Accuracy and Precision of Using Aerial Photography to Monitor Great Blue Heron Colonies on the Upper Mississippi River National Wildlife and Fish Refuge

Brie L. Anderson
Department of Resource Analysis, Saint Mary's University of Minnesota, Minneapolis, MN 55404

Keywords: Great Blue Heron, Colony, Aerial Photography, Accuracy, Monitoring

Abstract

The U.S. Fish and Wildlife Service (Service) has been monitoring great blue heron colonies on the Upper Mississippi River National Wildlife and Fish Refuge, a 260-mile stretch of the Mississippi River from Wabasha, Minnesota downstream to near Clinton, Iowa. Since the 1990s, the Service has utilized a standardized methodology consisting of digitizing nests on aerial photography. While this task has traditionally been completed by a Service biologist, it may be carried out by a more novice GIS analyst in the future. As a means to validate the Service's data collection model, novice GIS users with no prior nest detection skills digitized great blue heron nests at nine colonies from 2010. Nest location data from the novice was then compared to the experienced Service dataset. Accuracy was measured by comparing the total number of nests and the total number of the same nests both the novice and expert (Service) identified. Precision was measured by the nest distance error, the distance between the novice and expert points associated with the same nest. There were no statistical differences in the total number of nests per colony between the novice and expert. However, the number of the same nests identified by both the novice and expert compared to the expert was statistically different. Errors of omission (nests identified by the expert, but not the novice) and commission (nests identified by the novice, but not the expert) were most common in the southern three colonies, and may have been related to greater leaf out conditions. Nest distance error was significantly different amongst colonies, but within a reasonable distance given the typical size of a great blue heron nest. This study worked under the assumption that the expert data accurately reflects real-world conditions. However, this is not necessarily true as there is an element of human error in censusing a colony. The Service's monitoring method could be improved by utilizing two people, such as a novice and expert, digitizing nests independently followed by a collaboration whereby errors of omission and commission are discussed and eliminated between the users. This two person method would strengthen the monitoring approach by eliminating the assumption that the expert data accurately reflects real-world conditions, and instead, foster a more collaborative approach to account for differences in photo interpretation, experience, and nest detectability.

Introduction

The great blue heron (*Ardea herodias*) is the largest and most recognizable heron in North America, often seen silently wading along the shores of inland waterbodies, or flying high overhead, with deep wingbeats and its head hunched back onto its shoulders. It is one of the most widespread and adaptable wading birds in North America (Vennesland and Butler, 2011).

Anderson, Brie L. 2015. Accuracy and Precision of Using Aerial Photography to Monitor Great Blue Heron Colonies on the Upper Mississippi River National Wildlife and Fish Refuge. Volume 18, Papers in Resource Analysis. 10 pp. Saint Mary's University of Minnesota University Central Services Press. Winona, MN. Retrieved (date) http://www.gis.smumn.edu/

Great blue herons occur throughout much of the United States, with the exception of higher elevations associated with the Rocky Mountains, the desert southwest, and interior Alaska (Vennesland and Butler, 2011). Throughout the northern portion of their range, this species is migratory, returning to their breeding range between February and April (Bent, 1926).

Equally at home in coastal (marine) environments and in fresh water habitats, the great blue heron nests mostly in colonies, commonly large ones of several hundred pairs and occasionally interspersed with other colonial nesting waterbirds such as great egrets or double-crested cormorants (Nelson and Wlosinski, 1999). Great blue herons congregate during the breeding season in colonies called rookeries for the purpose of courtship, nest building, egg laying and incubation, and chick rearing (Vennesland and Butler, 2011). Generally, great blue herons re-use nest sites from the previous year, and rookeries will often grow in size over time. Nests are typically in the crowns of live or dead trees, often near water. The main determinant in rookery selection is proximity to lakeside and emergent wetlands, and secondarily to scrub-shrub and riverine wetlands for feeding habitat. Herons appear to locate colonies near important feeding habitat. Custer, Suarez, and Olsen (2004) found great blue herons nesting along the Upper Mississippi River foraged within five kilometers of their nests.

