Statistical Analysis of Point Count Bird Surveys and Measuring Biodiversity at Brookhaven National Laboratory

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Research Advisor: _____

Abstract: Point Count Bird Surveys have been conducted at Brookhaven National Laboratory over six different transects (Biology Fields, Peconic River, East Trenches, North Transect, South Transect, and Z-Path) from April through September annually for thirteen years. Within the last two years (2010-2011), the 200 acre solar farm has been added to the landscape and an additional transect was added in 2010 to document effects of this feature on bird populations. There have been one-hundred and twenty-two different bird species identified on the seven transects. The large data set of more than 13,000 entries was analyzed statistically by looking at the different variations among different bird species and by identifying variation from transects to transect. Analyzing the large data set, will allow us to find different trends by species and different trends by transect. Indices that were used to measure biodiversity were Simpsons Index and Shannon-Wiener Index. The indices help test for richness and evenness of each transect. Statistical tests were conducted on the top twenty-five most common birds across all transects to determine which species have increased or decreased over time. The analyses include the average number of birds, standard deviation, and a weighted average. The results are displayed on a scatter plot or a line graph to determine which species and which transects were increasing or decreasing over time. Two out of the seven transects have a slight increase in the average number of birds over the 13 years of data collection. Point Count Surveys are continuing in 2012, but have been reduced to 4 months/yr (May - August) from six (April – September) to focus more on migratory species. This work provides statistically sound data useful for making natural resource management decisions, and supporting environmental planning at Brookhaven National Laboratory and on Long Island.

Introduction: Bird surveys have been conducted at Brookhaven National Laboratory to detect the various bird species present and their relative abundance at specific locations across the 5,265 acre site. Point Count Surveys were started in the year 2000 and are continuing in 2012, but have been reduced to 4 months/yr from six. Therefore, an abundance of data has been recorded over the last thirteen years. Based on a survey by *U.S. Fish and Wildlife Service*, 51.3 million Americans watch birds. There are about 9,865 species of birds found worldwide. At Brookhaven National Laboratory, 122 different species have been detected across seven transects (Biology Fields (BF), Peconic River (PRB), East Trenches (ET), North Transect (NT), South Transect (ST), Z-Path (ZP), and the Solar Farm (SF). Each transect varies in the number and abundance of individual species found. This allows for calculation of species diversity and specific variations within species, and within and across transects. In order to record data, one has to recognize the various bird calls of each species. The date, location, the number of birds heard or seen, the time, temperature , dew point, relative humidity, wind speed, and wind direction at the beginning and end of each transect run are also recorded.

This paper provides information and conclusions based on statistical analysis of the data. Statistical analysis was completed to understand what is occurring over time. We used multiple statistical strategies and formulas to figure out which birds have declined or increased over time; to compare year to year variations; measure biodiversity; and to compare variations between transects. Biodiversity is the main focus of this paper.

Using multiple tests we were able to determine statistically significant changes in biodiversity over the 13 year period.

Materials/Methods: Point Count Bird Surveys have been conducted annually from 2000-2011. Surveys were conducted along multiple routes with point's spaces approximately 300 meters apart. All birds seen or heard during a 5-minute time period were recorded and data including start and stop temperature, dew point, relative humidity, wind speed, and wind direction was recorded into Microsoft Excel® for analysis. Microsoft Excel® is a commercial spreadsheet application written and distributed by Microsoft for Microsoft Windows® and Mac OS X. It features calculation, graphing tools, pivot tables, and a macro programming language called Visual Basic for Applications. Excel is a great tool to use when conducting and organizing large amounts of data such as the thirteen years of data entries.

From 2000-2011, more than 1,956 points were sampled throughout the seven transects at Brookhaven National Laboratory. From 2000-2001, there were 20 transect points surveyed (240 points). From 2002-2009, there were 28 transect points surveyed (1,344 points), and from 2010-2011 there were 31 transect points studied (372 points). The last two years the number of transect points increased due to the addition of a 200 acre solar farm to the landscape and an additional transect was added to document effects of this feature on bird populations. The exact points are surveyed annually over a six month period to obtain statistically sound analysis of the data. Point Count Surveys were initially conducted from March through October, but were reduced to April through September to capture mostly migrating species. Analysis conducted included calculation of the average number of birds, standard deviation, and developing a weighted average for each species. The weighted average normalizes the bird species data for easier comparison of species and to help identify differences in populations, if any. To calculate the weighted average (WA),

$$WA = \left(\frac{total\ number\ entries\ in\ one\ year}{total\ number\ transect\ points\ in\ a\ specific\ year}\right) \bullet (total\ \#\ species\ detected\ per\ year) \cdot$$

These tests helped standardize the population to help identify and compare transects and individual species.

