recreational beaches. During summer 2013, 31 gulls were captured on beaches and outfitted with radio transmitters to track movement patterns and land cover use in relation to human infrastructure via radio telemetry. Of these, 20 individuals were relocated for a total of 131 locations. A chi-square analysis indicated that gulls were selecting for beach and landfill habitats ($\chi^2 = 2616.6$, $P = <0.001$).

KEY WORDS gulls, habitat selection, beaches, landfills, radio telemetry, Great Lakes, Michigan

INTRODUCTION

Ring-Billed Gulls (*Larus delawarensis*) have shown a dramatic increase in numbers in the Great Lakes region, estimated at 10% per year since the early 1970's (Solman 1994). After

disappearing nearly entirely from the Great Lakes by the early 1900's, Ring-Billed Gulls returned to about 27,000 nesting pairs in Lake Michigan and Lake Huron by 1960 and by the mid-1980's had reached over 700,000 nesting pairs (Figure 1) (Blokpoel and Tessier 1986, Greenlaw and Sheehan 2003, Norwood 2011). Ring-billed gulls are classified as a migratory bird species and are thus protected by federal law under the Migratory Bird Treaty Act of 1918. This has aided them in the largest breeding population increase of any waterbird in the Great Lakes region, as well as establishing them as the most abundant (Solman 1994, Morris et al. 2011, Norwood 2011).

In addition to their federal protection status, the increase in Ring-Billed gull numbers may be attributed to number of anthropogenic factors. Gulls have been known to readily take advantage of human infrastructure such as parking lots, landfills and waste water treatment plants where food resources, loafing areas and nesting habitat may be abundant (Belant et al. 1998, Massachusetts Department of Conservation and Recreation 2010, Caron-Beaudoin et al. 2013, Washburn et al. 2013). Studies that have looked at gull habitat use have primarily been interested in foraging behavior relative to anthropogenic habitats (Caron-Beaudoin et al. 2013; Washburn et al. 2013). Washburn et al. (2013) is one of the only studies to have looked at gull habitat use at the coastal-urban interface, however this was done using dietary analysis only and no tracking methods. Despite the large amount of coastal-urban areas within the Great Lakes Region, no studies have been done observing gull movement and habitat selection in relation to human infrastructure.

With the increase in gulls over the past several decades comes a rise in gull-human interactions and conflicts, which in turn leads to general nuisance issues as well as potential human health and safety concerns (Hartmann et al. 2009). These effects can be most readily

observed at recreational beaches where high numbers of gulls and people are found together. Gulls are generally not very aesthetically pleasing and their frequent defecation can lead to property damage, reduced recreational enjoyment and even health risks due to accumulation of fecal matter (Hartmann et al. 2009). Ring-billed Gull fecal matter has been found to carry bacteria such as *Escherichia coli (E. coli)*, *Salmonella* spp., and *Campylobacter* spp., which may contribute to the contamination of recreational waters (Lévesque et al. 2000). The potential human health hazards posed by recreating at contaminated beaches can lead to swim bans and beach closings. These closings have the potential to result in significant economic losses to Great Lakes coastal communities. Rabinovici et al. (2004) estimated a Lake Michigan beach closing could lead to a net economic loss of up to $35,000 per day. Song et al. (2010) estimated a seasonal closure in one beach site may result in an economic loss of $130,000 to $24 million, while closing all Lake Michigan sites could be as high as $1 billion.

The goal of this study was to observe the movement patterns of gulls and their patterns of habitat use relative to human infrastructure. While it is known that gulls use human infrastructure (Belant et al. 1998, Massachusetts Department of Conservation and Recreation 2010, Caron-Beaudoin et al. 2013, Washburn et al. 2013), it is unclear if gulls frequenting recreational beach sites are the same gulls using landfills and waste water treatment plants.

METHODS

Study Area

This study took place in Ottawa County on the western edge of Michigan's Lower Peninsula. While all gulls were trapped in Ottawa County, telemetry tracking efforts took place across all of Ottawa County and parts of Muskegon County. This covered a total area of approximately 2,230 km^2. Notable sites within the study area included a large waste water

treatment facility, two landfills, two shopping malls, parking lots and several public beaches of both state and county parks. The Muskegon Waste Water Treatment facility was adjacent to the Muskegon State Game Area and encompassed 4,452 ha of land, including two 344 ha storage lagoons. The variety of land cover types available along with its proximity to the natural game area provided habitat for birds as 256 different species have been observed on the property since it was established in 1973 (Muskegon Co., MI, Website). The waste water property also included a solid waste landfill that encompassed approximately 45 ha. Another large landfill (Ottawa County Farms Landfill) within Ottawa County was located near Coopersville, MI, 24 km inland from the lakeshore and was approximately 112 ha in size.