Among wetland animals, populations of colonially nesting wading birds have shown great utility as bioindicators of contaminants (Custer, Rattner, Ohlendorf, and Melancohn, 1991; Elliot, Butler, Norstrom, and Whitehead, 1989; Thomas and Anthony, 2003; Whitehead, 1990), condition of prey stocks (Frederick and Spalding, 1994), and ecosystem behavior (Ogden, 1994). According to Carver, Lamb, Jennings, Moore, and West (1998), the great blue heron’s position as a top predator in wetland habitats makes it a biological indicator species for the health of wetland ecosystems. Because pesticides and heavy metals accumulate in heron’s primary prey, contaminated herons can indicate wider contamination of amphibians and fish (Short and Cooper, 1985). Additionally, great blue herons are sensitive to habitat loss and associated human disturbance (Bendel and Therres, 1999).

Monitoring of a species’ relative abundance can provide for early detection of declining and vulnerable populations and assess the efficacy of ongoing management plans (Thomas and Martin, 1996; Steinkamp, Peterjohn, Byrd, Carter, and Lowe, 2003). However, monitoring of great blue herons can be challenging, given the size, number, and spatial distribution of colonies, and high cost to conduct comprehensive surveys on a regular basis.

Colonial waterbird monitoring techniques vary depending on monitoring program goals, funding, accessibility, and seasonality. The three most common monitoring methods are ground surveys, aerial surveys, and aerial photography. Ground surveys are typically conducted by watercraft and are the accepted technique for smaller colonies. This method is labor and time intensive and can cause disruption to breeding birds. Aerial surveys can be more efficient; however, this method often underestimates the number of nests or birds and must consider effects of double counting, vegetation, and differentiating breeding and non-breeding individuals. Aerial photography is an accepted method for determining the number of nests in a colony. This method is dependent on clear imagery and has been shown to be more accurate than aerial surveys (Steinkamp *et al*., 2003). Aerial photography is, however, limited in that it does not provide data on productivity or chick survival.

Although the U.S. Fish and Wildlife Service (USFWS; Service) has monitored waterbird nesting colonies at the Upper Mississippi River National Wildlife and Fish Refuge (UMRWFR; Refuge) since the 1960s, standardized methodology and consistency of effort was not initiated until the 1990s. Nest count data have been systematically collected since the 1990s by USFWS staff digitizing nests on aerial photography acquired by USFWS pilots during annual spring flights. This approach is more cost effective and efficient than aerial or ground surveys (Angehr and Kushlan, 2007).

Traditionally, experienced Service staff conducted the nest count analysis. However, with high resolution digital aerial photography and the need for Service staff to allocate time to higher priority projects, it is projected that this task could be carried out by more novice GIS analysts in the future. This study serves to validate the Service's data collection model by analyzing the accuracy and precision of the novice compared to the Service staff in digitizing great blue heron nests at nine colonies on the Refuge during 2010.

Methods

Study Area

The Upper Mississippi River National Wildlife and Fish Refuge protects habitat along the Mississippi River for approximately 260 miles from Wabasha, Minnesota downstream to near Clinton, Iowa. Several great blue heron colonies are dispersed throughout the Refuge, nine of which were analyzed for this study (Figure 1). The nine colonies analyzed in this study and listed from north to south include: Wilcox, Mertes Slough, Smith Slough, Dairyland, Blackhawk Park, Butler Lake, Pleasant Creek, Plum River, and Camanche. To protect the nesting birds and avoid human disturbance, more detailed information on the colony locations cannot be provided.

Figure 1. Approximate locations of nine great blue heron colonies analyzed in this study.

Data Collection

The Service provided aerial imagery required for this study. USFWS pilots acquired aerial photography of nine colonies on the Refuge during an April

19, 2010 spring flight. This flight optimized weather and visibility conditions and partial deciduous tree leaf emergence, which creates a contrast for nest identification on the digital image. Imagery was captured with an Applanix 439 Digital Sensor System (DDS). The DDS is a complete medium format digital aerial imaging solution that includes the fusion of a 39-megapixel camera, a flight management system, and a GPS-aided INS Direct Georeferencing System. Imagery was taken from 1000 feet above ground level (AGL) resulting in a ground sample distance of 0.06 meters.