Based on the large data set, two tests were conducted using the Simpson Index (D); a measurement that accounts for the richness and the percent of each species from a biodiversity sample within a zone. The index assumes that the proportion of individuals in an area indicate their importance of diversity. The first is Simpson's index (the probability that two randomly selected individuals in the zone belong to the same subspecies:

$$D = sum(P_i^2)$$

The second is Simpson's index of diversity; the probability that two randomly selected individuals in a zone belongs to different subspecies: = 1- D. Another way to measure biodiversity was to use the Shannon-Wiener index (H). The first step is to calculate for each category (transect). You then multiply this number by the log of the number. While you may use any base, the natural log is commonly used. The index is computed from the negative sum of these numbers. In other words, it is defined as:

$$H = -sum(P_i \log|P_i|)$$

Using species richness (S) and the Shannon-Wiener index (H), you can also compute a measure of evenness:

$$E = H / \log(S).$$

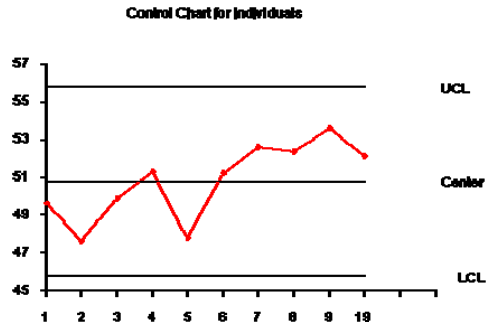
Evenness (E) is a measure of how similar the abundances of different species are. When there are similar proportions of all subspecies then evenness is one, but when the abundances are very dissimilar (some rare and some common species) then the value increases. (REWHC, 1999-2000)

Results: Out of the 122 different species, statistical analysis was done to identify the core subset of birds that make up 80% of the population. Displayed in **Table 1** is the average numbers of individual birds found throughout all twelve years including their percent total and cumulative percent. Based on the cumulative percent, 21 individual birds make up 80% of the population and serve as the core subset of birds. To display what is happening over time, Pareto Analysis was conducted to visually display the results (**Figure 1**). Pareto analysis is a statistical technique in decision making that is used for selection of a limited number of tasks that produce significant overall effect. The scale on the right in **Figure 1** tells us the percentage of defects, which means if the AMRO (American Robin) and BLJA (Blue Jay) were combined; the two individual species make up about 25% of the total population. Overall looking at the Pareto Chart, the core subset seems to be fairly even, which means the measures of different species are relatively similar.

"Species diversity is characteristically unique to the community level of biological organization. The most useful measures of species diversity incorporate consideration of both the number of species (richness) and the distribution of individuals among species (evenness)" (Brower, 1997). **Table 2** displays measures of biodiversity using Simpson's Diversity Index and Shannon-Wiener Index for the twelve years of data. Species richness is accounted for by the122 different bird species. "A community is said to have a high species diversity if many equally or nearly equally abundant species are present" (Brower, 1997). In this case, there is high species diversity. Comparing the species richness among all transects, the number of species are very diverse (**Table 2**). The transect with the highest diversity is the Biology Fields due to having the highest species richness (**Figure 2**). *Simpson's Index D* describes the randomly selected individuals who belong to the same subspecies. *Simpson's Index D* calculated ($D = sum(P_i^2)$, where P_i represents the percent total of the population) is closer to zero; therefore *Simpson's Diversity Index* (*= 1- D)* tells us that the individual each species is independent of the others. The closer to 100%, the more diverse each transect is (**Figure 3**). The results for *Shannon-Wiener Diversity index* ($H = -sum(P_i \log|P_i|)$) for *Evenness (E)* ($E = H / \log(S)$), the numbers calculated for evenness are closer to one which conclude that the there are similar proportions of all subspecies and tells us how similar the different species are throughout the population.

"A percent growth rate -- sometimes referred to as percent change, growth rate or rate of change -- is a useful indicator to look at how much a population is growing or declining in a particular area" (http://www.ehow.com/how_4532706_calculate-growth-rate-percent-change.html). Rate of Change is defined as the speed at which a variable changes over a specific period of time. In **Table 3**, we took the top seven birds most commonly found across all landscapes to find the annual rate of change. The annual rate

of change was calculated using the formula: *(Final Year - Initial year)/(number of years)* and then changing that number to a percent. Graphically, the rate of change is represented by the slope of a line. For this reason, **Figure 4a** represents the most prevalent bird found on the landscape where the rate of change (slope) is -0.0295. Therefore, the slope is closer to 0, which tells us that the population is not changing much on average. The number of American robins found each year is consistent. The blue jay is the second most common bird species found at Brookhaven National Laboratory. Looking at **Figure 4b**, blue jays have a greater decline rate over the past twelve years. Even though it graphically shows a greater decline, it does not necessarily mean that the population is changing on average. Looking at the annual rate of change, the blue jays slope equals -0.0851. Therefore, pretty much all the slopes for the top seven birds are changing little on average. "Control charts for individual measurements, e.g., the sample size = 1, use the moving range of two successive observations to measure the process variability" (Nist, http://www.itl.nist.gov/div898/handbook/pmc/section3/pmc322.htm). The Individual Charts (I-Charts) graphed for the top seven bird's display the overall average over the course of twelve years. The figure below is an example control chart for individuals. The center represents the mean (average). Upper Center Level (*UCL*) and Lower Center Level (*LCL*) represent the average of the moving range of two observations. The process (chart below) is in control, since none of the plotted points fall outside either the *UCL* or *LCL*. Applying this control chart to graph the top 7 most common birds, **Figure 5a** and **Figure 5b** display examples of I-Charts for American Robin's and blue jays. The two birds displayed in the charts are in control, as well as the rest of the top 7 birds that were graphed.



