EBIRD: ASSESSING THE APPLICATION OF LARGE SCALE CITIZEN SCIENCE DATA AND DATA COLLECTION STRATEGIES FOR LOCAL MANAGEMENT USE

A Thesis

by

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ABSTRACT

eBird, a citizen-science program developed by the Cornell Lab of Ornithology and National Audubon, allows users to enter bird sightings from around the world in order to develop a large scale data set for research. This study seeks to analyze eBird data and methods in order to determine if the data collected is robust enough to be usable as a basis for habitat management and, if so, to what extent. This is accomplished through a comparison of Piping Plover (*Charadrius melodus*) (a threatened shorebird of management concern) counts, trends, and methodologies made through a survey following a strict protocol versus data collected by eBird in three different areas (Bolivar Flats, Apfel Park, and San Luis Pass). Using descriptive statistics such as mean counts, counts adjusted for effort, and frequency, and confirming with Kruskal-Wallis tests, variation was found between eBird and survey data. eBird contained lower counts of Piping Plovers and a lower sighting frequency than survey data. When adjusting counts as a function of effort, similar results were found. Piping Plovers were found not to occur frequently at Bolivar Flats (9 birds over 2 surveys), while Apfel Park and San Luis Pass showed similar but inconclusive results. This study ultimately determined that, while of great use on large scales, use of eBird data on the local level, should be used with caution. Further study should be done to investigate sources of variation and methods to increase the effectiveness of eBird on small scales.

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NOMENCLATURE

AKN – Avian Knowledge Network

AP – Apfel Park

BF – Bolivar Flats Shorebird Sanctuary (aka "Bolivar Flats")

CLO – Cornell Lab of Ornithology

NABCI – North American Bird Conservation Initiative

NBR – Negative Binomial Regression

NSF – National Science Foundation

SLP – San Luis Pass

a – Structured Scientific Survey

TPWD – Texas Parks and Wildlife Department

USFWS – US Fish and Wildlife Service

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INTRODUCTION

The following management scenario formed the basis of this study: *A park manager wishes to open a new sanctuary for Piping Plovers. Three sites are marked by USFWS as critical habit in the area. The manager wishes to protect the site that is found to have the largest number of Piping Plovers*. This study uses this scenario to find which data analysis methods would most effectively and efficiently determine which site should be protected as well as determine whether the selection would be different using eBird and SSS data.

Citizen Science

Citizen science is the code word for projects that merge scientific research with the time and interest of the general public. This volunteer-based research has a long history with formal projects dating back to 1900 with the development of the Christmas Bird Count; and under less strict definitions, many important scientists such as Ben Franklin, Charles Darwin, and Gregor Mendel could be considered citizen scientists as science was not their primary occupation. Definitions vary on what is classified as citizen science. One definition is "a volunteer who collects and/or processes data as part of a scientific enquiry" (Silvertown 2009). Cornell Lab of Ornithology (CLO) defines citizen science projects as "projects in which volunteers partner with scientists to answer real-world questions" (Cornell, 2012). Regardless of the precise definition, the key factor is public participation. A rediscovery of the benefits of public interest and participation is in place and a wave of new research is emerging, driven by public efforts.

Currently, there are many citizen science projects underway in a vast range of topics from ornithology, to astronomy / astrophysics, to medicine, to history. Some projects require volunteer time in the field; other projects have been turned into a video game; and others simply require computer space (a loose form of citizen science but interesting nonetheless). These projects help provide the time and effort needed for research as well as reduce the cost of such research. In addition, citizen science projects can increase the geographical and temporal scales of research, as well as increase the processing ability of large databases to answer questions impossible to answer from most traditional research methods. For example, large astronomy databases can be scanned by users and classified to identify special objects of interest like moon craters, black holes, etc. (Zooniverse, 2012). It can also speed up research in critical areas such as climate change, and medicine by increasing the number of people working on the project (Khatib et al., 2011).

eBird

One such large scale project is eBird (ebird.org). eBird is a ornithology project developed by the Cornell Lab of Ornithology (CLO) in association with the National Audubon Society. This project allows any user to enter records of data online on bird counts and observations. The information then can be used to help both researchers as well as birders, allowing the birders to track their sightings and search out new birds to see.

As birding is one of the fastest growing hobbies in the United States (Cordell 2002) with an estimated 48 million birders (Carver, 2009), the number of people involved can provide a great deal of data for research. In 2008, eBird collected almost 10 million entries at an estimated cost of about 3 cents per observation (Sullivan et al. 2009). As of 2009, over 21 million observations have been made from over 1.6 million records.

These data have been used in a number of research areas. For example, in 2011, the State of the Birds Report to Congress (NABCI 2011), covering impacts of land use (particularly public lands) on bird distribution, was compiled using eBird data. A grant from the National Science Foundation (NSF) allowed CLO to pay for use time on the TeraGrid supercomputer in order to process eBird data on refined scales and included advanced statistical models to account for bias and gaps in data. By doing this, they were able to develop detailed distribution maps over time and compare these to land use maps to analyze the status of different groups of birds and suggest strategies for management of public lands (Figure 1).

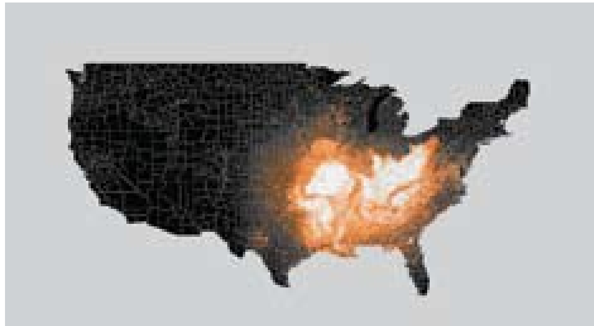

Figure 1: Frequency Map of Kentucky Warbler as Shown in the 2011 State of the Birds Report (NABCI 2011)

eBird data has been used recently to study effects of climate change on bird migration. Hurlbert and Liang (2012) used eBird data to look at migration timing of several species of birds. The species arrival timing in different areas was related to mean spring temperature and latitude. It was found that the arrival time of southern species was more affected by temperature difference than northern species.

Another use for eBird data is to supplement observation records and study expansion of birds into new ranges. For example, Cruickshank and Melcer (2010) published an article describing a visual record of a red-shouldered hawk in British Columbia. This observation, combined with eBird data, showing increasing numbers of red-shouldered hawks in Washington and Oregon, led the authors to suggest that the species occurrence in the British Columbia area should be elevated from hypothetical to accidental. Thus, eBird data can be used to study ranges and expansions preliminarily, and then to be confirmed by scientists. This has the potential to provide managers, government officials, and other stakeholders, more reliable and timely information. If eBird can provide similar results as scientific surveys, then use can be made of the data even faster and more effectively.

Avian Knowledge Network (AKN)

The Avian Knowledge Network is a data mine put together by the CLO with assistance from a number of outside organizations such as the National Science Foundation (NSF), Point Reyes Bird Observatory, Bird Studies Canada, and many others (http://www.avianknowledge.net). This tool compiles data collected by eBird and a number of other projects from various organizations including: the Great Backyard Bird Count, Land Bird Monitoring Program, Hawk Count, Project Feeder Watch, and others. This data mine is used to create a standardized collection of avian data that then can be used for research. Subsets of the data collected are sent to other biodiversity initiatives based on their requirements using a standardized group of information categories (e.g., species name, basis of record, sex, etc.) called the Darwin Core.

Until recently, information on the methodology of each data record, along with effort, area, etc., was only available via the AKN. However, in October 2011, eBird version 3 was launched. This update streamlined data entry, added several methods for tracking one's own records including competitive lists, and enhanced data visualization including several map options (e.g., street, satellite, hybrid). Importantly, now each record can be viewed via eBird including effort entries, protocol options, and whether or not it counts all birds seen. This version allows for much greater utility of eBird data by itself; however, AKN data still includes data that is not included on eBird allowing for greater sample sizes.

Potential Bias

One of the major issues with citizen science projects, especially in field-based observation projects like eBird, is that of the biases involved. These can include variation in species detectability, observer bias, and entry variability (Sullivan et al. 2009). The first example of bias is species detectability. This is the ease or difficulty of a particular species or individual of a species being detected due to certain characteristics such as coloration, behavior, size, habitat, etc. As a result of variations in detectability, the accuracy of some counts or records may be more or less accurate. For example, counts of smaller birds living in dense vegetation may be less accurate than that of species that dwell in the open. A bright coloration may make one species more distinct or easy to find than a species that blends in with the habitat or other similarly colored birds (Sullivan et al. 2009).

Also, the way observers detect, count, and record sightings may vary among individuals. Every individual has a unique skill set including experience, sensory function (e.g. eyesight and hearing), and quality of equipment, among others. These differences can affect how likely the birder is to detect any particular bird in the first place. Also, the amount of attentiveness and effort (as a measure of time) will also greatly influence the number of birds detected (de Solla et al. 2004). As well, the experience of the observer and the distinctiveness of the bird species will determine if the bird is correctly identified. Entry frequency may be different for different birds due to popularity, commonness, or detectability. These cumulative factors determine the accuracy of the observation record. Because of this, counts of less detectable birds may be less accurate or not recorded at all (Sullivan et al. 2009).

Lastly, variation can occur in how the observation is recorded. An observer can elect to record only the species found, the counts of all species, or only the counts of some species. This can be influenced by experience, time available, and species preferences of the birder, to name a few. Also, other factors may be recorded to provide better qualification of the data. For example, effort, location, distance traveled / area surveyed, weather or other environmental conditions may be recorded. However, variability in these or how they are recorded may create bias in analyzing the data. (Sullivan et al. 2009)

Current Validity Studies

It has been suggested that data collected by non-professionals (citizen science) are not as good as scientific data or not as useful (Droege 2007). As citizen science increases in popularity and usage by both birders and researchers, studies have presented arguments involving the validity of the data. Many of these discuss potential bias as noted above (Fitzpatrick 2009; Sullivan 2009).