Great blue heron nests were digitized based on 2010 aerial photography using a colony-specific grid. The grids were used to facilitate a systematic approach to nest detection on the aerial photograph. Generally, grids measured approximately 10 meters (m) by 10 m and were created for each colony prior to digitizing. The novice analyst zoomed to an appropriate scale for nest detection based on the angle of the aerial imagery, vegetative cover, and water or cloud reflection. The high-resolution imagery enabled nest detection at a large scale, i.e., 1:100. The analyst then systematically panned through the imagery using the grid and digitized great blue heron nests.

To decrease sampling bias, three novice GIS analysts with no prior experience digitizing great blue heron nests were used. This measure helped reduce photo interpretation bias that could potentially be introduced by comparing one novice to one expert. Each of the three novice analysts digitized nests of three different colonies; there was no overlap amongst novice analysts and none of the colonies were digitized twice. Colonies were randomly assigned to each novice.

The Service provided nest data digitized by experienced staff for each of the nine colonies. These data were assumed to represent true field conditions and provided a baseline nest location for which to compare novice data to. Additionally, the Service provided great egret and double-crested cormorant data, both of which are colonial nesting species and sometimes share colonies with great blue herons. Great egret is a solid white wading bird and double-crested cormorant is solid black, making both species identifiable on aerial photography. Some of the colonies contained one or both of these species. Nests were not identified for these species; rather, the data associated with these species were displayed during digitizing to help avoid misidentifying them as great blue herons.

Data Analysis

Expert and novice nest location data were compared using a spatial join. To ensure each observer's nest location was associated with the same nest on the aerial image, the spatial join was limited to those features within three feet of the target feature. This distance provided an adequate buffer to include both the novice and expert nest location for the same nest and exclude neighboring nests. Unmatched nests were noted in the attribute table as "omission" – those nests that the USFWS identified, but the novice failed to find. Conversely, nests that the novice identified that the USFWS did not were noted as "commission." These terms help define accuracy of the data. Finally, as a function of the spatial join, the distance between the novice and expert nest pair was calculated. This distance is considered nest distance error and was analyzed as a function of precision. Nest counts, omission, commission, and nest distance were compared for each colony between the novice and expert datasets.

The colony boundary was delineated for each dataset and colony. This polygon provides a visual representation of colony shape and size based on the number and locations of nests. Additionally, parameters such as colony area and nest density per colony were computed from this area to provide additional parameters for comparison.

The colony boundary was delineated based on the total number of nests in each colony. The raw nest location data was used to create a kernel density raster, which was input into the open source software Geospatial Modeling Environment (GME; Beyer, 2012). The isopleth tool within GME was used to create a polygon based on the raster dataset representing a probability surface. Isopleths represent the boundary lines that contain a specified volume of a surface. In this case, the 1.0 isopleth represents the line containing 100% of the volume of the raster surface, which was used as the colony boundary. Colony area and nest density were calculated based on the colony boundary. Colony boundaries were delineated for both the novice and expert data at each of the nine colonies.

Statistical Analysis

The novice and expert data were compared using paired student's t-tests. Specific comparisons included total nests per colony, number of nests identified by both the novice and expert, colony area, and nest density. Additionally, an analysis of variance (ANOVA) was conducted on the nest distance error for each colony. Finally, a 2-factor ANOVA without replication was conducted on the total nest count (dependent variable) for the colony and observer (novice vs. expert) parameters. Statistics were analyzed using IBM's SPSS Statistics 22 software (IBM Corp., 2013).

Results and Discussion

Nest Identification

Overall, novice users underestimated the total number of nests compared to the expert user. However, the total nests for each colony were not statistically different between the novice and expert ($t = 1.063$, $p > 0.05$). This was reinforced by the ANOVA 2-factor test, which found no significant differences between the novice and expert ($F = 1.130$, $p>0.05$) but, as expected, identified highly significant differences between colonies ($F = 830.107$, $p<0.05$). Much of the underestimation occurred at the three most southern colonies: Pleasant Creek, Plum River, and Camanche.