For each transect, the number of birds detected for the entire year was recorded. **Figure 6** displays six graphs of the six different transects (Biology Fields, East Trenches, South Transect, North Transect, Peconic River, and Z-Path). The seventh transect, Solar Farm (SF), did not have enough information to significantly tell what is happening over time because there was only two years of recorded data. Z-Path was added in 2002 so there are only nine years of Bird Count Surveys recorded. However, based on the graphs, the trends lines help visually see if there is an increase or decrease over time. The Biology Fields and North Transect are slightly increasing in the number of birds detected in each year. East Trenches, South Transect, Peconic River, and Z-Path are slightly decreasing over time.

Calculating the weighted average gives us a more accurate comparison from year to year as to which individual bird species is increasing or decreasing over time. The top 25 most common birds that were recorded over all transects were American robin, black-

capped chickadee, blue jay, Canada goose, common grackle, chipping sparrow, Baltimore oriole, brown-headed cowbird, grey catbird, common yellowthroat, eastern towhee, great crested flycatcher, goldfinch, eastern wood peewee, northern cardinal, northern flicker, red-breasted nuthatch, pine warbler, northern mockingbird, yellow-billed cuckoo, ovenbird, tufted titmouse, American crow, mourning dove, and red-eyed vireo. Finding the weighted average normalizes the bird species data so that it is easier to compare between species and see various trends. **Figure 7** displays the 16 out of 25 birds that are increasing overtime and **Figure 8** displays the 9 out of 25 birds that are decreasing over time.

Discussion: Point Count Bird Surveys completed at Brookhaven National Laboratory have resulted in significant amounts of data available for statistical analysis. Each year the same two people conduct bird surveys by recording the same data variables every year. This is important because it improves comparability of the data set for a more accurate analysis. The analysis done in this research was focused on the distribution of the biological data only. It did not take into account other factors such as temperature, time, dew point, humidity, wind speed, or wind direction. We only looked at variations, trends, and measures of biodiversity based on the individual numbers of birds found, the overall number of birds found, and within and between transects.

Estimating abundances and trends in abundance is an objective of many wildlife monitoring programs, with point-count surveys being the most popular approach for monitoring avian populations. As an example, Thompson and La Sorte conducted Bird Count Surveys for seven years (1997-2004) in the Ozark-Ouachita Interior Highlands (OOIH). Counts at each point were conducted for 10 minutes. The birds that were consistently detected for their data collection are Acadian flycatchers, Blue-winged warblers, Ovenbirds, Prairie warblers, Red-eyed vireos, and Wood thrushes. (Thompson & La Sorte, 2008) At Brookhaven National Laboratory (BNL), we have been conducting bird count surveys for twelve years (2000-2011) and counts at each point are conducted for 5 minutes. We have found the same exact birds at our location that were found in the Interior Highlands. The results show a huge difference in the number of birds found among the different areas. In 2000, one blue-winged warbler was found at BNL, where 42 were found in OOIH. The biggest difference was comparing the red-eyed vireos. Only 28 were located at BNL, where 1,086 were found in OOIH. The biggest factor that is probably affecting such a huge difference in the results is the location that the birds are nesting. Even though the same exact birds were found at BNL and OOIH, OOIH is within the Central flyway while BNL is on the Atlantic flyway and variations in habitat and nesting areas play a key role in abundance.

Habitat destruction, degradation, and location of areas play a factor where birds nest. Changes in habitat and nest site availability could be the main reason why some of the top 25 most common birds are either declining or increasing. Sixteen out of twenty-five species are increasing over time indicating either stable populations or populations adapting well to gradual environmental changes. Nine out of the twenty-five common species are decreasing which, depending on the rate of decline, may indicate an inability to adapt to gradual changes. While areas served by the transects have had little significant man-made change. Natural change has occurred in large areas of the Laboratory resulting in changes to habitat due to loss of tree species affected by insects. Two out of seven

transects show increasing numbers while the others are decreasing in bird population. The analysis completed did not take into consideration the outside environmental information that could affect bird populations. For example, in 1999, presences of the West Nile Virus began affected bird populations. West Nile Virus affected two commonly found bird species at BNL; blue jays and American crows. This could explain why these two species are decreasing over time. Other changes that have happened at BNL are the disappearance or decline of the scarlet oak trees, the over population of deer, control of fire, and clearing of approximately 165 acres within and near the Biology Fields to develop the Solar Farm. The data raise questions as to why some of the birds are increasing while others are decreasing. This initial statistical analysis, suggests the need for more research to be done to better understand the changes seen.

Acknowledgements: Statistical Analysis could not have been done without the hard work Tim Green and Ernie Lewis have put into dedicating their time for twelve years conducting surveys. Tim has guided me through how to analyze his data as well as refer me to a very helpful statistician, Fred Rispoli at Dowling College. I worked with Fred for about two weeks and I want to thank him for his time he put into helping me further analyzing this large data set. I would also like to thank Brookhaven National Laboratory and the SULI program for providing me with this wonderful opportunity.