Obviously, different types of projects encounter different types of problems and some issues are easier to justify than others. Some projects rely on a relatively simple classification or identification of a non-changing standard such as a photograph, or a captured animal. Samples can then be taken of proportions of correct answers and related to methods, demographics, etc. and correction factors for similar projects applied. Several of these types of projects have published studies of the potential error rate and have used those to develop methods for reducing or accounting for that error. Galaxy Zoo, an astronomy project, requires users to classify photographs of galaxies. In 2008, two papers discuss processing methods for photographic identification data from this project, bias involved with the project, and methods of correcting it. The first paper discusses the setup of the project and general processing steps (Land et al. 2008). The second shows a particular use, bias, and bias correction (Lintott et al. 2008). These two papers demonstrate how some types of projects can be analyzed for reliability with relative ease.

However, the process is not always easy. A study done in Australia tested how accurately the general populace could identify an invasive toad versus a native frog. Captured specimens were shown to members of the public; the results showed that the age, education, and profession of the observers, as well as age and gender of the specimen, significantly influenced accuracy of identification. Error varied from about 10% to about 43% based on specimen type; however, it was shown that interest (via a group membership or an education course) reduced error by as much as 11% (Somaweera et al. 2010). While a relatively simple validation analysis, this shows that observation error can vary significantly depending on the observer even when observing in a controlled situation. The variance could be even more significant in the wild.

<u>Small Scale Use</u>

Local managers, developers, and other stakeholders require small scale data (referring to site level information) from their localities in order to make decisions on where to protect, or build and to what extent. Traditionally, these data may be obtained from either personal experience or paid surveys depending on the situation. However, eBird now offers another option by providing existing data over time. Site level data are recorded by individuals, and "hotspots," or locations that are set out during online entry for easy and consistent records, are made available. These are better suited to small scale use.

Preliminary use has been made of eBird data on these small scales. One such example is the 2011 State of the Birds report previously mentioned (NABCI 2011). In compiling that report, large scale data were analyzed creating fine resolution abundance maps. This critical step provided useful data analysis to large scale managers and may be of great use for local managers and developers in decision making and conservation efforts. However, until technology catches up and such intensive data processing becomes more accessible, frequent, and even more fine-tuned, more specific analysis has to be done by looking directly at the data from a location in question.

Direct data including species occurrence and counts is available via eBird; however, the site level sample size, and multi-observer aspect of eBird may limit the utility of eBird when compared to a structured, scientific survey (SSS) utilizing standardized protocols (discussed in the Methods Section) and consistent observers / equipment. This study seeks to analyze the methodologies and data collected by eBird and compare that to an SSS to evaluate the limits of local data use.

<u>Piping Plovers</u>

Piping plovers (*Charadrius melodus*) are a species of shorebird categorized as a small plover (Kaufman 2000). They are small, greyish brown with bright orange legs.

During the summer, they are quite distinct with an orange and black bill, and a dark ring around the neck (Figure 2). However, during their time off the breeding grounds, their bills become solid black, the plumage becomes a lighter grey, and the neck ring disappears (Figure 3). They can be distinguished from other plovers by a combination of plumage darkness and orange legs versus black or grey. (Sibley 2003)

Figure 2: Piping Plover in Breeding Plumage

Figure 3: Piping Plover in Wintering Plumage

Piping Plovers are found throughout central and eastern North America, with occasional sightings in the Caribbean. Most of their time is spent on their "wintering" grounds along the south Atlantic coast, Gulf of Mexico, and down into Mexico (Figure 4). They gradually arrive at the wintering sites from July to October and return to their breeding grounds from February to May (TPWD 2010).

When they leave their wintering grounds, they split into three populations: Atlantic, Great Plains, and Great Lakes (Figure 4). Of these three genetically distinct populations (Miller et al. 2010), the Atlantic and the Great Plains populations are considered threatened, while the Great Lakes population is considered endangered. As a species, they are considered threatened. Breeding populations and locations are well-studied; however, on the wintering grounds, the populations mix together, but to what extent is uncertain. Several attempts to track Piping Plovers throughout their annual cycle have been made using counts and banding efforts (Haig and Oring 1985; Haig and Pilssner 1993, 2000). Although these studies have led to a better understanding of changes in population sizes, understanding of detailed migration patterns is incomplete. One factor contributing to this lack of knowledge is that populations outside of the United States are not well studied, particularly in the Caribbean. It may be that because of this, much of the wintering population remains unaccounted for (Lewis et al. 2006).

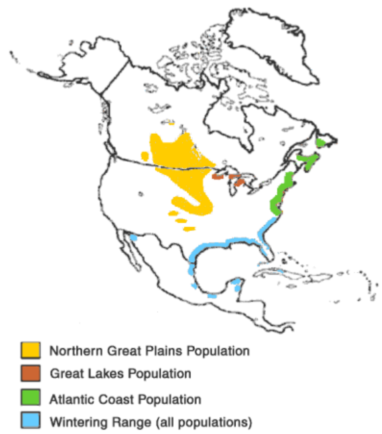

Figure 4: Range Map of Piping Plovers Showing Division of Populations During Breeding (http://www.fws.gov/plover/facts.html)

Because of their status as a threatened species, as well as the complications involved in identifying their annual movements, the Piping Plover is an excellent species for management concern. Their locations on a high resolution spatial and temporal scale are of potentially great importance to providing an effective management strategy. A comparison of eBird data with SSS data using the Piping Plover as a template species provides a unique opportunity for assessing the usability of eBird on a local scale and potentially enhancing management strategies. It may also provide insight into ways eBird can evolve in order to increase its effectiveness as a tool across all levels of use by pointing out sources of variations in data.

<u>Questions</u>

This study evaluates the validity of eBird data on a local level. Broadly, the study attempts to answer the question: Is eBird a tool that can accurately provide information for use in local conservation management? Using Piping Plovers as a template species, this question was further divided:

1) Do eBird counts provide the same results as a structured scientific survey (SSS)?
    a. Hypothesis 1: There is no statistically significant difference between eBird data results and results from an SSS (the hypothetical manager can use both sources equally)
        i. There is no statistically significant difference in abundance of Piping Plovers (P.P.) between eBird data and SSS data. (Raw data)
        ii. There is no statistically significant difference in "birds per hour" of P.P. sightings between eBird data and SSS data. (Corrected for effort)
        iii. There is no statistically significant difference in frequency of P.P. sightings between eBird data and SSS data. (Broad usage)
    b. Hypothesis 2: There is no difference in the comparison between eBird and an SSS among 3 different locations.
        i. If a difference is present, are there similar trends in data that may be useful?
2) Does AKN provide additional resources to improve small scale usage?
3) What changes have or can be made to improve usefulness on a small scale?

METHODS

In order to answer these questions, comparisons were made between counts of Piping Plovers made available on eBird and counts from a structured scientific study (SSS), as well as comparisons of the methodologies of these two. A management scenario was developed to study this: A park manager wishes to open a new sanctuary for Piping Plovers. *Three sites are marked by USFWS as critical habit in the area. The manager wishes to protect the site that is found to have the largest number of Piping Plovers.* This study uses this scenario to find which data analysis methods would most effectively and efficiently answer this question as well as determine whether the answer would be different using eBird and SSS data.

<u>Assumptions / Limitations</u>

While use of large scale data has been shown to be of value at small scales, these studies involved the use of a supercomputer and highly complicated statistical functions (NABCI, 2011). In order to accommodate local managers, this study seeks to address only direct data collected by eBird with no statistical or large scale averaging involved; in other words, to look at the usefulness of the raw data.

To support using raw data, it was assumed that since the locations were the same, and the personal abilities of the eBird users are unknown, the potential individual bias from such factors was the same between eBird users and the SSS researcher. Also, it was assumed that all observers (regardless of protocol) have an equal chance of high or low counts due to arrival or departure, or miscounts, so that the net effect is null.

The time of day of observation is kept at a constant during the SSS. However, eBird records are extremely unlikely to match this time frame exactly. As a result, while the times of eBird observations are examined and discussed, this factor is not incorporated into statistical analysis. This may present a complication that can be improved by increased eBird sample sizes and offers potential for future study.

eBird contains some specific portals (sites for data entry) that cater to specific regions or projects. As these are all combined into the general database and data entry is virtually identical apart from some extra questions in some portals, it is assumed that the portals do not affect eBird data itself. In certain cases, specific methodologies are used by these portals. No data analyzed in this survey utilized any of these specialized methods.

Lastly, this study focuses on a single species of shorebird (the Piping Plover) as a template species. As a result, this study does not include effects of habitat such as open beach areas versus dense forest areas. These differences play a great role in detectability and warrants future study.

<u>eBird Structure, Data Collection, and Options</u>

eBird is an online data entry tool for recording bird sightings from around the world. It allows unrestricted entry into that database; however, filters and other methods are in place to reduce fraudulent or dramatically erroneous data.

First, examination of data is open access, but to enter data, a profile must first be created. This is a standard procedure, requiring an email and password, that allows users to personalize and keep track of their data as well as providing a barrier from falsified data. Once signed in, a number of actions are open to the user (Table 1).

Submit entries	View data tables
View personal records (e.g., life or year list)	View graphs of data
Search current eBird updates	View maps of species
View alerts of rarities, high counts, and arrivals/departures	Search data by location, time, or species

Table 1: Possible Actions Within eBird

To enter data, first a location must be selected where the birding occurred. This can be selected from a list of a user's prior locations, or on a map from "hotspots" (locations pre-selected for easy and consistent recording). A new location can also be entered via latitude / longitude coordinates or map selection. An option to enter a broad area (e.g. city, country, state) is also offered but with a warning to enter more specific locations in order that the entries provide the most value to analysts (Figure 5).