Significant differences were detected when comparing the number of nests both the novice and expert identified (i.e., the number of nest "matches") to the baseline data, total number of nests identified by the expert ($t = -3.026$, $p < 0.5$). As stated in the methods section, the total number of nests identified by the expert is assumed to be an accurate reflection of real-world conditions, and thus, the baseline data is assumed to not contain errors. Errors of omission, nests identified by the expert but not the novice, were highest at Dairyland, Pleasant Creek, Camanche, and Plum River, which all had errors of omission greater than 10 nests (Table 1). Two colonies, Wilcox and Blackhawk Park, did not have any errors of omission. Errors of commission, those nests identified by the novice but not the expert, were highest at Butler Lake and Dairyland (Table 1). All of the other colonies had errors of commission less than 10 nests.

As indicated by the errors of omission and commission, nest detection varied amongst the nine colonies. Errors of omission were much more prevalent at the southern three colonies: Pleasant Creek, Plum River, and Camanche. Novice users' lack of experience is likely associated with the error at these colonies. All three colonies are more than 75 miles south of the next southern-most colony and had greater leaf emergence, making it much more difficult to differentiate nests. Shadows created by overhanging limbs and nests that were situated lower in the tree's crown, beneath the top story, obstructed views of nests. Additionally, novice users reported taking a conservative approach to digitizing, only digitizing nests they were confident were nests, which was primarily determined by the circular or oval shape and/or a heron visible in the nest.

Where the view was obstructed, novice users were not confident in nest detection. Nest identification was also complicated by four colonies with great egrets and/or double-crested cormorants present. These colonies included Camanche, Mertes Slough, Smith Slough, and Butler Lake. While USFWS provided data on these species, novice users did not consistently use this information while digitizing nests, particularly at the Butler Lake colony, which led to additional errors of commission as the novice interpreted the black cormorants as shadows. Conversely, at the Camanche colony, at least some of the error of omission is related to presence of great egrets, which led to confusion for the novice user, and they therefore conservatively did not detect nests where they should have. The presence of great egret and/or double-crested cormorant at Mertes Slough and Smith Slough did not affect errors of omission and commission as much as the other two colonies.

The Dairyland Colony had the most error in terms of omission and commission. Much of the error with this colony was related to discrepancies in aerial photography.

Table 1. Comparison of novice and expert nest detection at nine great blue heron colonies on the Upper Mississippi River National Wildlife and Fish Refuge.

Colony	**Expert Total Nests**	**Novice Total Nests**	**# of the Same Nests Both Identified**	**Error of Omission[1]**	**Error of Commission[2]**
Wilcox	189	190	189	0	1
Mertes Slough	450	453	449	1	4
Smith Slough	466	466	460	6	6
Dairyland	392	380	368	24	12
Blackhawk Park	62	64	62	0	2
Butler Lake	326	339	322	4	17
Pleasant Creek	206	190	187	19	3
Plum River	204	195	193	11	2
Camanche	320	308	303	17	5
Totals	**2615**	**2585**	**2533**	**82**	**52**

[1]Error of Omission refer to those nests identified by the expert, but not the novice
[2]Error of Commission refers to those nest identified by the novice, but not the expert

Due to the colony's size, the Service provided two images to provide adequate coverage of the colony. Overlap of these images was not seamless, and at least some of the error observed at this colony was dependent on which aerial image was used between the novice and expert. It should be noted that Smith Slough also had two aerial images to provide adequate colony coverage; however, the overlap was much more seamless and did not result in an unusual amount of error.

Colony Area and Nest Density

Colony area and nest density are both functions of nest detection. Colony area amongst all nine colonies was not statistically different between the novice and expert ($t = -0.645$, $p > 0.05$). Differences in colony area were most recognizable at the Smith Slough colony, likely due to the irregular colony shape (Figure 2). The other eight colonies showed little variability in colony shape and area, which may be a function of total nests identified and at least partially in conjunction with these colonies having a more regular colony shape (Figure 3).