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Figure 1:
80% of Bird Population (Average, Percent Total & Cumulative Percent over 12 years)

	Common Name	Overall Averages	% of Total	Cumulative %
1	American Robin	239.08	10%	10%
2	Blue Jay	213.33	9%	19%
3	Eastern Towhee	212.92	9%	28%
4	Chipping Sparrow	183.58	8%	36%
5	Common Grackle	141.25	6%	41%
6	Black-capped Chickadee	133.42	6%	47%
7	Canada Goose	79.33	3%	50%
8	Brown-headed Cowbird	67.17	3%	53%
9	Ovenbird	66.75	3%	56%
10	Eastern Wood Peewee	64.67	3%	59%
11	Goldfinch	61.25	3%	61%
12	Grey Catbird	60.08	3%	64%
13	American Crow	56.67	2%	66%
14	Pine Warbler	53.17	2%	68%
15	Baltimore Oriole	46.08	2%	72%
16	Double-crested Cormorant	45.33	2%	74%
17	Mourning Dove	35.17	1%	76%
18	Tufted Titmouse	29.00	1%	77%
19	Red-breasted Nuthatch	27.08	1%	78%
20	Northern Flicker	26.42	1%	79%
21	Cedar Waxwing	23.33	1%	80%

Figure 1:
Pareto Analysis; Average number of Birds (left axis), Percentage of Defects (right axis)

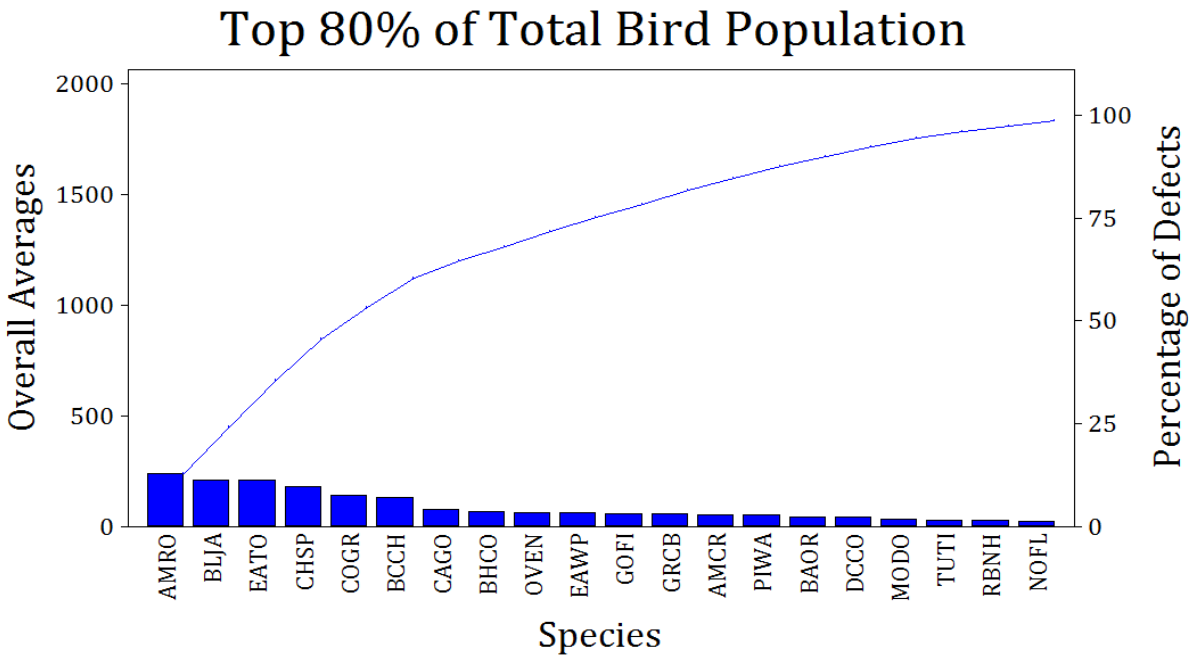


Table 2:
Measures of Biodiversity using Simpson's Diversity Index & Shannon-Wiener Index (2000 – 2011)

Indices	Overall	BF	ET	ST	PRB	NT	ZP
Species Richness S	122	108	62	68	92	71	78
Simpson's Index D	0.047	0.024	0.019	0.015	0.074	0.067	0.013
Simpson's Diversity Index	95.31%	97.570%	98.051%	98.462%	92.612%	93.271%	98.671%
Shannon-Wiener Index H	3.600	4.388	4.043	4.193	3.722	3.656	4.335
Eveness	0.749	0.937	0.980	0.994	0.823	0.858	0.995

Figure 2:
Species Richness (S)
Total Number of Individual Species per transect
(Biology Fields (BF), Peconic River (PRB), Z-Path (ZP), North Transect (NT), South Transect (ST), and East Trenches (ET))

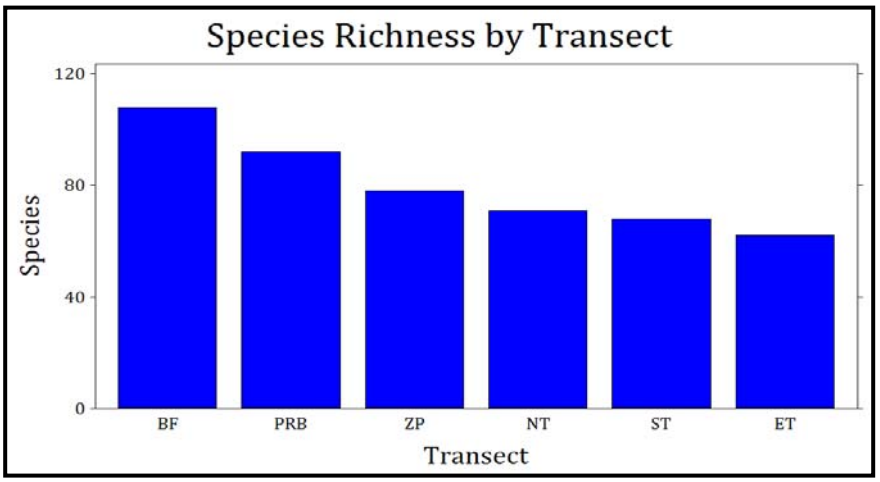


Figure 3:
Simpson's Diversity index
(Simpson's Diversity Index tells us that the individual species belong to different subspecies.
The closer to 100%, the more diverse each transect is.