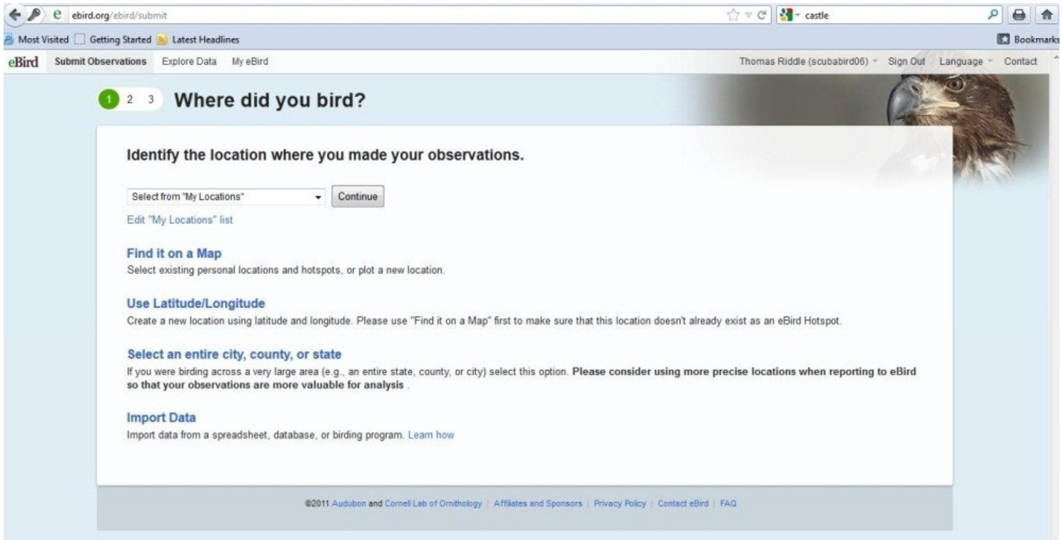

Figure 5: eBird Location Selection Screen (eBird.org)

Once a location is selected, a date and a survey type are required. The listed survey types are: travelling, stationary, incidental, or other. The travelling count is defined as traveling a distance while birding; examples are given such as a trail or field birding. A stationary count is defined as staying put while birding such as watching from a window. This would also include point counts, watching from a bench, etc. An incidental count is described by the eBird website as when: “Birding was not your primary purpose or you lack required effort information [such as] noting a bird while driving or gardening, historic records that lack effort info”(eBird, 2012). Other choices made available include an area count, random observations, or a method for one of a number of specific projects (Figure 6).

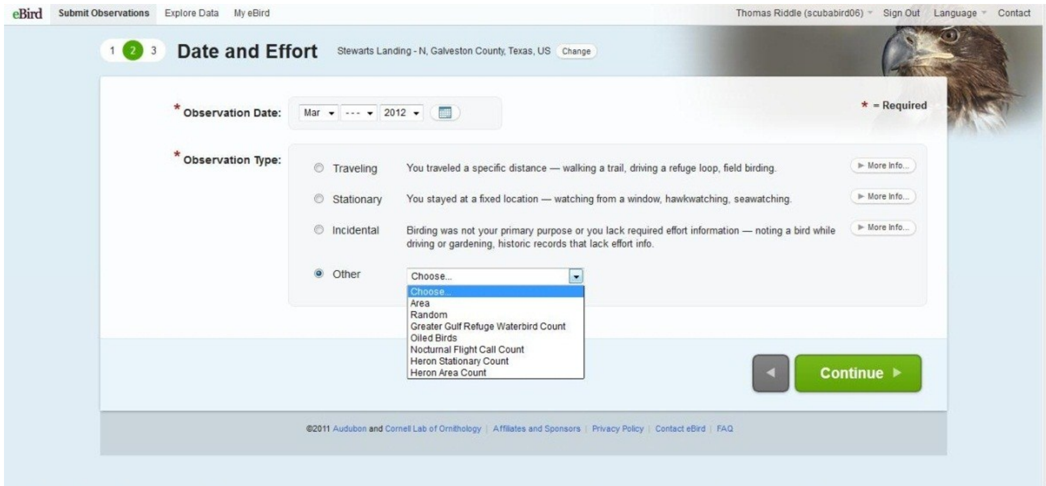

Figure 6: eBird Protocol Selection Screen (eBird.org)

Once a method is chosen, a number of new questions are shown depending on the selection. These can include start time, duration, area, distance traveled, party size, and in some cases, questions about the status of the area (e.g., tar balls, oil coverage, garbage, human usage, etc.). Depending on the method, different questions may either be required or are optional. A comment section is also available (Figure 7).

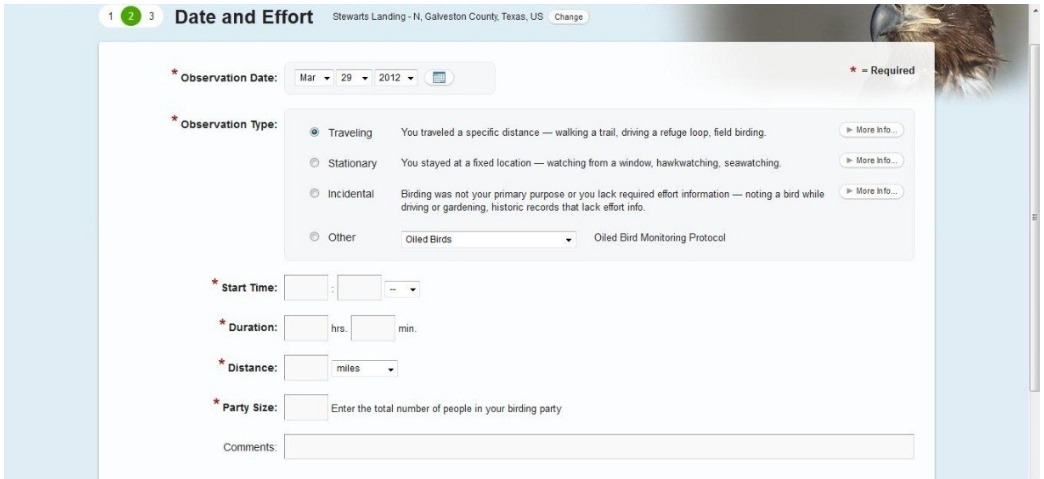

Figure 7: eBird Protocol Selection Screen After a Selection is Made (eBird.org)

Lastly, a checklist list of common species for the time and area is given. Numbers for each of the species can be entered, along with comments, and an option to add species not on the list (such as an extreme rarity). Filters to show or not show rarities and subspecies are given; as well, there is a “search for species” tool. eBird also asks whether or not the user is submitting a complete checklist. At this point, the user can submit the check list to eBird (Figure 8).

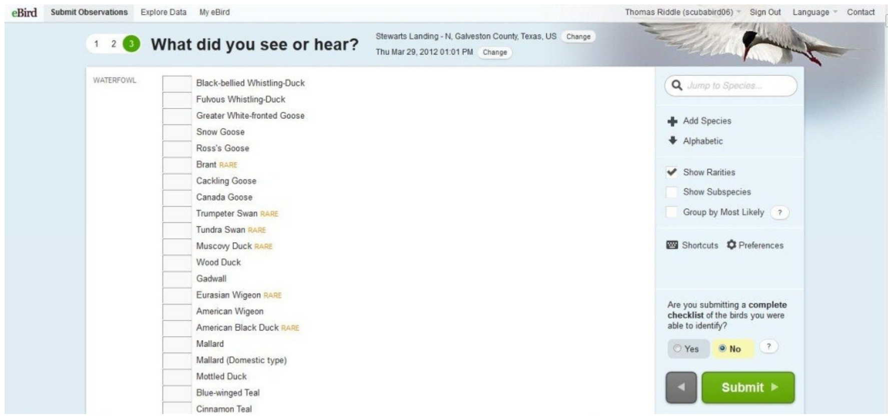

Figure 8: eBird Count Entry Screen (eBird.org)

Once submitted, a two part verification process begins as described by Sullivan, et al. (2009). The first part includes an automatic filter for abnormal entries. The second is a series of experts that examine flagged records to determine potential. The automatic filter checks the rarity of each species as well as the recorded counts and compares it to current average values. If an abnormal record is found, eBird requests confirmation from the user. If confirmed, rare species or abnormal counts are tagged and sent to a regional expert for conformation. In addition, any species not provided on the lists of common or rare species, while able to be added via the “add species” tool, is automatically tagged for review. This prevents situations like penguins being recorded in Arizona. The regional experts verify these abnormal records and use current data to refine filters for the area (Sullivan et al. 2009). Of 21 million observations at the time, 1.2 million were tagged as abnormal and approximately 62% were validated (Sullivan et al. 2009).

These methods are used across the eBird universe; however, regional portals exist to promote particular projects or regions. These may have particular methods which are available as options for entry or simply exist to promote birding. Variations in display (language, entry appearance, extra data entry fields, etc.) may exist to accommodate portal developer needs and preferences; however, these variations are limited as to avoid bias. Examples of portals include: Texas eBird, eBird Mexico, Department of Defense eBird, and Priority Migrant eBird.

<u>Structured Survey Methodologies</u>

To compare eBird counts, a structured survey was developed. Three locations were studied in the Galveston county area (Figure 9). Each area was separated into grids based on visibility and each grid was surveyed for Piping Plovers an equal amount of time. Each location was surveyed approximately twice a week from November, 2010, to February, 2011.

Figure 9: Google Earth Map with Locations of Sites Marked

The Galveston area was selected due to close proximity to the researcher, as well as being an important area for birds as it lies on a migratory “highway.” Galveston is also in the wintering area of Piping Plovers, the focus species. The three locations were chosen for two reasons. First, they are the three USFWS designated critical habitat designations for this area (50 CFR 17.95(b)). Secondly, they represent three distinct types of land use and protection status. The first area is Bolivar Flats Shorebird Sanctuary (BF). This area is a shorebird sanctuary along the Bolivar Peninsula and managed by the Houston Audubon Society. Vehicle traffic is blocked off by the use of wooden barricades that reach outwards into the water. Hunting, vehicles, and domestic animals are also prohibited via posted signs (Figure 10); however, the extent of enforcement and compliance is uncertain.

Figure 10: Posted Rule Sign on Road Barricades at the Entrance to Bolivar Flats Shorebird Sanctuary

The second location is Apfel Park (AP). This area is located on the north-east tip of Galveston Island and is a recreational park inside city limits. Vehicular traffic is partially blocked off; however, it was observed that large numbers of vehicles go through gaps in the barricades rendering them ineffective. Usage is variable but is generally moderate to high (mean observed people = 14.8; range: 2-42) year round with large numbers of anglers, as well as beachgoers, people with pets, and hobbyists (e.g., windsurfers, and remote airplane hobbyists) (Figure 11).

