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A Landscape Perspective on Bird Beak Deformity:

An Epizootic of Unknown Etiology

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Abstract

Although birds with beak deformities have been documented throughout the literature, the recent spike in occurrences in certain regions has caused concern in the scientific community. A major concern relates to the role of contaminants and environmental degradation in causing or exacerbating this epizootic. This study used spatial and statistical analyses to examine the problem from a landscape perspective. The objectives of this study were to 1) locate and compile a database of known bird beak occurrences, 2) conduct a preliminary assessment of the environmental correlates of this epizootic in order to identify patterns, and 3) make recommendations that could guide future research and data collection. Logistic regression models were generated using known occurrences of bird beak deformity, as well as randomly generated points compared with spatial data on relevant environmental variables. Generalized linear models predicted high probability (P(deformity)=0.88) of deformity occurring when all environmental variables were present. With more collaboration among researchers and data sharing, this method could provide insight into the currently unknown etiology of bird beak deformity.

Introduction

Many studies have documented observations of birds with abnormal beak growth (see Craves 1994 for summary). Reasons for the abnormal growth are not always known, but may include damage by injury, nutrient deficiencies, viral, or bacterial infection (Handel et al. 2010). Contaminants in the environment have also been implicated as a possible cause of bird beak deformity. Although deformities tend to be restricted to individuals or regionally to populations, underlying environmental contributors to the problem cannot be ruled out. Persistence of the problem over long periods of time could have serious repercussions on meta-populations of affected species and their ecosystems. The overall objectives of this study were to survey availability of bird deformity data and explore use of the available data in discerning correlations between deformity occurrence and environmental variables through spatial and statistical analysis. Specific objectives were to 1) locate and compile a database of known bird beak occurrences, 2) conduct a preliminary assessment of the environmental correlates of this epizootic in order to identify patterns, and 3) make recommendations that could guide future research and data collection. Any patterns of correlation suggested by such preliminary analyses can guide further research and form the basis for improvements in data collection efforts and dissemination of data.

Background Information

Bird Beak Deformity

Beak deformities in the wild are generally infrequent, often with unknown etiology; however, in certain cases, the causes were linked to environmental contamination. In the 1970s, high rates of beak and other congenital deformities were documented in aquatic birds in the Great Lakes region (Gilbertson et al 1976; Fox et al. 1991; Yamashita et al. 1993; Bowerman 1994; Ludwig et al. 1996; Ryckman et al. 1998; Custer et al. 1999). These deformities are part of a disorder named Great Lakes Embryo Mortality, Edema, and Deformities Syndrome (GLEMEDS) (Gilbertson et al. 1976). High levels of persistent organochlorines were also recorded in this region during this time. Increased rates of chick mortality and deformities are characteristic of GLEMEDS; it is now generally accepted that there is a strong relationship between this syndrome and contaminants (Ludwig et al. 1996). In the 1980s, high occurrences of similar deformities were found among chicks and unhatched embryos in central California; the causes were found to be high levels of selenium from agricultural runoff (Ludwig et al. 1995, Ohlendorf et al. 1996). More recently, the United States Geological Survey (USGS) published their findings from an ongoing study on beak deformity, which they called avian keratin disorder. High proportions among two species in particular, black-capped chickadee (*Poecile atricapillus*) and northwestern crow (*Corvus caurinus*), were documented at unprecedented rates of deformity within populations, averaging 6.5 ±

0.5% and 16.9 ± 5.3%, respectively (Handel et al. 2010, Van Hemert and Handel 2010). Environmental toxins are suspected to be involved in this outbreak, although their direct effect in causing the deformities has not been conclusively demonstrated.