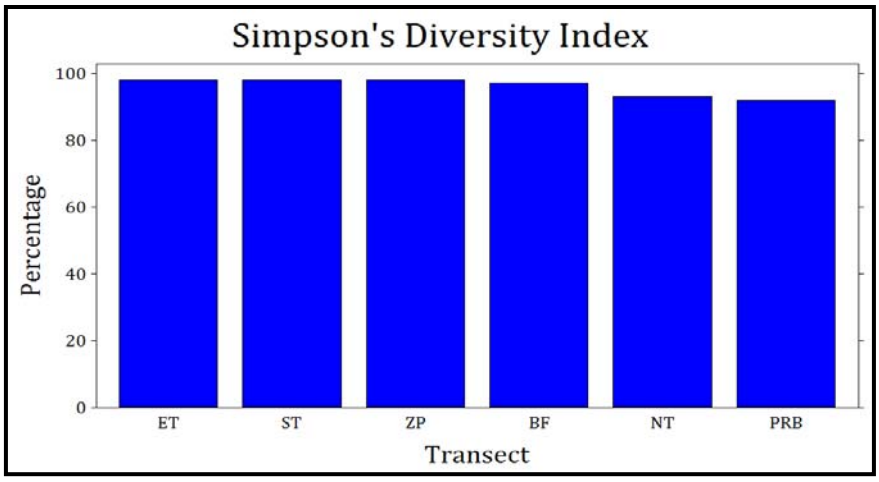


Table 3:
Estimating Annual Rate of Change

Specie	Average	Annual Rate of Change	Annual Rate of Change Percentage
American Robin	239.08	6.7	3.2%
Blue Jay	213.33	4.3	3.5%
Eastern Towhee	212.92	7.9	5.2%
Chipping Sparrow	183.58	8.2	6.6%
Common Grackle	141.25	2.5	6.1%
Black-capped Chickadee	133.42	4.5	7.6%
Canada Goose	79.33	4.1	8.5%

Figure 4a:
American Robin (Linear Regression)

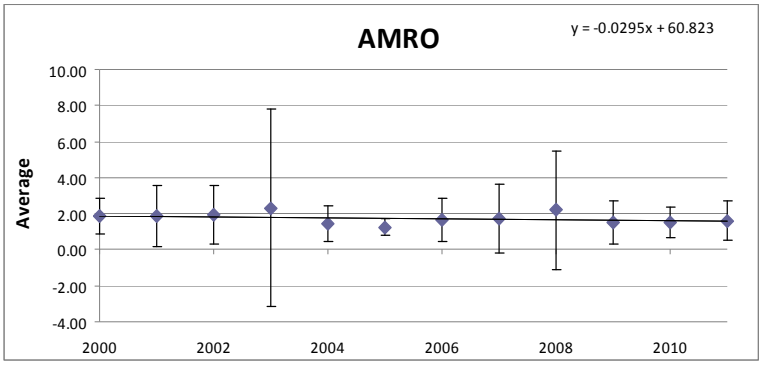


Figure 4b:
Blue Jay (Linear Regression)