Study Design

Transmitters along with Teflon ribbon for making harnesses were purchased from Advanced Telemetry Systems (ATS, Isanti, MN). All harnesses were sewn together by hand using cotton thread, Teflon tape and a quick drying marine adhesive. Each harness was designed with a loop to be placed around the gull's neck and a strap that went down the sternum connecting to another loop around the bird's midsection, under the wings. The lower loop was left unconnected to allow for ease of fitting it to the bird and adjusting size if necessary. These harnesses were designed in order for the transmitter to sit snuggly on the middle the bird's back between the wings.

Gull Trapping

Gull trapping took place opportunistically between 13 June and 9 July 2013. The majority of gulls were captured on Grand Haven City Beach, with additional captures on North Beach Park and a private beach on the property of Tom Izzo (Grand Haven, MI). Two capture methods were attempted, a box trap and a net launcher. The mesh wire box trap (1 m x 1 m x 0.5 m)

proved to be an ineffective capture method as most birds seemed too wary of the device. As a result of this a net launcher (Super Talon Net Launcher, Bird-B-Gone Inc., Irvine, CA) was used to capture all gulls.

Gulls were baited into range of the net launcher using anthropogenic foods. Immediately upon capture each gull was placed in a pillow case to reduce stress while waiting to process each individual. For each captured bird, I recorded federal band number and bird weight. On a sample of birds, I also took a cloacal swab for microbial analysis in a related study. Each bird was outfitted with a VHF transmitter fitted to their back using a harness made of 4 mm Teflon ribbon. Transmitters and harnesses weighed on average 16.14 g. Birds were released immediately after the final connection on the transmitter harness was sewn using cotton thread, glued with a marine adhesive and wrapped in Teflon tape. My research was approved by the Institutional Animal Care and Use Committee at Central Michigan University (IACUC #12-14A).

Gull Tracking

I used both hand-held and mobile vehicle radio telemetry to relocate gulls. On foot a R2000 ATS receiver (Advanced Telemetry Systems, Isanti, MN) was used in combination with Telex headphones (Telex Aviation Headsets, Burnsville, MN) and 3-element Yagi antenna (AF Antronics Inc., Urbana, IL). A truck was outfitted with a R2000 ATS receiver and 5-element Yagi antenna mounted 1 m above the roof. This in combination with a degree delineated compass rosette and an Azimuth marine compass (KVH Industries Inc., Middletown, RI) allowed for easy interpretation of antenna and signal direction (Lovallo et al. 1994). Gull tracking took place 5 days a week (Monday-Friday) for 8 h a day. Tracking gulls throughout the evening and nighttime hours was attempted but met with little success. Gulls were located via

visual detection and their positions recorded using a handheld Garmin eTrex 30 GPS receiver (Garmin International Inc., Olathe, KS).

Gull Habitat Analysis

I loaded gull locations into ArcMap 10.1 (ESRI, Redlands, CA) and overlaid them on a map of Ottawa and Muskegon County land use and land cover (Michigan Geographic Data Library). I drew a minimum convex polygon (MCP) around all points and clipped out this area of the land cover classification map. Land cover classes included: open water, beach, agriculture, developed (buildings, parking lots, roads, etc.), waste water lagoon and landfill. The latter two classes encompassed the waste water treatment facility as well as two landfill sites of interest. These were identified using satellite imagery and added as new polygons to the land use land cover shapefile in ArcMap. I calculated the hectares of each habitat type available in this land cover classification clip and their proportion of availability based on percentage of the whole area. I defined use as proportion of relocations within each land cover class. I used a chi square goodness-of-fit test with Bonferroni confidence intervals to determine patterns of habitat use (Neu et al. 1974; Byers et al. 1984).

RESULTS

Gull Captures

I caught a total of 34 gulls, of which 31 were fitted with VHF transmitters. Of the 3 remaining gulls, one escaped prior to completely fitting the transmitter harness. The second gull was found offshore by boaters and was taken to a wildlife rehabilitator. The third gull had an eye injury and was not fitted with a transmitter due to behavioral concerns. Gulls were captured opportunistically and thus consisted of a combination of adults and sub-adults. Average weight

of captured gulls was 448.7 g (SE = 8.8). Average harness and transmitter weight was <4% of mean gull body weight.

