2018 Nuttall Ornithological Club's Blake Nuttall Progress Report:
Assessing the value of Mass Audubon's citizen science data for climate change biology

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Introduction

Citizen science, the process of engaging the public in data collection, analysis, and reporting, is a rapidly growing field in its scale as well as its contributions to science, education, and society (Dickinson et al., 2010, Bonney et al., 2015, Kobori et al., 2016). While traditional long-term monitoring studies, including those involving birds, are often geographically limited, and expensive to carry out and maintain, many citizen science programs cover broad geographic areas and temporal scales, sometimes resulting in large, cost-efficient data sets that are an excellent resource for land managers, ecologists, and ornithologists (Bonney et al., 2014). However, many potentially valuable citizen science data sets remain unanalyzed and unused by researchers. The first step in unlocking the potential of citizen science is to identify high-quality data sets, quantify their error and identify biases, and assess their value for climate change science and natural resource management (Kosmala et al., 2016).

Conservation organizations with robust citizen science monitoring programs are a source of long-term ecological data (Kobori et al., 2016). Mass Audubon, a Massachusetts conservation organization made up of 56 wildlife sanctuaries statewide, is one such entity that possesses un-analyzed data from citizen science monitoring programs. Here, we assess two long-term ornithological citizen science data sets from Mass Audubon for continuity over time, data quality, and value to ecological research. We will then utilize these data sets to characterize trends in bird abundance, diversity, and breeding success over time and the effect of climate variation on phenology in Massachusetts. The evaluation of these data from an established citizen science program will inform future monitoring efforts at Mass Audubon and beyond, improve our understanding of how climate change affects bird diversity, abundance, phenology, and reproductive success, and help inform management decisions in the sanctuaries.

Project Objectives

Our proposed research will answer three questions with respect to Mass Audubon's citizen science programs in (A) nest box monitoring and (B) historic bird observation data:

> Q1. Are the programs successful in reaching their scientific and educational goals? What aspects of each program make them more or less successful?
>
> Q2. Are the volunteer-collected data of high enough quality and standardized enough to be combined and compared across sanctuaries and over large geographic areas?

Q3. For data determined to be of sufficient quality and methodology in Q2, how do bird abundance, diversity, breeding success and phenology vary over time and in relation to climate variation and degree of urbanization?

Preliminary Results and Discussion

(A) Nest box monitoring: We investigated the value of nest box monitoring programs at four Mass Audubon sanctuaries (Broadmoor, Habitat, Pleasant Valley, and Long Pasture Wildlife sanctuaries) in reaching science and outreach goals as well as contributing to our understanding of the effects of climate change on phenology and reproduction in aerial insectivorous cavity nesting birds.

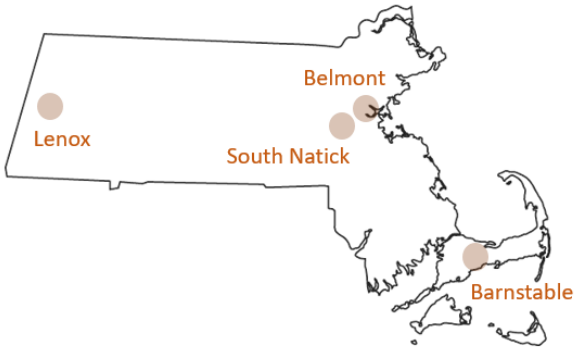

Figure 1. Locations of Mass Audubon Sanctuaries with ongoing nest box monitoring included in our assessment: Pleasant Valley in Lenox, Broadmoor in South Natick, Habitat in Belmont, and Long Pasture in Barnstable.

Synthesizing nest box monitoring data across sites Through a series of site visits, interviews with Audubon staff, and examination of the data at each sanctuary, we determined that the Tree Swallow monitoring protocols were not consistent enough to synthesize across these four sanctuaries (see Table S1). The primary drivers of this conclusion were the variation in monitoring protocols, large gaps in data collection, and differences in predator control methods and philosophies made it impossible to compare clutch initiation date, clutch size, hatching and fledging success across sites.