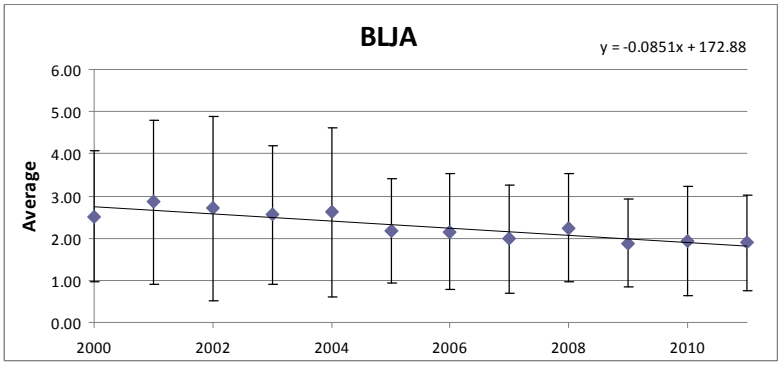


Figure 5a:
I-Chart for the Average Number
Overall of AMRO's detected

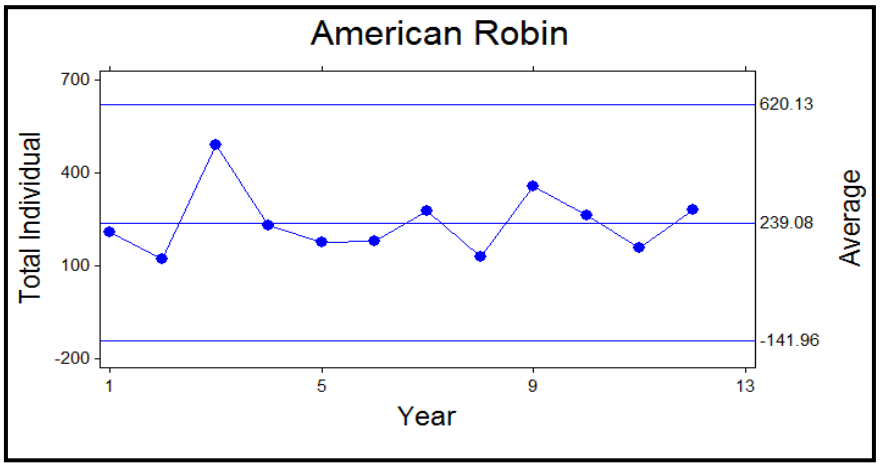


Figure 5b:
I-Chart for the Average Number
Overall of BLJA's detected

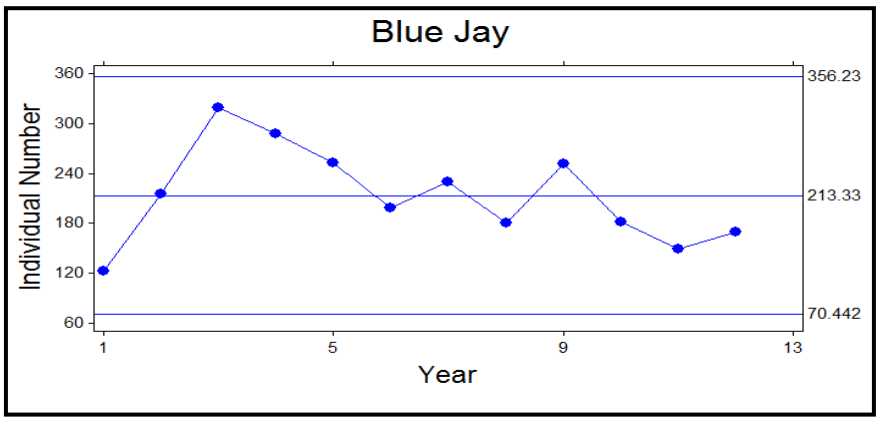
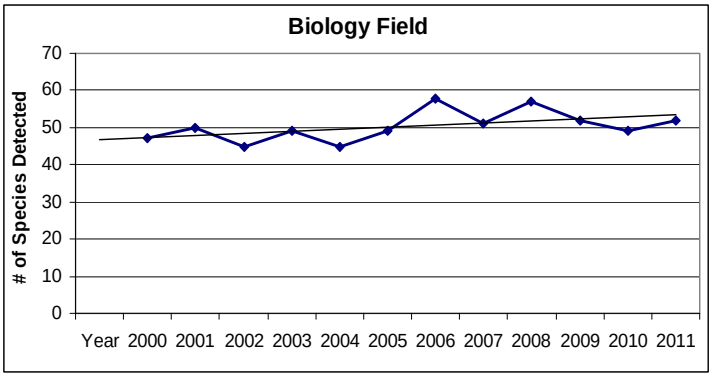
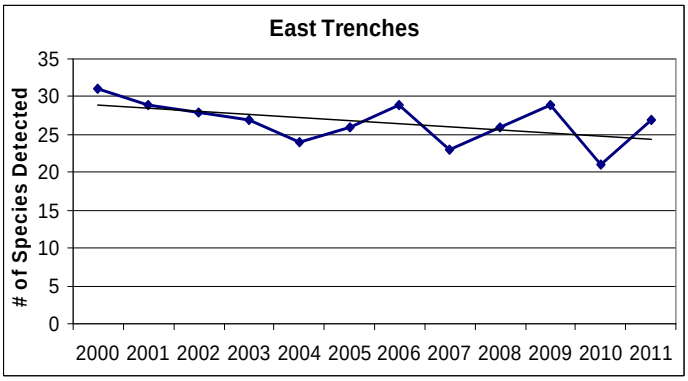
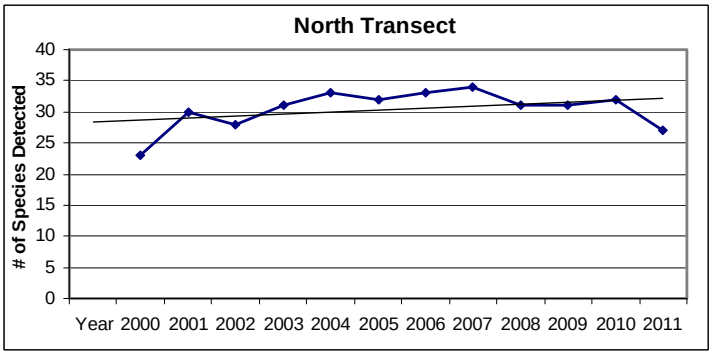
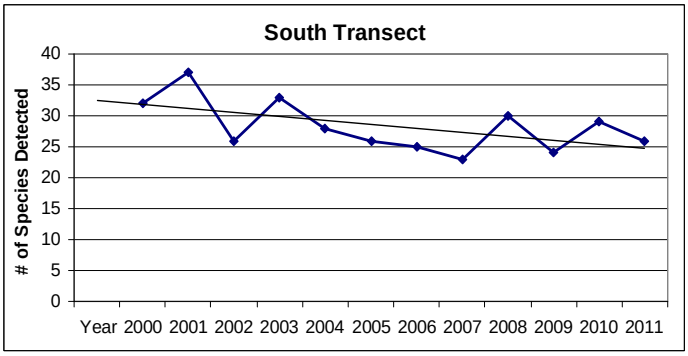