Spatial Analysis

Birds serve as sentinels for environmental health, so spatial analyses incorporating environmental factors can provide potential clues to the etiology of beak deformity. This study investigated the importance of environmental features in predicting occurrence of bird beak deformity and the use of various spatial analysis methods to consider landscape factors as correlates to the problem. Integrating spatial epidemiology and geographic information system (GIS) technology with avian research can be valuable in conserving ecosystem health. Spatial epidemiology is “the study of spatial variation of disease risk or incident”. It focuses on spatial features that may factor into the spread of the disease and can identify environmental predictors (Norman 2008). Application of GIS software has provided managers with valuable predictive models, which have been used in a variety of ways, such as predicting areas of potentially suitable habitat and understanding the distribution and spread of epizootics. For example, spatial models have been used to successfully predict influential factors in outbreaks of prairie dog plague in western U.S. (Savage et al. unpubl.). GIS can help predict if occurrences of epizootics are random clusters or widespread, as well as predict areas of potential hotspots for future outbreaks (Norman 2008). This method is suitable for such a problem like beak deformity because it allows for examination of interactions between birds and multiple environmental variables. This study focused on three landscape features as potential correlates: cropland (CL), contaminated sites (S) and bodies of water (W).

Toxins are often directly or indirectly released into water, for instance discharged as manufacturing or industrial waste, through which exposing aquatic biota to pollution. Some compounds become bound to fine sediments and are transported by erosion or runoff from agricultural or developed land (USGS 2005). Many of these toxins, organochlorines in particular, have long half-lives and remain persistent in the environment for many years, so can continue to affect ecosystems despite restrictions on use or banned all together (USFWS 2000). This persistence makes them an even greater threat to wildlife. Many of these chemicals are used as pesticides, fungicides or in manufactured materials or processes. Organochlorines are water insoluble and fat-soluble, therefore do not dilute in water and accumulate in tissues of fish. The bonds of these compounds are very strong and are resistant to metabolism, so are often stored by the body in fatty tissue (CDC 2011). Many of the birds and eggs in these studies had high levels of various organochlorines or tetrachlorodibenzo-dioxin equivalents (TCDD-EQs) in their tissues and yolk, respectively. Organochlorines, such as polychlorinated biphenols (PCBs), dioxin, and dieldrin, are compounds of carbon, hydrogen, and chlorine. TCDD-EQs and PCBs have been linked with bill deformities, as well as craniofacial deformities in mammals (Pratt et al. 1984). A causal link has suggested by Fox et al. (1991) between PCBs and the distribution and occurrence of bill deformities in Great Lakes populations and comparative analysis between this and three similar studies validate the strength behind such causation (Ludwig et al. 1995).

Methods

Spatial Database

Data on occurrence of beak deformity were primarily compiled through extensive literature search. Each deformity was evaluated for inclusion based on three criteria. First, any article that discussed at least one bird with a deformity was considered for inclusion in the analysis. Beak deformity was classified as any beak with abnormal growth (excessively longer or shorter than average length for that species), mandibles crossed or laterally offset from one another. Those that were unusual only due to breakage, inflammation, scabbing, or flaking were not included. Second, only data that were collected since 1970 was included. This decade represents the beginning of environmental consciousness among the American public and federal policy. Many significant regulations were put into place since then; for example, the pesticide DDT was banned in 1972 (EPA 2011). This temporal boundary was selected because it allowed the study to incorporate relatively recent articles, which generally all discussed potential correlations with environmental contaminants as contributing causes of the deformities. However, in two cases, research began just prior to 1970, although most of the data collection occurred after that date, so these were included in the analysis. Third, only data collected in contiguous U.S. were included. Reducing the amount of variability in natural environments, as well as variability among environmental regulations and possible contaminants, was necessary for spatial analysis.

Based on correlations presented in previous studies, ‘agricultural land use’ and ‘environmental contamination’ were selected as two of the predictor variables for this pilot analysis. In addition, through initial observation, a common characteristic stood out among those birds documented in the literature with a beak deformity: many of the focal species in the literature were predominantly piscivores, which rely on fish as their main source of food. These include species of terns, gulls, cormorants and herons (Gochfeld 1975; Gilbertson et al. 1976; Monks 1994; Ryckman et al. 1998; Custer et al. 1999). This trophic level is greatly susceptible to biomagnification, where toxins stored in fatty tissues of fish, and in turn, stored in tissues of its predator. Based on the aquatic nature of these affected species and their relationship with water, ‘proximity to water’ was also selected as a predictor variable.