Data Quality Of the four sanctuaries examined, the nest box monitoring program monitoring tree swallows at Broadmoor Wildlife Sanctuary in South Natick, MA contained the most ecologically relevant data over the longest time scale. Because we are interested in examining relationships between reproductive variables and climate change our analysis will use only these data. At Broadmoor there are 55 nest boxes distributed across the 253 ha wildlife sanctuary in South Natick, MA (Figure 2A). The nest boxes are and have always been concentrated in two open fields on the property: the nature center field (23 boxes) and the wildlife pond (12 boxes). The nature center boxes represent a dry field habitat, while the wildlife pond boxes are adjacent to a flooded wetland.

In assesing the quality and continuity of nest box monitoring data at Broadmoor, the data for the 13 of the 31 years since nest box establishment was robust enough to include in the climate analysis; these years are 1987-1991, 1994, and 2012-2018. We included years in the analysis when nests were visited once weekly during the nesting season (April through July/August). The date of clutch initiation was estimated to within one day by backdating one egg per day from the date of the first record of eggs in a nest (Dunn and Winkler 1999). Tree swallows generally lay one egg per day and are single brooded (Robertson et al. 1992). If boxes are not checked weekly, researches cannot confidently estimate the clutch initiation date. The preliminary results reported here are for tree swallow nests using data from 1987 to 2017.

Variation in tree swallow reproductive timing and success with climate We predict that clutch initiation will begin earlier in warmer years and that clutch sizes will be smaller in years with higher precipitation, both due to the sensitivity of insects, tree swallow prey, to spring and

summer temperatures and rainfall (Parmesan 2009). We do not predict to observe a change in reproductive success due to the abundant available nest sites (Dunn and Winkler 1999).

Weather data was provided by NOAA and collected at the Blue Hill Observatory and Science Center in Milton, MA (28 km from Broadmoor). Weather variables include mean/average max, average min March, April, May, and June temperatures as well as total precipitation for each month in each study year. We have examined linear relationships between spring temperature and precipitation and clutch initiation and clutch size. These analyses are done in the style of Dunn and Winkler 1999, an assessment of the relationship between tree swallow reproduction and climate variables in North America using data largely collected before aerial insectivore declines began. We are interested in comparing out findings to those of this study.

We also propose to use a linear mixed-model approach to test the effect of environmental conditions as well as location and box dimensions on a tree swallow reproductive success and phenology, using clutch initiation date as a measure of seasonal timing and clutch size as a measure of reproductive success. Box dimensions are thought to influence breeding success by many conservation organizations (i.e. Tree Swallow Projects) and location within the sanctuary may indicate some effect of nest box density or differences in insect abundance (Dunn et al. 1994). We cannot include specific box numbers, as they changed frequently during the 30 year monitoring period. The results of our preliminary analysis will inform the climate variables that we will include in the mixed effects model.

Preliminary results Clutch initiation date is significantly related to total April rainfall (lm, $p<0.001$, Figure 2B), with later egg laying with higher rainfall. Clutch initiation is also earlier in years with warmer average March temperatures (lm, $p=0.03$), about 0.25 days $°C^{-1}$. However, in both cases the R squared values are very low (0.053 and 0.016 respectively), calling into question the biological relevance of this result. We found no trend in clutch initiation date with time over the 30 year monitoring period. Clutch sizes are significantly (lm, $p<0.001$) smaller now than they were in the past (about 0.25 eggs/nest smaller). Clutch sizes are significantly larger in years with warmer mean ($p=.027$) and minimum ($p=0.007$) April temperatures.