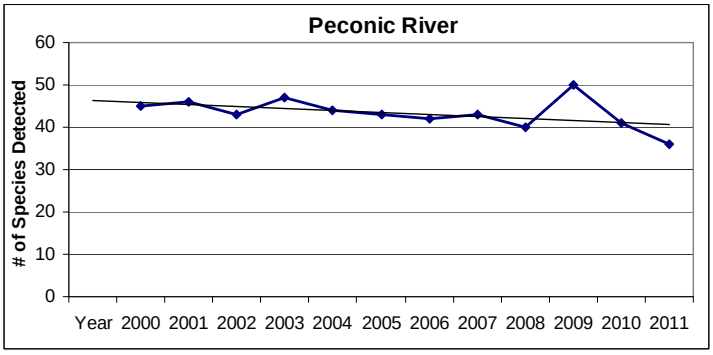
Figure 6:
The six graphs (below) display the total number of individual species detected in each year for each transect.
(Except Solar Farm; not enough information to display a trend line)











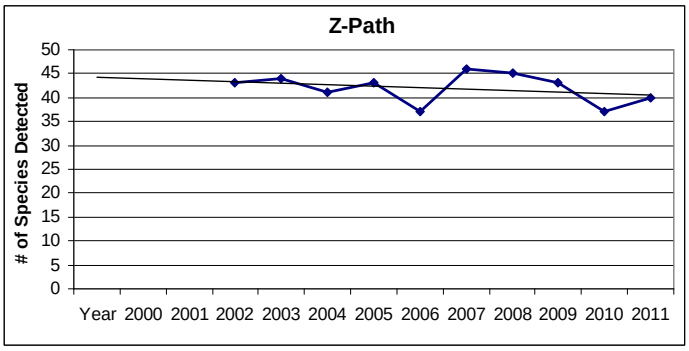


Figure 7:

Top 25 most common birds that are increasing over time according to the weighted average (2000-2011) 16/25 Birds