Figure 11: Protect Piping Plover Sign at Apfel Park w/ Large Numbers of Vehicles and People in the Background

The third area is San Luis Pass (SLP). This area is a public access beach area comprising a u-shaped area around the south-western tip of Galveston Island (Figure 12). It is privately owned by nearby developers; however, it has been operated and maintained by the Galveston Park Board because of its federal designation as a critical habitat area. It is not developed beyond trash barrels set at regular intervals and a network of crude roads. Usage is similar to Apfel Park including similar activities (with the addition of camping and ATV riding) with similar usage levels (mean= 15.7; range 2 – 46) (Figure 13). San Luis Pass is more remote, however, situated about 20 mi outside of Galveston.

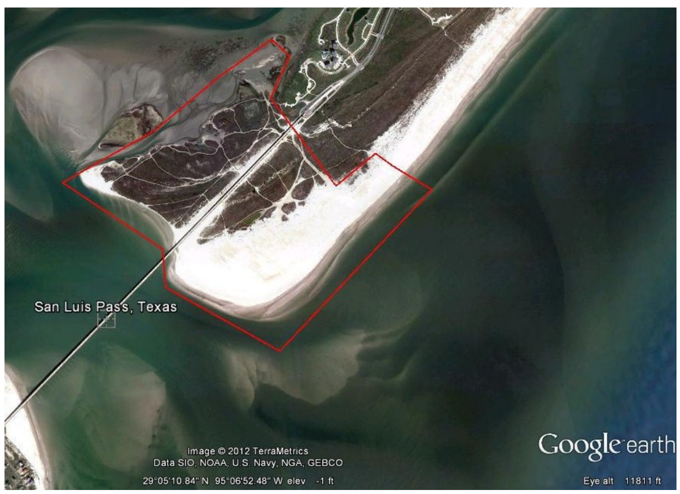

Figure 12: Approximate Outside Boundaries at
the San Luis Pass Site

Figure 13: Views of a Regulation Sign at the Gulf Side Entrance (left),
and the Pass Side of the Beach (right).

As noted previously, each of these three locations was surveyed approximately twice a week from November, 2010, to February, 2011. Exceptions were made for inclement weather such as rain (however, not merely for cold temperatures). During each week, one survey for each location was made on a week day (Monday through Friday) and one on a weekend (Saturday / Sunday) to help correct for any potential bias due to day of the week or random high activity.

To reduce potential bias due to time of day, two days were allowed to survey all three areas. This kept the time to perform surveys approximately equal and within a morning (sunrise to noon) time frame. SLP was done on one day (as it had a larger area and more survey grids) while BF and AP were completed on a separate day. On the weekends, Saturday was one set of locations and Sunday was the other. On weekdays, Tuesdays and Fridays were selected for survey. Each week, the sites for each day were switched, and the rotation was set up so Friday and Saturday surveys were never the same set of sites (to allow for more random sampling of days). In addition, on the BF/AP days, each week, the site chosen to begin the survey alternated. The survey times started about 30 minutes to an hour after sunrise and ended by about 5 hours after. Surveys were kept as short as possible to further reduce bias due to time of day. Appendix A shows a sample calendar with days surveyed (first day labeled is starting site for the day).

During each survey, each location was divided into grids. Each grid was based on the largest area in which clear identification could be made (< approx. 500ft.). Perpendicular distance to shoreline was from the vegetation line to waterline. In cases of mudflats, distance into them was based on visibility from closest spot to high tide line. Each grid was surveyed for 5 minutes from the middle of the area. Five minute intervals were chosen in order to minimize time spent while effectively counting all birds. Movement from area to area was in an orderly and regular pattern and care was taken to avoid any birds in the area, e.g. flushing birds and causing miscounts. In cases where any birds were stirred for any reason, care was taken to try and track movements of plovers. If this happened, a note was made and the survey continued according to protocol. If a bird was identified and counted prior to a flush, and was able to be visually tracked to the next site, it was not counted again. In most cases, this was possible. However, due to outside influences (e.g., other people or animals in the areas or unknown sources of flushing), error in counts was possible at times and was considered as part of observer bias as described in the assumptions / limitations.

Counts were made only during the 5 minute window, and Piping Plovers were only counted if a confident identification (ID) could be made. An ID was considered confident if, through a combination of plumage or leg coloration, size, behavior, and/or other individuals in the immediate area, other possibilities could be reasonably eliminated. An arrival outside that window was not counted; and if an arrival was made from a previously surveyed area with a confidence that it was counted prior, then it was not counted. Any arrival, departure, or movement was noted along with possible cause of disturbance. Appendix B shows a sample form for entry including grid area, counts, presence of people, vehicles, or domestic animals, and comments regarding disturbances or other important notes.

Surveys were made with either one (78% of cases) or two observers (22%) present. The primary observers duties were to ID, track, and count Piping Plovers as well as monitor all survey activities. A secondary observer, if present, assisted in data recording, holding gear, and tracking time. The secondary observer's job was designed so that it assisted the primary observer without affecting counts made. Due to other people present in the survey areas, as well as care to avoid disturbing birds during movements from area to area, it was assumed that the extra observer did not impact bird behavior (i.e., increasing risk of flushing birds). No observations during surveys contradicted this assumption.

<u>Methods of Analysis</u>

To answer the above hypotheses, descriptive statistics (counts, effort adjusted counts, and frequencies) were used to determine the "best" site selection, i.e. the site with the most Piping Plovers. Comparisons between eBird data and SSS data were made of the results of this selection, using each descriptive statistic. Kruskal- Wallis tests were run using counts and adjusted counts (the count for each survey divided by the effort (in minutes)) compared by location ("site") to confirm these selections. The frequency (number of surveys where Piping Plovers were counted divided by the total number of surveys) was also compared between eBird and SSS data. A Kruskal-Wallis test was also run comparing counts by data source ("source") to determine whether the data sources had different results across all locations. Kruskal-Wallis tests were chosen as the data are counts that are not normally distributed (strongly skewed to the right – See Appendix C).

RESULTS

From November, 2010 to February, 2011, 60 study surveys were made among the three locations. During the same period, 98 entries were made to eBird containing complete checklists (users reported that they entered all birds seen) or Piping Plover sightings (Table 2). Of these, 97 were complete checklists (99.0%). The remaining entry was an "incidental" sighting of 6 Piping Plovers at Apfel Park (AP) in December. This entry was included in analysis as deficiencies in other species counts are not within the scope of this study.

	Location	Sample Size	% of total
SSS			
	AP	20	33.3
	BF	20	33.3
	SLP	20	33.3
	Total	**60**	**100%**
eBird			
	AP	36	36.7
	BF	32	32.7
	SLP	30	30.6
	Total	**98**	**100%**

Table 2: Number of Surveys From Each Source and Site.

Count data was recorded directly as well as adjusted for effort by dividing the count data by the time spent observing (if available). Frequencies (number of observations with positive Piping Plover sightings divided by total numbers of surveys) were also calculated. Each record was also defined by its "source" (eBird vs SSS), what month it was taken at ("month"), and location ("site") (AP, BF, or SLP).

Survey Results

Twenty surveys were performed at each of the 3 locations, for a total of 60 surveys. Piping Plovers were seen 63.3% of the time (38 out of 60). The mean abundance count for the entire study was 9.42 birds with an average count (removing all zero records) of 14.87 (See Appendix D-1 for descriptive statistics).

Using direct counts, superficially, SLP had the highest abundance with 18.4 birds versus 9.8 at AP and .05 at BF. Using a Kruskal-Wallis test on SSS data (Figure 14), a significant difference was found between locations ($p < .001$). BF had a much lower mean rank than AP or SLP at 12.13, while AP and SLP were relatively close (37.48 and 41.90 respectively) with SLP being slightly higher. This suggests that SLP is favored by the Piping Plovers (and thus our manager), but may or may not statistically be significant compared to AP. Figure 15 shows the mean count for each location.

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Bird_count	60	9.42	13.458	0	51
count_adj_effort	60	.15486	.211790	.000	.785
Site	60	2.00	.823	1	3

Kruskal-Wallis Test

Ranks

	Site	N	Mean Rank
Bird_count	ap	20	37.48
	bf	20	12.13
	slp	20	41.90
	Total	60	
count_adj_effort	ap	20	37.65
	bf	20	12.38
	slp	20	41.48
	Total	60	

Test Statistics[a,b]

	Bird_count	count_adj_effort
Chi-Square	35.648	34.522
df	2	2
Asymp. Sig.	.000	.000

a. Kruskal Wallis Test

b. Grouping Variable: Site

Figure 14: Kruskal-Wallis Test Outputs From SPSS; Comparison of SSS Counts and Adjusted Counts by Location

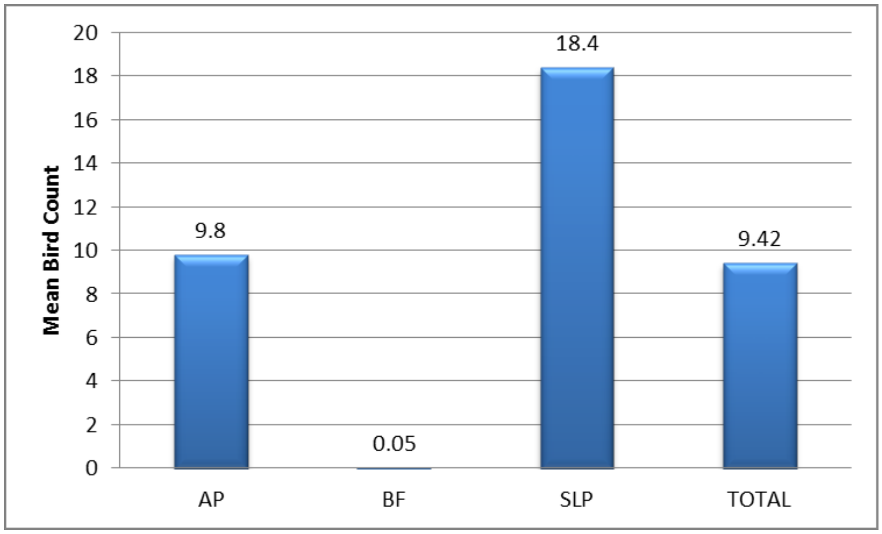

Figure 15: SSS Mean Counts

Adjusting for effort, results were almost identical to results without adjustment. BF again had the lowest mean rank at 12.38 with AP and SLP with 37.65 and 41.48 respectively. Adjusted mean values are shown in Figure 16. A Kruskal-Wallis test of counts by location (Figure 14) confirmed that a significant difference was found between locations ($p<.001$). The similarity between direct and adjusted analysis was expected, as effort was consistent for each location.