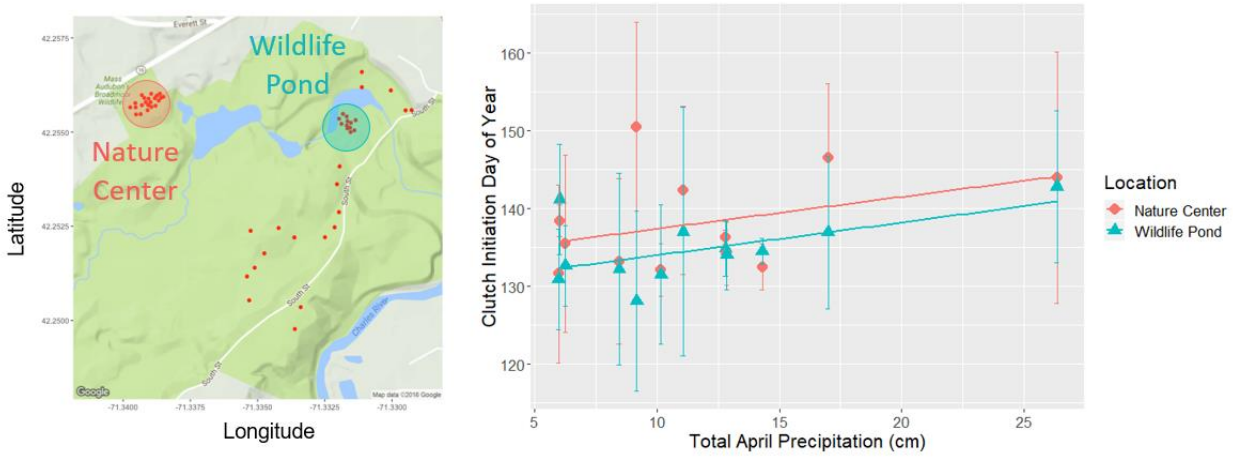

Figure 2. (**A)** Map of the nest box distribution at Broadmoor Wildlife Sanctuary in South Natick, MA with the Nature Center nest box cluster circled in pink and the Wildlife Pond nest box cluster circled in blue. (**B)** Average clutch Initiation day of year for the Nature Center and Wildlife Pond box locations for each year of box monitoring, error bars represent one standard deviation. Clutches are initiated significantly earlier at the Wildlife Pond site than the Nature Center, and clutches are initiated later in years with high April precipitation.

Nest box density and proximity to a water source are thought to potentially effect tree swallow reproductive success. To investigate the effect of location on tree swallows at Broadmoor we separated boxes into five groups based on their location within the sanctuary. We employed a one-way analysis of variance to test for significant differences in clutch initiation and then clutch size with location within the sanctuary over the 30 year monitoring period. We found that clutch initiation varies significantly with site ($p=0.03$, Figure 2B) and using a post hoc pairwise t-test found that the Wildlife Pond, a set of 12 closely associated boxes adjacent to a waterbody, has significantly earlier clutch initiation dates than three of the other locations. We did not find a difference in clutch size between locations.

(B) Statewide bird observation "notecards": While visiting Mass Audubon sanctuaries and staff, we uncovered several potential new citizen science data source to include in this analysis that we were previously unaware of. A summary of the data characterized to date is available in Table S2. Of these potential data sources, we are pursuing the addition of the "notecards" to this project (Figure 3). These notecards contain individual bird observations made by Mass Audubon members from the 1940s to mid-2000s. This is a large an unexpected – but exciting! – finding that we will couple with breeding bird survey data (BBS) to further strengthen our assessment of Mass Audubon citizen science data and its potential applications for ecological research.