Gull Locations

Of 31 gulls outfitted with VHF transmitters, 20 individuals were relocated using radio telemetry. Despite extensive searching, I could not relocate 11 tagged birds. I relocated 20 individuals at frequencies between one and 21 times, for a total of 131 locations (Figure 2).

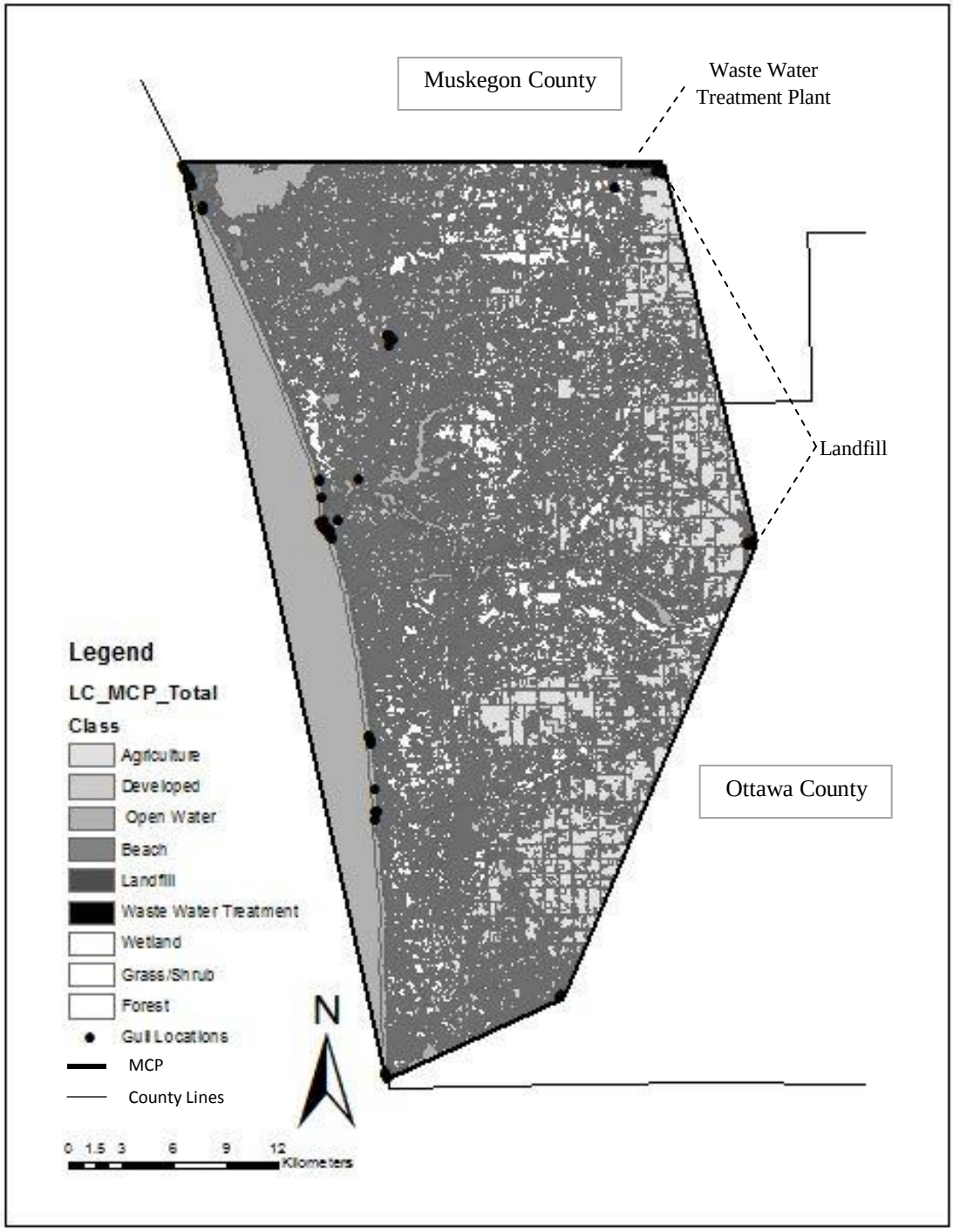

Figure 7. Gull Locations, minimum convex polygon and cover types across study area. Non-essential habitat types are denoted in white.

I located gulls as far north as Muskegon State Park (22 km north of the capture site) and one individual was observed as far south as Benton Harbor, MI (105 km south of capture site). Multiple gulls were found flying as far inland as the Coopersville landfill site, 24 km from the capture point on Lake Michigan. I pooled all individual locations to assess patterns of habitat use for my sample of gulls since gulls are highly mobile and exhibit strong social and flocking behavior (Belant, et al. 1998, Dosch 2003, Calvino-Cancela 2011).