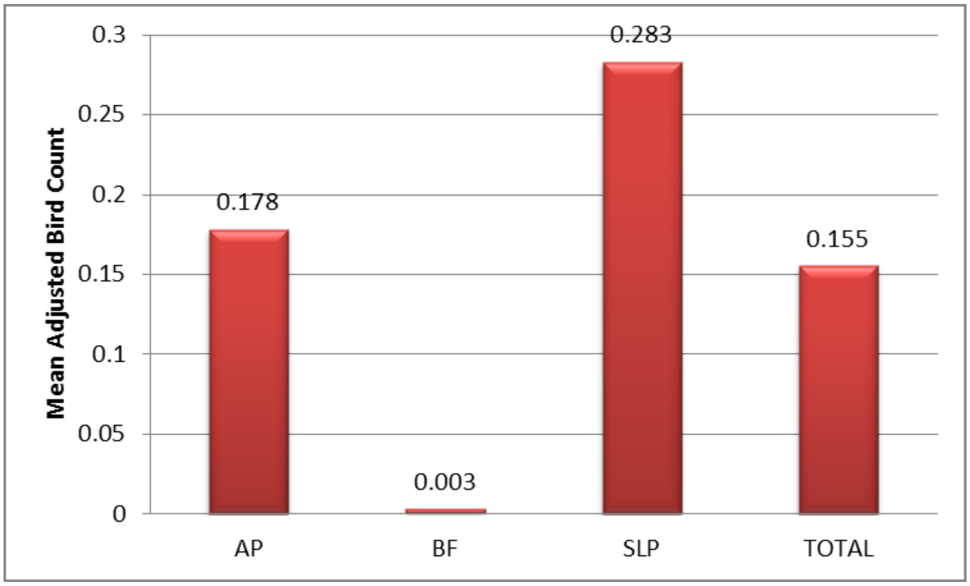

Figure 16: SSS Mean Adjusted Counts

On a broader level, frequency calculations showed a similar trend as well. During the SSS, only 1 out of 20 surveys (5.0%) had positive sightings of Piping Plovers at BF. AP and SLP had close frequencies (90.0% and 95.0% respectively; see Figure 17).

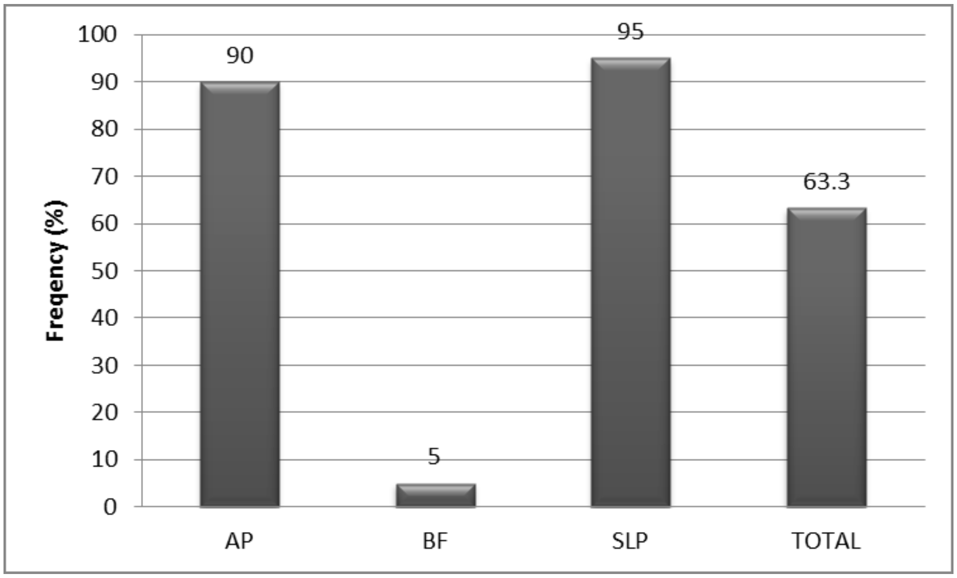

Figure 17: Frequency of Piping
Plover Sightings (SSS)

Analyzing survey results, all levels of analysis showed similar trends. BF was in all cases much lower in Piping Plover counts than the other two sites, likely due to a lack of suitable beach habitat at higher tides from erosion during Hurricane Ike. AP and SLP showed very close statistics at all levels of analysis with SLP each time being slightly higher.

eBird Results

eBird data contained 98 total records for the three locations that either had Piping Plover sightings, and/or acknowledged that the entry contained all birds seen. Seventeen out of these 98 (17.3%) had positive sightings of Piping Plovers. The mean abundance count of Piping Plovers was 1.51birds with an average count (no zeros) of 8.7 birds (see Appendix D-2 for descriptive statistics).

Using direct counts, BF was again significantly less than the other sites with a mean count of .25. AP and SLP were closer with mean counts of 2.42 and 1.77 respectively. Unlike the SSS, AP had the higher of the two counts. Statistically, using the Kruskal-Wallis test (Figure 18), a significant difference among locations was found (P=.037). This is likely BF as the mean rank was 42.58 versus 52.14 and 53.72 for AP and SLP respectively. It is interesting to note that while AP had the higher mean count (Figure 19), SLP had the higher mean rank (Figure 20). As a result, there is even less of a clear "best" choice using direct eBird data.

NPar Tests

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Bird_count	98	1.51	4.396	0	25
count_adj_effort	97	.01750	.054821	.000	.333
Site	98	1.94	.823	1	3

Kruskal-Wallis Test

Ranks

	Site	N	Mean Rank
Bird_count	ap	36	52.14
	bf	32	42.58
	slp	30	53.72
	Total	98	
count_adj_effort	ap	36	52.15
	bf	32	42.47
	slp	29	52.29
	Total	97	

Test Statistics[a,b]

	Bird_count	count_adj_effort
Chi-Square	6.584	6.157
df	2	2
Asymp. Sig.	.037	.046

a. Kruskal Wallis Test

b. Grouping Variable: Site

Figure 18: Kruskal-Wallis Test Outputs From SPSS; Comparison of eBird Counts and Adjusted Counts by Location

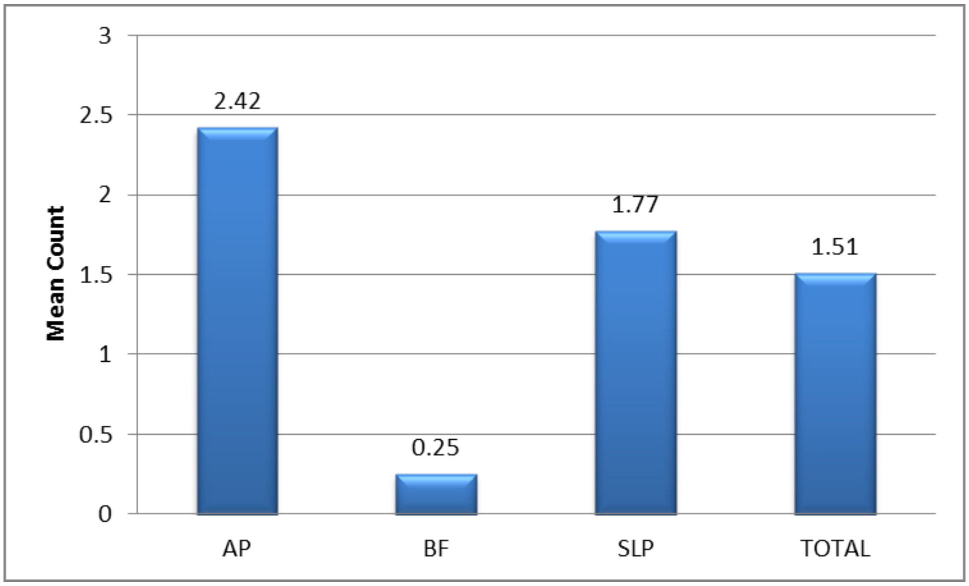

Figure 19: eBird Mean Counts

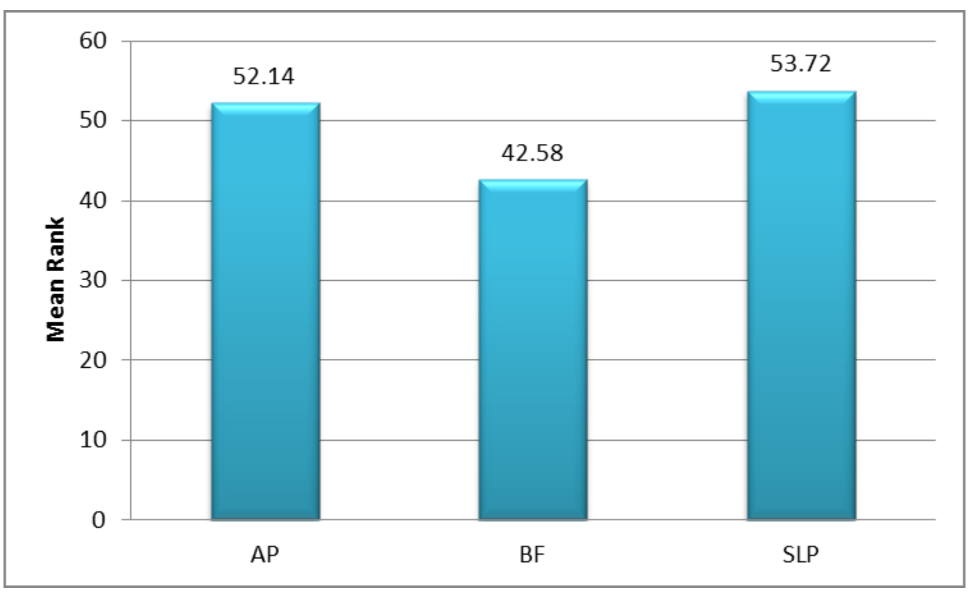

Figure 20: eBird Mean Ranking

Adjusting for effort, AP and SLP were almost tied at mean ranks of 52.15 and 52.29 respectively. Mean adjusted counts, however, favored AP more clearly at .031 versus .018. BF, maintained the lower level at a mean rank of 42.47 and a mean adjusted count of .0017. From these numbers, adjusted counts show very similar trends to using just a direct count from eBird data (Figure 21). Statistically, using a Kruskal-Wallis test (Figure 18), a significant difference was found among the 3 sites (p=.046); however, again this is likely due to low counts on BF. The relationship between AP and SLP is uncertain, and thus which is the “best” choice is not clear.