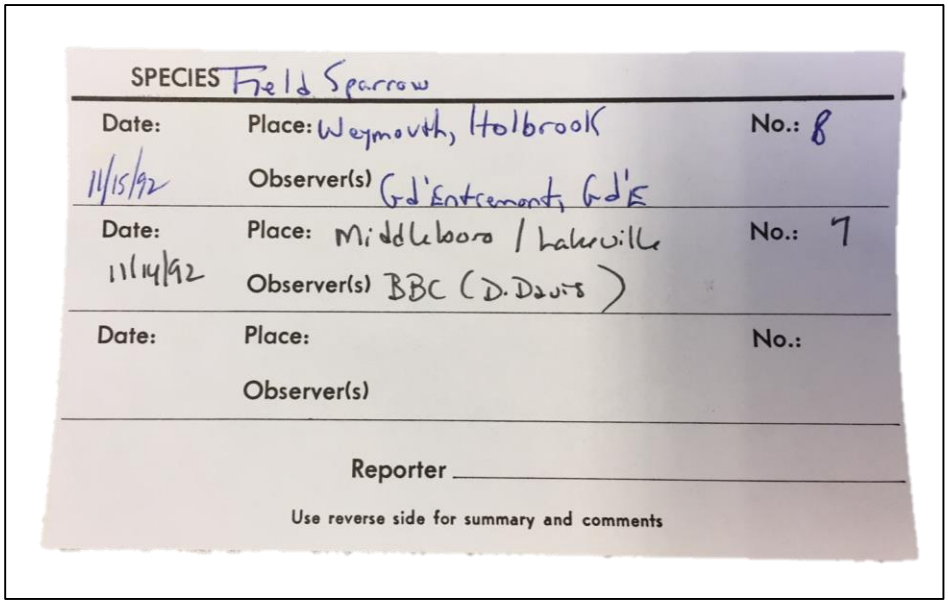

Figure 3. Example of a Mass Audubon notecard from 1992 with two observations of field sparrows. We have called them notecards for the size and shape of the observation slips.

We are pursuing several methods to digitize the many notecard observations. (1) We first chose a subset of the boxes of notecards, four total boxes of cards, to determine how long it would take to identify a single species and enter the data. All the data examined was from 1973 and 1992. Data on the notecards includes the date, location, and number of individuals observed for each species, and can contain up to 4 species total – though most contain one. Of the four boxes, there were 20 cards with tree swallow observations. Finding these cards took an hour and fifteen

minutes, while entering the data took around 30 minutes. (2) We then spent several days entering all the notecard observations within a single box to determine how long digitization would take and get a sense for the spatial coverage of a subset of data. The data entered is from 1988 and gives the date, location, species, and number seen for a variety of miscellaneous birds spotted. Lab members were able to enter approximately 100 observations per hour. The majority of these observations are from Cape Cod, with some from Eastern Massachusetts. (3) We are also currently exploring online, crowd sourced digitization of this data. In this case we would upload images of the notecards to a web platform, like CitSci.org, and encourage Mass Audubon members to digitize the cards at their leisure. This method has been successful in herbarium specimen digitization.

We have been granted an extension on our project to continue the process of notecard digitization and analysis. We plan to assess sampling effort and intensity by comparing notecard observations to BBS data. By comparing the numbers of target benchmark species observed during the BBS to notecard observations in overlapping years we will quantify differences in sampling effort and identify geographic and species biases in the notecard data. This will allow us to determine if the notecard data is ecologically relevant to furthering our understanding of climate effects on Massachusetts bird populations.

References

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Table S1. Summary of nest box monitoring programs for Mass Audubon Wildlife Sanctuaries across the state of MA: Long Pasture in Belmont, Habitat in Belmont, Broadmoor in South Natick, and Pleasant Valley in Lenox.

Sanctuary	Initial Goal	Years of Monitoring Data	# Nest Boxes	# Volunteers per year	Nest box monitoring frequency	Volunteer Training	Current Monitoring Protocols	Location of data	Remove House Sparrows (Y/N)	Predator Control (Y/N)	Variables Recorded	Absences Recorded	Publications to date (Y/N)
Broadmoor	Public engagement, education; TS reproductive success	1987-1991; 1994; 2012-2013; 2015-2017	55	3	1 x per week	Shadow former volunteer, no formal materials	Independent protocol, described in methods	Digitized, stored at Broadmoor	Y	Y - pole greasing	Nest Presence, Species, # Eggs, # Young, # Fledge	Y	N
Habitat	Public engagement, education	2015-2017	46	3 to 5	every 4 to 5 days	Shadow former volunteer, Nestwatch protocol	Cornell Nestwatch	Nestwatch	N	N	Nest Presence, Nesting attempt, Species, # Eggs, # Young, Status and activity codes	N	N
Pleasant Valley	Participation in North American Nest Report Card Program	1982-1995; 2016-2017	16	unknown	2 x per week reported, data shows frequent 1-2 week gaps	Shadow former volunteer, no formal materials	Mass Audubon published nest box monitoring protocols	Not digitized, stored at Long Pasture	Y	Y - PVC poles	Species, # Eggs, # Young	N	N
Long Pasture	Unknown	2006-2017 (little data 2006-2014)	30	3	2 to 3 x per week reported, data shows frequent 1-2 week gaps	Shadow former volunteer, no formal materials	Cornell Nestwatch	Nestwatch	N	N	Nest Presence, Nesting attempt, Species, # Eggs, # Young, Status and activity codes	N	N