Gull Habitat Use

The most abundant land cover types available in the study region were developed and open water, while least available were waste water lagoons and landfill areas. The most heavily used habitat types included beach and developed, which contained 87 and 21 gull locations, respectively (i.e., 82% of total locations). Gulls used cover types differently (χ^2 = 2616.6, P = <0.001). Gulls used beach and landfill cover types greater than expected given their availability in the landscape. Gulls used waste water habitat in proportion to its availability. Gull used open water, developed and agriculture less than expected given their availability (Table 1).

Table 1. Gull habitat use-availability with 90% Bonferroni Confidence Intervals. Percent availability is the proportion of each habitat type available in the study area while percent gull use was the proportion of total gull locations found in each habitat type.

Habitat Type	% Availability, Expected	% Gull Use, Observed	90% BCI x 100	Behavior
Open Water	33.64	6.11	0.59 - 11.6	-
Beach	2.53	66.41	55.5 - 77.2	+
Agriculture	6.44	1.53	0.00 - 4.34	-
Developed	56.93	16.03	7.58 - 24.4	-
Landfill	0.21	8.40	2.01 - 14.7	+
Waste Water	0.25	1.53	0.00 - 4.34	N

DISCUSSION

It was not surprising that gulls were selecting for beach and landfill habitats, as this was expected based on well known gull behavior that is easily observed (Belant et al. 1998, Caron-Beaudoin et al. 2013). The number of gulls found using developed areas was surprisingly low, given the propensity of this species to be found in parking lots and other anthropogenic developments (Massachusetts Department of Conservation and Recreation 2010, Washburn et al. 2013, Caron-Beaudoin et al. 2013). Open water was found to be used proportionately less than it's availability, however this can be misleading in that open water is directly adjacent to beach land cover, which was heavily selected.

While waste water habitat was not selected, it was a small area of land cover habitat within the landscape. In addition to this, it was directly adjacent to a landfill site that was used heavily by gulls. Many gulls were observed flying between the landfill and waste water treatment lagoons. Also, during early summer months the edges of waste water lagoons were used by a large nesting colony of gulls and these high numbers remained present throughout the lagoons and adjacent landfill for the remainder of the season.

Previous studies have already shown Ring-Billed Gulls to be opportunistic feeders that rely on anthropogenic food sources and habitats (Belant et al. 1998, Caron-Beaudoin et al. 2013, Washburn et al. 2013). Belant et al. (1998) found that Ring-Billed Gulls rely on landfills as food sources in the Lake Erie area and will fly up to 26 km from nesting colonies to visit landfills. This is similar to the finding in my study that showed gulls travelling up to 24 km from beach sites to visit landfills. Caron-Beaudoin et al. (2013) showed that Ring-Billed Gulls make targeted flights to landfills and waste water treatment plants, however they were found to spend less time there and more time foraging in nearby agricultural areas. Of four gull species observed,

Washburn et al. (2013) found Ring-Billed Gulls to have the most diverse and opportunistic feeding strategies, using a variety of habitat across the coastal-urban interface. They observed Ring-Billed Gulls foraging in marine, terrestrial and anthropogenic habitats. My study found similar results as previous studies in that Ring-Billed Gulls readily use landfills available in their environment. An exception was their use of developed and agricultural cover types, which my gulls used less than was expected given previous research. This study differs in that it tracked gulls already found visiting recreational beaches and their land cover use relative to both beaches and human development such as landfills and waste water treatment plants in a Great Lakes coastal region.

It is no surprise that gulls are using landfills and waste water cover types. More interesting is that all individuals marked in this study were captured on beaches. This study demonstrates that gulls found on recreational beaches are flying dozens of kilometers inland and visiting locations such as waste water treatment plants and landfills before returning to loaf or forage on beaches. This raises questions of human health concerns considering the potential for gulls to transport bacteria and pathogens within the broader landscape. Gulls may serve as a long distance vector for transporting pathogens to areas of probable human contact and concentration (i.e., at recreational beaches). Given this possibility it may be desirable for beach managers to implement strategies for reducing or excluding gulls from some public recreational beaches where they are most likely to interact with people. Furthermore, managers of landfills or waste water treatment plants may want to look into strategies for controlling numbers of gulls, excluding them from their properties, or possibly reducing the amount of anthropogenic food sources available to gulls.

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