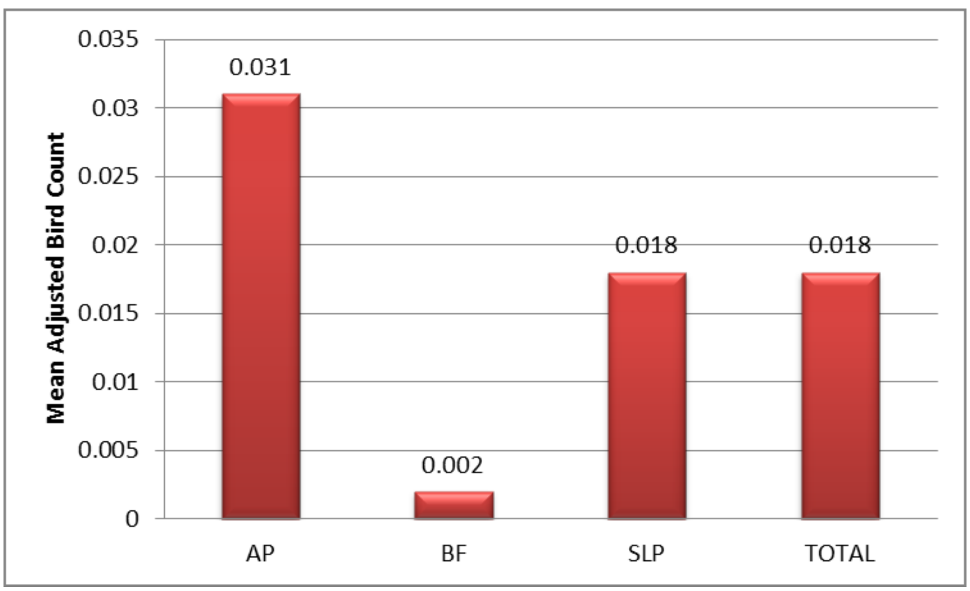

Figure 21: eBird Mean
Adjusted Count

Using frequency calculations, SLP had the highest percent sightings at 26.7%. AP was next at 16.7% and BF was the lowest at 3.2% (Figure 22). The variation among different levels of analysis and methods shows that AP and SLP were in fact very close and it was probable it was BF that created a statistical difference. It is then difficult to determine a clear "winner" using this eBird data (Table 3).

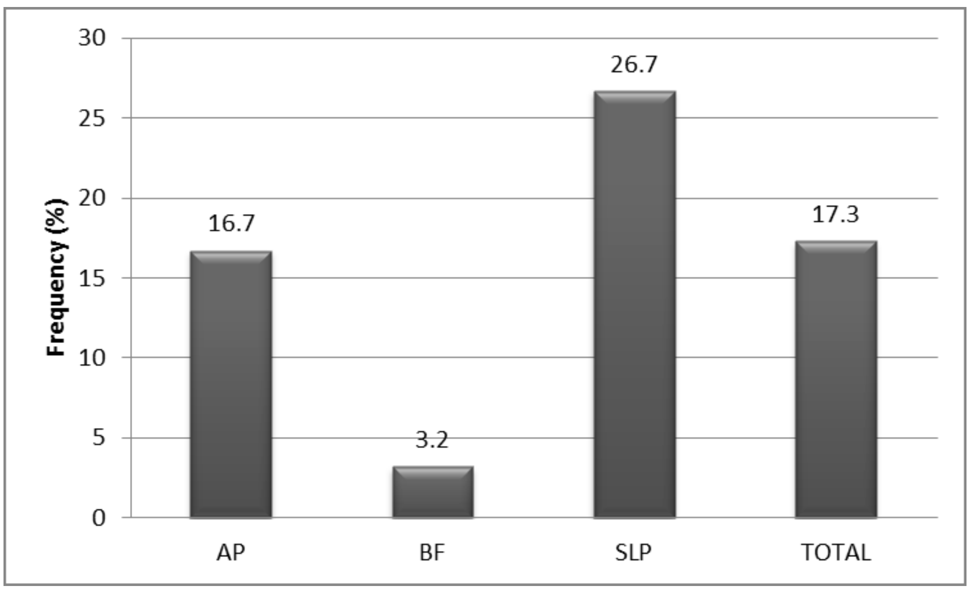

Figure 22: Frequency of Piping Plover Sightings (eBird)

Method	“Winner” (Most Birds)
Mean Direct Count	AP
Mean Count Rank	Tie / SLP
Adjusted Count	AP
Frequency	SLP

Table 3: Decision Outcomes of Hypothetical Manager Based on High Values of Different Statistics

Comparisons

When comparing results between data sources, two critical differences were noted: a difference in the mean and range of counts, and a difference in outcomes. First, SSS data showed a much higher average count than eBird. The average SSS count overall was 9.42 versus eBird at 1.51. This higher SSS count also occurred at each location with the exception of BF, which only had 1 record counting Piping Plovers in each data source (Figure 23). This suggests that eBird data may generally have undercounted data. Thus, the hypothetical manager could potentially make a wrong decision if comparing to some expected critical value. It also could be misleading if compared to scientific studies. This undercount shows up at all three levels of analysis: direct counts (Figure 23), adjusted counts (Figure 24) (which generally followed the same trends as the direct counts), and frequencies (Figure 25).