Table S2. Mass Audubon dataset names, dates and locations discovered that may be of interest to researchers. The entered data spans the years 1973-1992 and contains the date of the report, the type of report it was, and where the report was taken.

Date	Type of Data	Location
8/13/1988	Massachusetts Daily Field Card	P.I. Marshes by boat
12/3/1986	Massachusetts Daily Field Card	Fresh Pond
12/6/1986	Massachusetts Daily Field Card	Westport, Acoaxet, Dartmouth
12/6/1986	Massachusetts Daily Field Card	Newburyport
12/7/1986	Massachusetts Daily Field Card	Amherst, Winsor, Quabbin
12/7/1986	Massachusetts Daily Field Card	Nohant, Revere-Winthrop, E. Boston
8/28/1988	Massachusetts Daily Field Card	Plum Island Marshes
Aug-88	Bird Census Data	Allens Pond South Dartmouth
12/8/1992	Raptor Survey	Parker River NWR
11/6/1992	Shorebird, Gull, and Tern Survey	Parker River NWR
11/19/1992	Shorebird, Gull, and Tern Survey	Parker River NWR
11/24/1992	Shorebird, Gull, and Tern Survey	Parker River NWR
11/24/1992	Waterfowl, Marsh, and Wading Bird Survey	Parker River NWR
11/6/1992	Waterfowl, Marsh, and Wading Bird Survey	Parker River NWR
11/19/1992	Waterfowl, Marsh, and Wading Bird Survey	Parker River NWR
11/24/1992	Raptor Survey	Parker River NWR
11/6/1992	Raptor Survey	Parker River NWR
11/19/1992	Raptor Survey	Parker River NWR
7/31/1988	Bird Walk Data	Cuttyhunk and Elizabeth Islands
Jul-88	Bird Census Data	Allens Pond South Dartmouth
5/14/??	Massachusetts Daily Field Card	Nantucket
5/29/1988	Breeding Bird Survey	Off Toad Island Rd, Taunton
May-88	Bird Census Data	Allens Pond South Dartmouth
5/29/1988	Route No. 008, Route Name Maynard	Laurel, MD
8/7/1992	Shorebird, Gull, and Tern Survey	Parker River NWR
8/7/1992	Shorebird, Gull, and Tern Survey	Parker River NWR
8/21/1992	Raptor Survey	Parker River NWR
8/21/1992	Waterfowl, Marsh, and Wading Bird Survey	Parker River NWR
8/21/1992	Shorebird, Gull, and Tern Survey	Parker River NWR