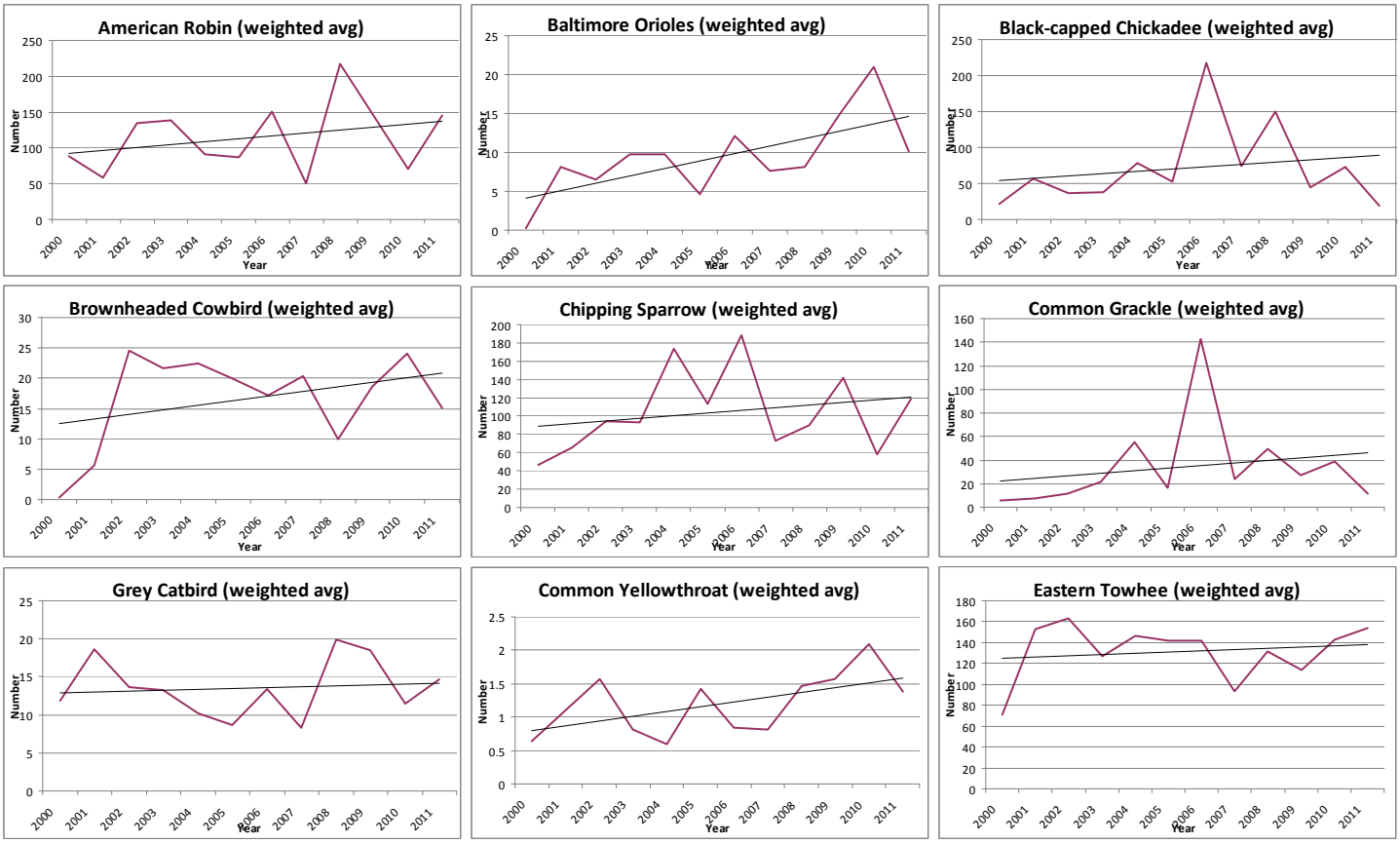
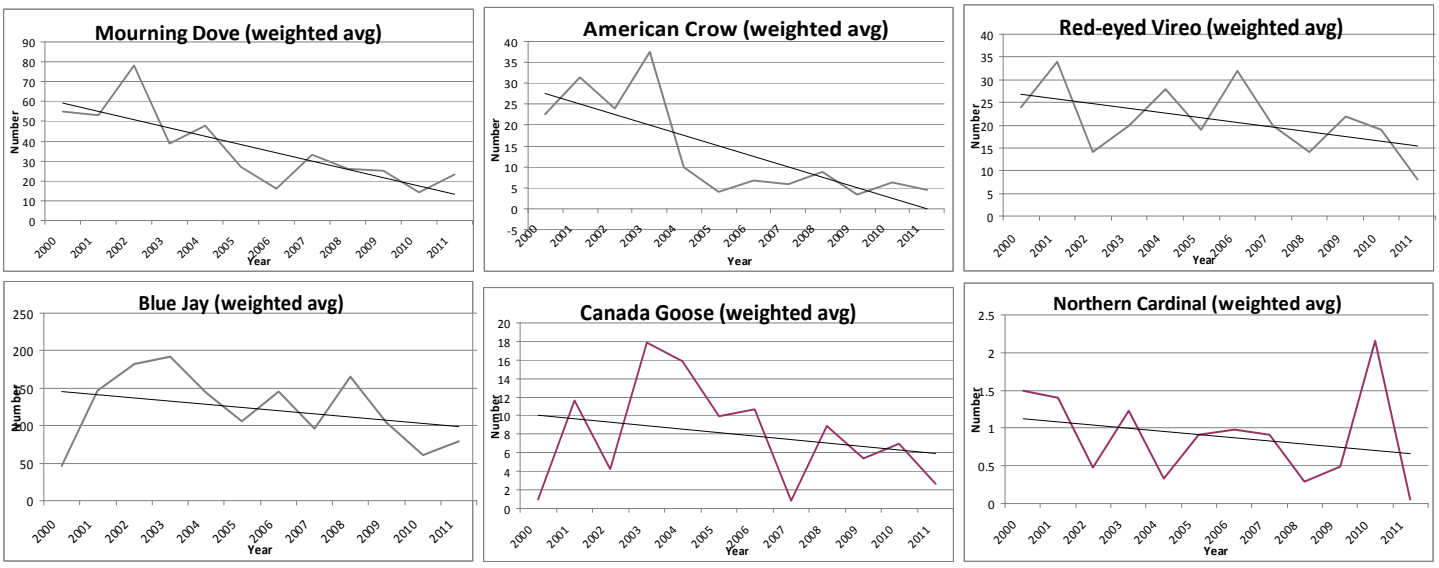
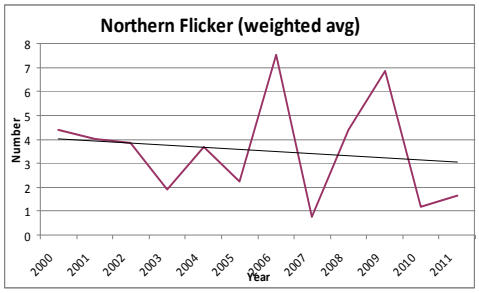
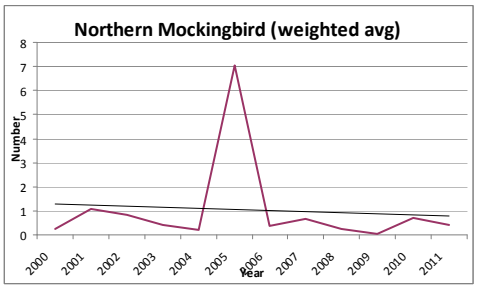
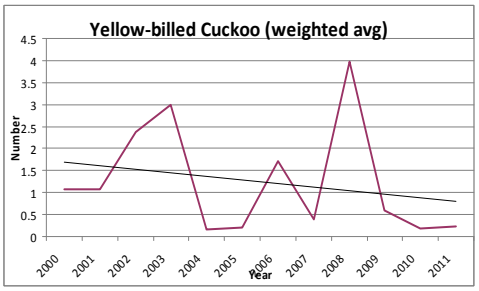


Figure 8:
Top 25 most common birds that are decreasing over time (2000-2011) 9/25 Birds




Northern Flicker (weighted avg)
Number
Year
0
1
2
3
4
5
6
7
8
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011


Northern Mockingbird (weighted avg)
Number
Year
0
1
2
3
4
5
6
7
8
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011


Yellow-billed Cuckoo (weighted avg)
Number
Year
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011