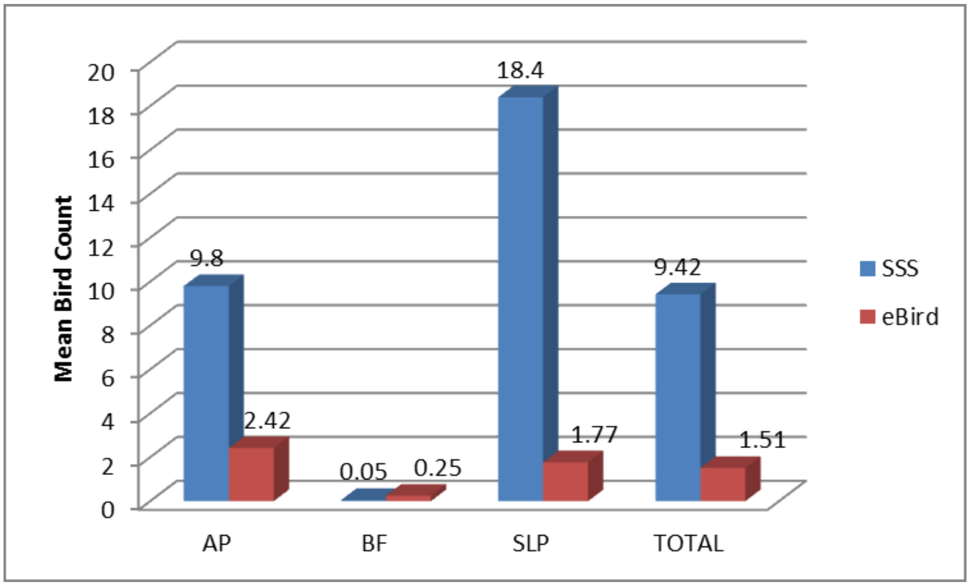

Figure 23: Comparison of Counts
Between SSS and eBird Data

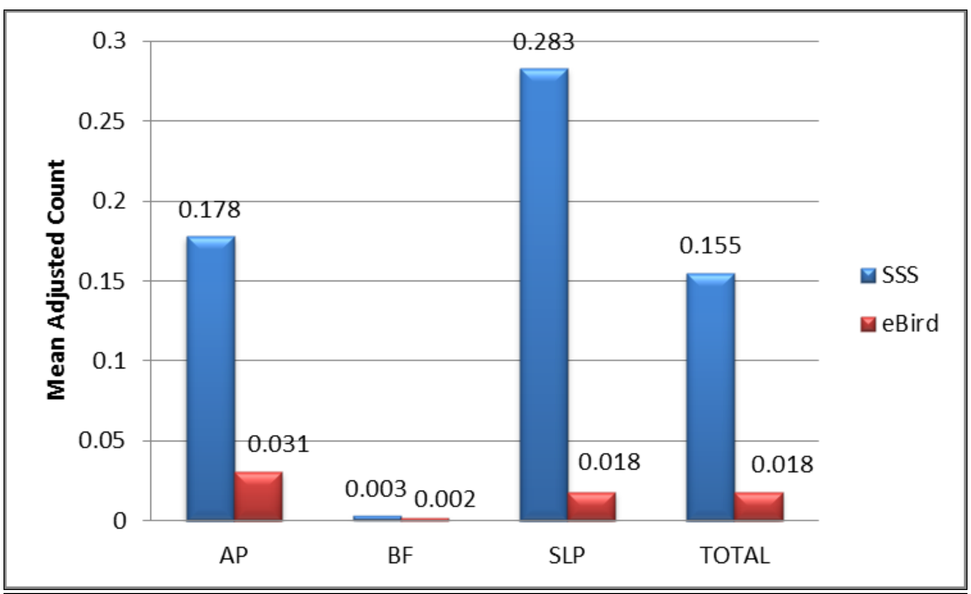

Figure 24: Comparison of Adjusted
Counts Between SSS and eBird Data

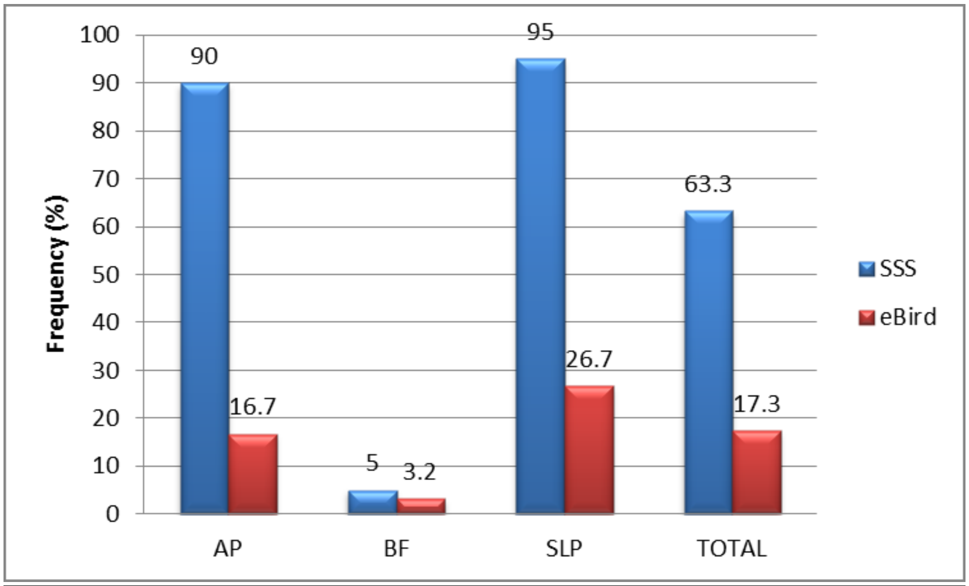

Figure 25: Comparison of Frequencies
Between SSS and eBird Data

<u>Effects of Time</u>

Data was also analyzed to determine if different time periods would affect the comparison between eBird and SSS data. Month time periods were chosen to do this in order to provide enough data for each period to compare. Kruskal-Wallis tests for both SSS and eBird data (Figure 26), showed no significant difference between overall counts of each month (SSS: P=.865; eBird: p=.138). When graphed (Figures 27 and 28), no clear relationship was observed between SSS and eBird data either in overall data or at the site level.

(a) **NPar Tests**

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Bird_count	60	9.42	13.458	0	51
count_adj_effort	60	.15486	.211790	.000	.785
Month	60	2.28	1.043	1	4

Kruskal-Wallis Test

Ranks

	Month	N	Mean Rank
Bird_count	Nov	17	31.71
	Dec	18	29.97
	Jan	16	32.06
	Feb	9	26.50
	Total	60	
count_adj_effort	Nov	17	31.91
	Dec	18	29.78
	Jan	16	31.91
	Feb	9	26.78
	Total	60	

Test Statistics[a,b]

	Bird_count	count_adj_effort
Chi-Square	.735	.689
df	3	3
Asymp. Sig.	.865	.876

a. Kruskal Wallis Test

b. Grouping Variable: Month

Figure 26: Kruskal-Wallis Test Outputs From SPSS; Comparison of SSS (a) and eBird (b) Counts by Month

(b) **NPar Tests**

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Bird_count	98	1.51	4.396	0	25
count_adj_effort	97	.01750	.054821	.000	.333
Month	98	2.83	.908	1	4

Kruskal-Wallis Test

Ranks

	Month	N	Mean Rank
Bird_count	Nov	11	57.86
	Dec	17	55.44
	Jan	48	46.24
	Feb	22	47.84
	Total	98	
count_adj_effort	Nov	11	57.36
	Dec	17	55.71
	Jan	47	45.34
	Feb	22	47.45
	Total	97	

Test Statistics[a,b]

	Bird_count	count_adj_effort
Chi-Square	5.513	6.696
df	3	3
Asymp. Sig.	.138	.082

a. Kruskal Wallis Test

b. Grouping Variable: Month

Figure 26: Continued

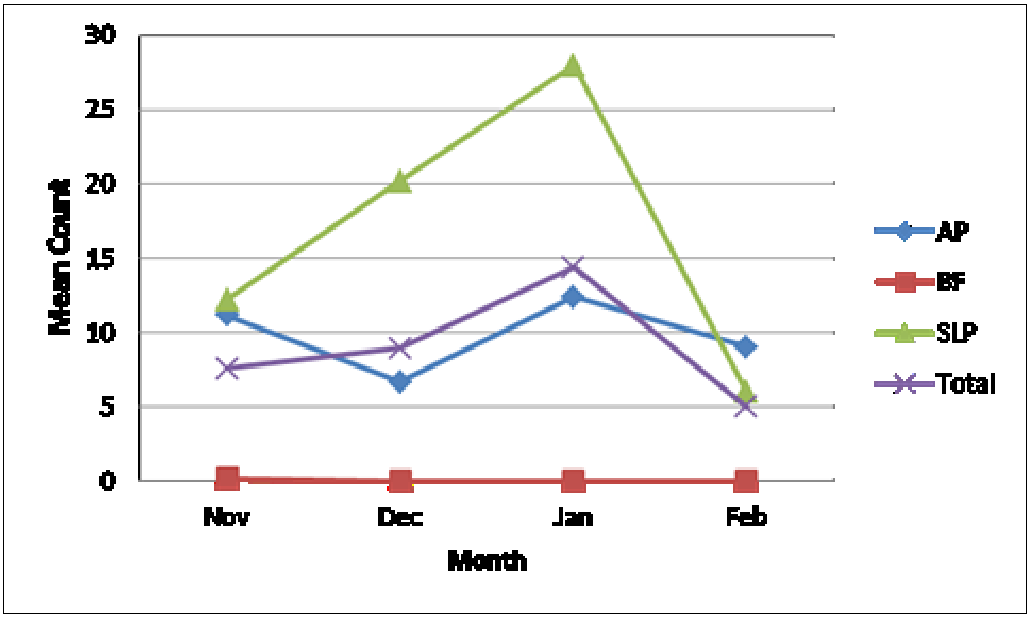

Figure 27: SSS Mean Counts
by Month

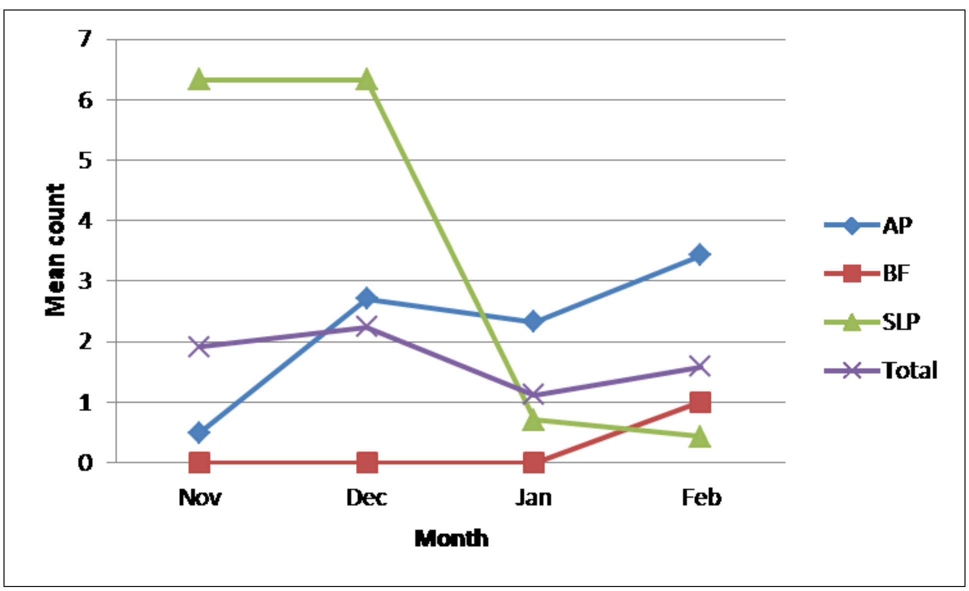

Figure 28: eBird Mean Counts
by Month

DISCUSSION / CONCLUSIONS

Summary of the Differences in Methodologies between eBird and an SSS

The goal of this study was to analyze the differences in the methodologies and data analysis between eBird and an SSS. When comparing the methodologies of eBird versus a structured protocol, several differences were found.

First, the area surveyed was not consistent. During the SSS, survey locations were divided into a grid and the boundaries were based on a combination of eBird hot spots and USFWS critical habitat designations. With eBird entries, however, area boundaries were based on the user's preferences and interpretation of the boundaries of the eBird hotspot. It should also be noted, that all eBird entries for the site may not have been entered under the eBird hotspots used in analysis. This may or may not influence average counts and warrants further study.

Also, the focus and effort of observers are varied between data sources. During the SSS, the site was surveyed using consistent divisions of time and surveyed for only Piping Plovers. eBirders, on the other hand, may observe multiple or all species and may favor their efforts in certain areas of the site.

eBird also can incorporate different protocol types. The SSS uses a series of point counts (observing birds within an area from a stationary point), while eBird can use this (called a stationary count on eBird) or one of another protocol types (area, traveling, random, ect.). The influence of various protocol types on the comparison between SSS and eBird data is a topic warranting further study.

Summary of Findings

Data from eBird and the SSS was found to be significantly different. Two hypotheses were posed:

Hypothesis 1: There is no difference between eBird data results and results from an SSS.

Significant differences were found between eBird and SSS count data regardless of the level of analysis. When looking at direct count data, mean counts visually showed differences as seen in Figure 23. eBird surveys undercounted Piping Plovers compared to SSS data. This was confirmed using a Kruskal-Wallis test (Figure 29) which showed significant differences ($p<.001$) due to the data source (eBird vs. SSS).