Colony shape was affected by the spatial location of and relationship to other errors of the same type (e.g., omission or commission) in a colony. For example, errors that occurred in the internal portion of the colony had less impact on colony boundary than errors on the periphery of the colony. Additionally, colony boundary is a function of a density raster; therefore, colony boundary is more impacted by omission/commission errors that are closer to one another, such as the cluster of omission errors in the southern portion of the Smith Slough colony (Figure 2).

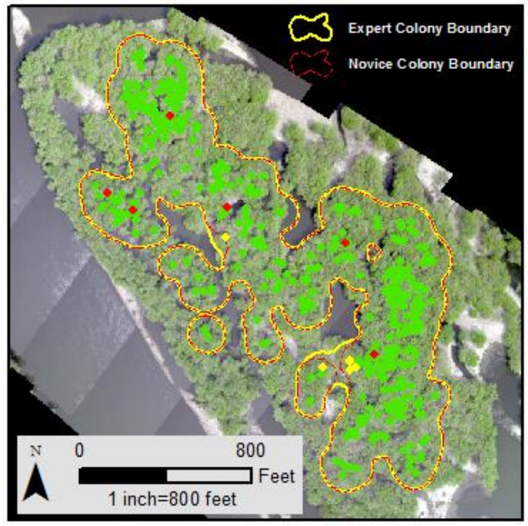

Figure 2. Comparison of colony boundaries for Smith Slough as a function of total nests identified by the novice and expert. Green dots represent nests identified by both users; yellow dots represent nests identified only by the expert; and red dots are nests identified only by the novice.

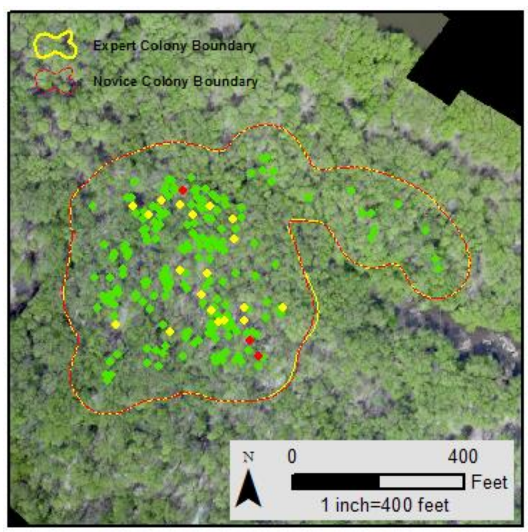

Figure 3. Comparison of colony boundaries for Pleasant Creek as a function of total nests identified by the novice and expert. Green dots represent nests identified by both users; yellow dots represent nests identified only by the expert; and red dots are nests identified only by the novice.

At the Smith Slough colony, errors of commission are more isolated from each other and internal to the colony and therefore do not impact the colony boundary. Conversely, at the Pleasant Creek colony, where errors of omission and commission were amongst the highest observed at the nine colonies, colony area and shape were less impacted and visually less noticeable due to the location of the errors relative to other identified nests and the generally compact colony shape (Figure 3).

Nest Distance Error

There were significant differences in the magnitude of nest distance error when evaluating the precision of the novice to digitize a nest in the exact same location as the expert ($F = 66.777$, $p < 0.05$). The average nest distance error for eight of the nine colonies was less than one foot; only the Camanche Colony had an average nest distance error greater than one foot (Figure 4). There was a fair amount of variability in the range of error distances and error does not seem to be related to the number of nests in the colony (Figure 4). At the Camanche Colony, nest distance error was clustered in an area in the central portion of the colony and differences between the novice and expert nest locations were related to the expert digitizing the nest and the novice digitizing the bird in or on the periphery of the nest.

Generally, nest distance error was within a reasonable range that would be expected amongst several users. The average nest distance error is also consistent with the size of a great blue heron nest, which typically measures from 1.5 to 4 feet across (Vennesland and Butler, 2011). At least some of the nest distance error can be associated to the scale at which the nests were digitized. At the southern three colonies, and due to the leaf emergence, nest detection was better when at a smaller scale (1:500) than that recommended by the Service (1:100). At the Dairyland Colony, which also had a large magnitude of nest distance error, much of the error is related to the multiple colony images and the differences in which user used each photo.