8/28/1992	Shorebird, Gull, and Tern Survey	Parker River NWR
8/28/1992	Shorebird, Gull, and Tern Survey	Parker River NWR
8/28/1992	Waterfowl, Marsh, and Wading Bird Survey	Parker River NWR
8/7/1992	Waterfowl, Marsh, and Wading Bird Survey	Parker River NWR
8/16/1992	Massachusetts Daily Field Card	Fall River
Jul-92	Bird Census Data	Allens Pond South Dartmouth
7/14/1992	Shorebird, Gull, and Tern Survey	Parker River NWR
7/14/1992	Waterfowl, Marsh, and Wading Bird Survey	Parker River NWR
7/23/1990	Shorebird, Gull, and Tern Survey	Parker River NWR
7/23/1990	Waterfowl, Marsh, and Wading Bird Survey	Parker River NWR
7/2/1992	Waterfowl, Marsh, and Wading Bird Survey	Parker River NWR
7/2/1992	Shorebird, Gull, and Tern Survey	Parker River NWR
7/28/1992	Shorebird, Gull, and Tern Survey	Parker River NWR
7/28/1992	Waterfowl, Marsh, and Wading Bird Survey	Parker River NWR
Jun-92	Bird Census Data	Allens Pond South Dartmouth
6/12/1992	Shorebird, Gull, and Tern Survey	Parker River NWR
6/12/1992	Waterfowl, Marsh, and Wading Bird Survey	Parker River NWR
6/26/1992	Shorebird, Gull, and Tern Survey	Parker River NWR
6/26/1992	Waterfowl, Marsh, and Wading Bird Survey	Parker River NWR
6/2/1992	Shorebird, Gull, and Tern Survey	Parker River NWR
6/16/??	Daily Field Card	Boxford, Turkey Hill
10/6/1992	Cape Cod Bird Club Walk and Field Trip List	Forestdale
10/15/1992	Cape Cod Bird Club Walk and Field Trip List	Forestdale

10/18/1992	Cape Cod Bird Club Walk and Field Trip List	Forestdale
10/20/1992	Cape Cod Bird Club Walk and Field Trip List	Forestdale
10/25/1992	Cape Cod Bird Club Walk and Field Trip List	Forestdale
Oct-92	Bird Census Data	Allens Pond South Dartmouth
10/2/1992	Raptor Survey	Parker River NWR
10/8/1992	Raptor Survey	Parker River NWR
10/16/1992	Raptor Survey	Parker River NWR
10/22/1992	Raptor Survey	Parker River NWR
10/27/1992	Raptor Survey	Parker River NWR
10/2/1992	Waterfowl, Marsh, and Wading Bird Survey	Parker River NWR
10/8/1992	Waterfowl, Marsh, and Wading Bird Survey	Parker River NWR
10/16/1992	Waterfowl, Marsh, and Wading Bird Survey	Parker River NWR
10/22/1992	Waterfowl, Marsh, and Wading Bird Survey	Parker River NWR
10/27/1992	Waterfowl, Marsh, and Wading Bird Survey	Parker River NWR
10/2/1992	Shorebird, Gull, and Tern Survey	Parker River NWR
10/8/1992	Shorebird, Gull, and Tern Survey	Parker River NWR
10/16/1992	Shorebird, Gull, and Tern Survey	Parker River NWR
10/22/1992	Shorebird, Gull, and Tern Survey	Parker River NWR
10/27/1992	Shorebird, Gull, and Tern Survey	Parker River NWR
Oct-92	Selected Reports From Boston	Boston
9/4/1992	Raptor Survey	Parker River NWR
9/18/1992	Raptor Survey	Parker River NWR
9/25/1992	Raptor Survey	Parker River NWR
9/25/1992	Waterfowl, Marsh, and Wading Bird Survey	Parker River NWR
9/18/1992	Waterfowl, Marsh, and Wading Bird Survey	Parker River NWR
9/4/1992	Waterfowl, Marsh, and Wading Bird Survey	Parker River NWR

9/25/1992	Shorebird, Gull, and Tern Survey	Parker River NWR
9/18/1992	Shorebird, Gull, and Tern Survey	Parker River NWR
9/4/1992	Shorebird, Gull, and Tern Survey	Parker River NWR
Sep-92	Bird Census Data	Allens Pond South Dartmouth
Jun-88	Bird Census Data	Allens Pond South Dartmouth
Jun-88	June Birds Report	Misc Locations i.e. Bolton, Plymouth, Milford, etc…
6/19/1988	Breeding Bird Census	Mid-Cape
Jun-73	A Checklist of Massachusetts Birds	Cape Cod
Aug-73	A Checklist of Massachusetts Birds	Cape Cod
Jul-73	A Checklist of Massachusetts Birds	Cape Cod