NPar Tests

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Bird_count	158	4.51	9.738	0	51
count_adj_effort	157	.06999	.152636	.000	.785
Source	158	1.62	.487	1	2

Kruskal-Wallis Test

Ranks

	Source	N	Mean Rank
Bird_count	survey	60	103.22
	eBird	98	64.98
	Total	158	
count_adj_effort	survey	60	103.80
	eBird	97	63.66
	Total	157	

Test Statistics[a,b]

	Bird_count	count_adj_effort
Chi-Square	35.959	40.265
df	1	1
Asymp. Sig.	.000	.000

a. Kruskal Wallis Test

b. Grouping Variable: Source

Figure 29: Kruskal-Wallis Test Outputs From SPSS; Comparison of Counts by Data Source

When effort is accounted for, similar comparisons were found between data sources. Again, eBird underestimated counts compared to SSS data and to a very similar extent as direct counts (Figures 23 and 24). These results show that adjusting for effort may not always be an effective way to calculate abundance and that differences between SSS and eBird data may be due largely to factors other than effort; for example: over and undercounts due to detectability variation and the focus during the survey (e.g., Piping Plovers exclusively versus all birds).

Lastly, when looking at frequency as a broader analysis of local Piping Plover abundance, it was found that the frequency of sightings was very different between eBird and SSS data (Figure 25). There are a number of potential causes of this including: eBirders incorrectly stating that they recorded all birds seen; variations between SSS area and the area surveyed by eBirders; and misidentification of species seen.

Hypothesis 2: There is no difference in the comparison between eBird and an SSS among 3 different locations.

Significant differences were found among the three locations. While unable to statistically determine which site was different, BF consistently had much lower values (regardless of statistic) than AP and SLP. AP and SLP were seemingly close, with variation in which of the two had higher values depending on the statistic used. However, as AP had a higher mean in eBird data, while SLP had a higher mean in SSS data (Figures 23 and 24), there is an apparent difference suggested in the comparative results among locations. Overall, with an extreme case such as BF (with so few sightings) and inconclusive results from the other two sites, it is impossible to confirm the effects of location on an eBird versus SSS comparison.

The Managers' Decisions

The numbers show that our hypothetical managers will not reach the same conclusions. A manager using the SSS data will find larger numbers with a higher abundance at SLP using all three analysis methods. On the other hand, a manager using eBird data alone, in this case would undercount the number of Piping Plovers, and a decision on which site is the "best" choice is more ambiguous.

Use of AKN

With the development of eBird v3 described previously, much of the potential resource of the AKN is now incorporated into eBird. AKN still provides an additional data source that may able to be used as an alternative to eBird (as it merges eBird data with other projects). However, as project methodologies are varied, this may affect reliability of the data without using complex analysis models.

Significance and Suggestions for Future Research

This study shows that there are significant differences between eBird data and data collected using a structured scientific survey (SSS). Results show a general undercount of numbers and species of birds seen during eBird surveys when compared to the SSS. The usefulness of eBird data in small scale studies is unclear as mean count and frequency were both underestimated while determinations of which of the three sites had the highest abundance were inconclusive.

Further study should be done to determine how species, location, and time frame of survey impact analysis. Longer term studies, studies with more sites, and studies focusing on multiple species would increase the understanding of exactly what the limitations of eBird data are. The use of smaller sub-projects, such as through portals, may also provide a key for more universal eBird use.

Currently small scale use of eBird is largely through specific portal projects as discussed in the methodology section. These portals increase the consistency of the data by utilizing relatively standardized protocols. However, this limits the data, as these projects focus on specific species or locations in a similar manner to larger citizen sciences projects like the Breeding Bird Survey and the Christmas Bird Count. Further study into the effectiveness of these portals and the statistical requirements of studies using these projects warrants investigation.

Conclusion

In conclusion, eBird is a useful tool, shown to be of particular value for use in large scale research, improving the understanding of avian populations and behavior. However, as with all tools, it must be used with caution as data may not show similar results that a more intensive scientific study does due to limitations in protocol consistency, and data numbers on smaller scales. eBird is constantly evolving, however, and new additions / modifications (such as the addition of entire records including protocols and other specifics, and new ways of visualizing data) are being made to the project to maximize its use. Unquestionably, eBird is a tool that can enhance research into species' numbers, habitats, and migration patterns. Further research into the limitations of the project and sources of bias, along with the increasing number of entries, and continued refining of protocols, may ultimately lead to a project that has universal application.

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APPENDIX A

Sample Survey Schedule

December 2010						
Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
		1	2	3 SLP	4 BF/AP	5 SLP
6	7 SLP	8	9	10BF/AP	11SLP	12BF/AP
13	14AP/BF	15	16	17SLP	18AP/BF	19SLP
20	21SLP	22	23	24AP/BF	25SLP	26AP/BF
27	28BF/AP	29	30	31SLP		

APPENDIX B

Sample Data Sheet

DATE: Time Start: Wind Direction

Location: Time End:

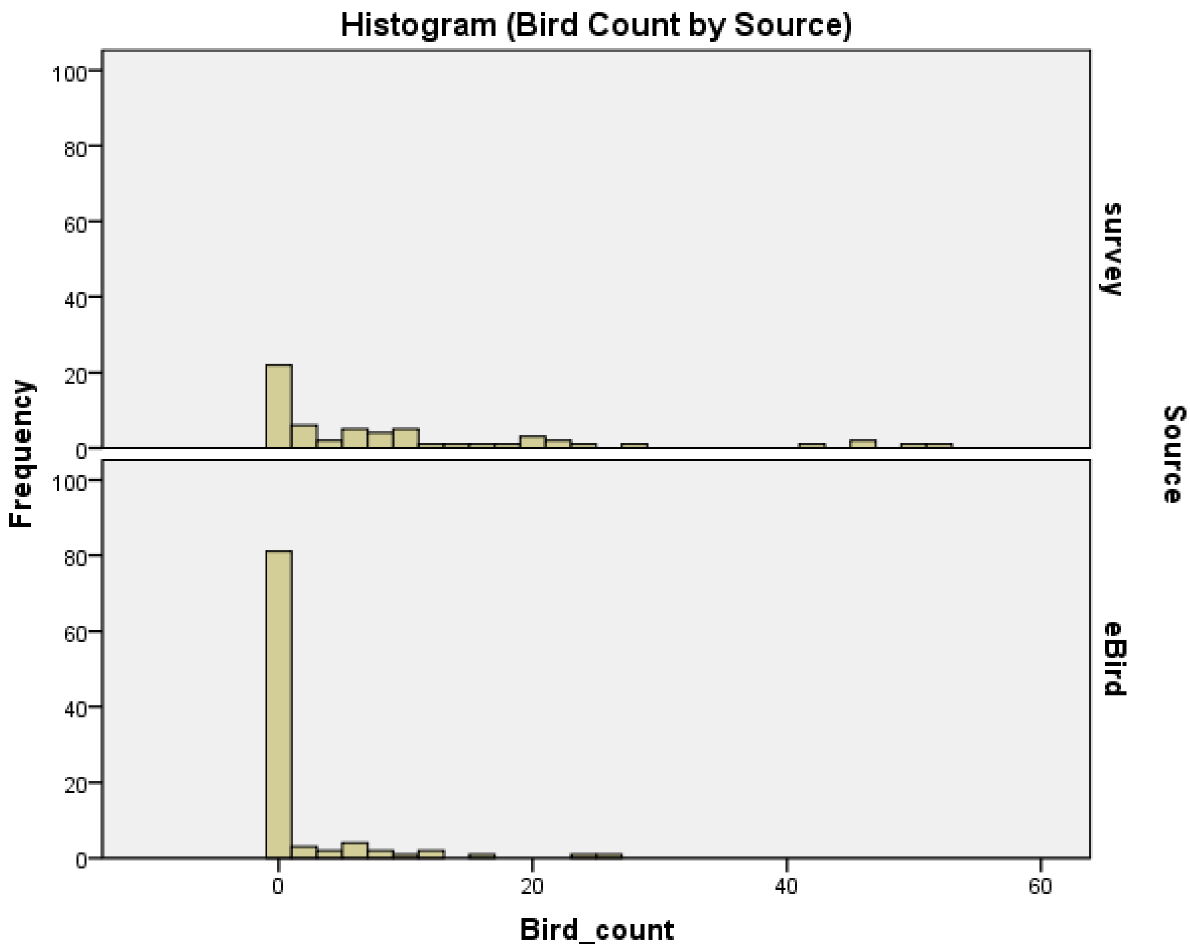
Observers: L. Tide
H. Tide

Weather: Sunrise: Temp:

Sec.	# P.P. Seen	# Vehicles	# People	# Dom. Animals	Notes:
A					

APPENDIX C

Histogram of Counts by Source



APPENDIX D

D-1: Descriptive Table of SSS Data

Report

Bird_count

Site	Month	Mean	N	Std. Deviation	Range
AP	Nov	11.17	6	6.585	19
	Dec	6.67	6	5.680	14
	Jan	12.40	5	11.887	28
	Feb	9.00	3	8.544	17
	Total	9.80	20	7.931	28
BF	Nov	.17	6	.408	1
	Dec	.00	6	.000	0
	Jan	.00	5	.000	0
	Feb	.00	3	.000	0
	Total	.05	20	.224	1
SLP	Nov	12.20	5	8.408	19
	Dec	20.17	6	18.606	43
	Jan	28.00	6	23.992	51
	Feb	6.00	3	1.000	2
	Total	18.40	20	17.946	51
Total	Nov	7.59	17	7.961	24
	Dec	8.94	18	13.632	45
	Jan	14.37	16	19.339	51
	Feb	5.00	9	5.852	17
	Total	9.42	60	13.458	51

D-2: Descriptive Table of eBird Data

Report

Bird_count

Site	Month	Mean	N	Std. Deviation	Range
AP	Nov	.50	4	1.000	2
	Dec	2.71	7	3.498	8
	Jan	2.33	18	6.399	25
	Feb	3.43	7	9.071	24
	Total	2.42	36	6.068	25
BF	Nov	.00	4	.000	0
	Dec	.00	7	.000	0
	Jan	.00	13	.000	0
	Feb	1.00	8	2.828	8
	Total	.25	32	1.414	8
SLP	Nov	6.33	3	5.508	11
	Dec	6.33	3	7.767	15
	Jan	.71	17	2.443	10
	Feb	.43	7	1.134	3
	Total	1.77	30	3.901	15
Total	Nov	1.91	11	3.807	12
	Dec	2.24	17	4.191	15
	Jan	1.12	48	4.221	25
	Feb	1.59	22	5.315	24
	Total	1.51	98	4.396	25