Conclusions

Utilizing a GIS-based approach to monitor great blue heron colonies can be efficient and cost effective. Accuracy and precision of great blue heron nest identification are important characteristics of monitoring great blue heron colonies using aerial photography. This study worked under the assumption that the expert data accurately reflects real-world conditions. However, this is not necessarily true as there is an element of human error in censusing a colony.

The Service’s monitoring method could be improved by utilizing two people, such as a novice and expert, digitizing nests independently followed by a collaboration whereby errors of omission and commission are discussed and eliminated between the users. This two person method would strengthen the monitoring approach by eliminating the assumption that the expert data accurately reflects real-world conditions, and instead, foster a more collaborative approach to account for differences in photo interpretation, experience, and nest detectability.

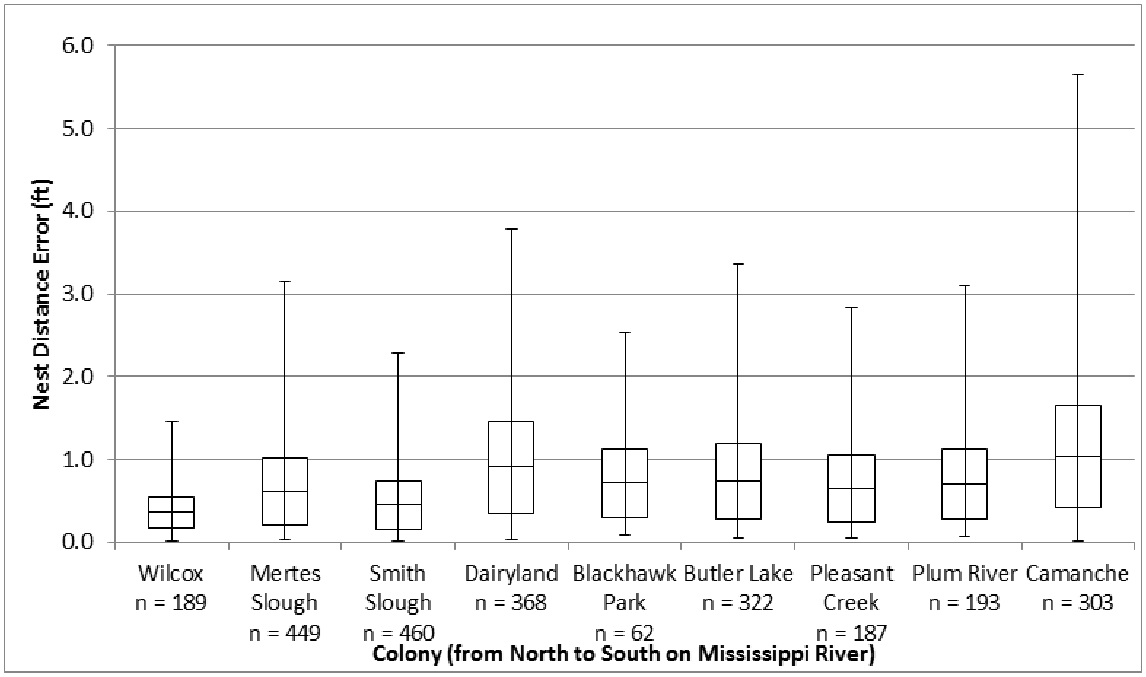

Figure 4. Nest distance error of novice at nine great blue heron colonies on the Upper Mississippi River National Wildlife and Fish Refuge, indicating the mean, the mean ± standard deviation (vertical rectangle), and the range (vertical line).

Acknowledgements

I would like to thank Stephen Winter and Brian Stemper of the USFWS Upper Mississippi River National Wildlife and Fish Refuge for their guidance and support throughout this project. I would also like to thank the Resource Analysis staff at Saint Mary's University of Minnesota including David McConville, John Ebert, and Greta Poser for continually challenging, supporting, and mentoring me throughout this degree program. Finally, thanks to the members of my cohort for helping make the past two years an enjoyable and challenging experience.

References

Angehr, G. R., and Kushlan, J. A. 2007. Seabird and colonial waterbird nesting in the Gulf of Panama. *Waterbirds* 30(3):211-215.

Bendel, P. R., and Therres, G. D. 1999. Proximity of waterbird colonies to development in Maryland. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 53:425-433.

Bent, A. C. 1926. Life histories of North American marsh birds. Bulletin 135, North American Marsh Birds, United States National Museum Bulletin. Washington Government Printing Office, Washington, DC.

Beyer, H. L. 2012. Geospatial Modelling Environment (Version 0.7.3.0). (software). Retrieved from http://www.spatialecology.com/gme.

Carver, B. D., Lamb, J. W., Jennings, L., Moore, R., and West, G. 1998. Great blue heron colony status and nest site characteristics at Sinking Pond, Tennessee. *The Migrant* 69(4):176-178.

Custer, C. M., Suarez, S. A., and Olsen, D. A. 2004. Feeding habitat characteristics of the great blue heron and great egret nesting along the Upper Mississippi River, 1995-1998. *Waterbirds* 27(4):254-468.

Custer, T. W., Rattner, B. A., Ohlendorf, H. M., and Melancohn, M. 1991. Herons and egrets as proposed indicators of estuarine contamination in the United States. *Acta International Ornithological Congress* 20:2474-2479.

Elliot, J. E., Butler, R. W., Norstrom, R. J., and Whitehead, P. E. 1989. Environmental contaminants and reproductive success of great blue herons (*Ardea herodias*) in British Columbia, 1986-87. *Environmental Publication* 59:91-114.

Frederick, P. C., and Spalding, M. G. 1994. Factors affecting reproductive success of wading birds (Ciconiiformes) in the Everglades ecosystem. Pages 659-691. *In* S. Davis and J.C. Ogden [eds.], Everglades: the ecosystem and its restoration. St. Lucie Press, Del Ray Beach, FL.

IBM Corp. 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.

Nelson, E. C. and Wlosinski, L. B. 1999. Wetland Birds of the Upper Mississippi River National Wildlife and Fish Refuge. *The Passenger Pigeon* 61(3): 299-306.

Ogden, J. C. 1994. A comparison of wading bird nesting dynamics, 1931-1946 and 1974-1989 as an indication of changes in ecosystem conditions in the southern Everglades. Pages 533-570. *In* S. Davis and J.C. Ogden [eds.], Everglades: the ecosystem and its restoration. St. Lucie Press, Del Ray Beach, FL.

Short, H. L., and Cooper, R. J. 1985. Habitat suitability index models: Great blue heron. U.S. Fish and Wildlife Service Biological Report 82(10.99). 23 pp.

Steinkamp, M., Peterjohn, B., Byrd, V., Carter, H., and Lowe, R. 2003. Breeding season survey techniques for seabirds and colonial waterbirds throughout North America. Unpublished Final Report. Retrieved January 27, 2015 from http://www.waterbirdconservation.org/pubs/PSGManual03.PDF.

Thomas, C. M., and Anthony, R. G. 2003. Environmental contaminants and nesting behavior of great blue herons from the Columbia and Willamette Rivers, Oregon and Washington. *Northwest Science* 77(4):320-330.

Thomas, L., and Martin, K. 1996. The importance of analysis method for breeding bird survey population trend estimates. *Conservation Biology* 10(2):479-490.

Vennesland, R. G., and Butler, R. W. 2011. Great Blue Heron (*Ardea Herodias*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North American Online: http://bna.brids.cornell.edu/bna/spsecies/025.

Whitehead, P. E. 1990. Toxic chemicals in great blue heron *(Ardea herodias*) eggs in Strait of Georgia. Pages 177-183. *In* K. Vermeer and R.W. Butler [eds.], The status and ecology of marine shoreline birds in the Strait of Georgia, B.C. Canadian Wildlife Service, Ottawa.