GIS Methods

A point layer of 114 bird beak deformity locations was created in ESRI ArcMap 10 using locations of deformity occurrences were collected from the literature. When coordinates were not given, locations were georeferenced using Biogeomancer and Google Earth. Banding stations, which include the Rogue River Bird Observatory in Dearborn, Michigan and Powdermill Avian Research Center in Rector, Pennsylvania, provided other observational data. A second layer with 114 random points was generated for comparison with the bird beak deformity occurrence model.

Agricultural data were extracted from a 2001 U.S. national land use layer (USGS 2011). This included any land that was classified as one of the following: mostly cropland, cropland with grazing land or cropland mixed with pasture, woodland or forest. These were selected based on the assumption that land designated as cropland is a source of chemical pesticides and herbicides in the environment. A layer of water bodies within the contiguous U.S. was obtained from ESRI Data and Maps software. This included all lakes, rivers and wetlands in continental U.S. Locations of sites designated under the U.S. EPA Superfund Program included Brownfield sites and locations of permittees under the National Pollutant Discharge Elimination System (NPDES) (EPA 2011). NPDES locations were not included in the analysis because of the broad range of pollutants that are regulated and high number of permits, which would have skewed the statistical analysis.

Spatial and Statistical Analysis

Extraction tools in ArcMap 10 were used to determine if a variable occurred within a specified distance of a point. Each variable was analyzed at two distances (10 and 20 km for cropland and Superfund sites, and 5 and 10 km from a body of water). These buffers were selected based on the estimation of distance at which birds might be affected by or interact with the spatial feature, not necessarily based on scientifically significant values. Each point was assigned a binary code for each variable, depending on whether the occurrence point was within or outside of the buffer, and tabulated with each location and corresponding value for each variable.

This table was run through statistical software SPSS 17.0 to create logistic regression models. Linear regression, using generalized linear models, was used because it allows for comparison of two competing models and fits the data to a model, allowing a model to test predictions based on the variables. Model selection follows Akaike's Information Criterion (AIC) to evaluate the best-fitting model (Burnham and Anderson 2002).

The predictor variables exhibited binomial distribution and the model followed the equation:

$$P(\text{deformity})= 1-(1/1+a), \text{ where } a=\exp[-(B_{1X1}+B_{2X2}+B_{3X3})]$$

These models predicted the probability of deformity (P(d)) occurring based on three independent environmental predictor variables for the spatial coefficients and occurrence of beak deformity as the dependent variable.

Results

Logistic regression was conducted using a generalized linear model, with which two models were created. Both were found to be significant through an omnibus test, which detects if there is variance in the data different from normal distribution

(D’Agostino 1971), so further regression tests were conducted. The first model, using the smaller buffers, indicated CL and S to be significant variables, however, W was not significant (table 1).

$$\text{Model 1} = P(d) = 1-(1/1+(\exp[-(-1.951- 0.743[CL] + .940[W] + 1.692[S])])$$

Where all variables were present, this model predicted high probability of deformity occurring (P(d)=0.88; table 3). This model was tested for each possible scenario, which also predicted high probability of deformity when W and SF were both present (P(d)=0.94) and SF only (P(d)=0.85). This model stated that deformity with all variables present was 49 times more likely to occur than not, based on the odds ratio.

Model 2 performed similarly, but resulted in lower probabilities relative to model 1. Both CL and W were not significant in model 2 (table 2).

$$\text{Model 2} = P(d) = 1-(1/1+ \exp[-(-1.391 – 0.001[CL] + .323[W] + 1.473[S])])$$

As expected, with larger buffers, it is less likely to be able to predict occurrence of deformity. With all variables present, this model predicted occurrence with a lower probability than the same scenario in model 1 (P(d)=0.80; table 4). Based on these variables, the odds ratio predicts that deformity was 14 times more likely to occur than not. Based on protocol for using AIC for model selection, there was no empirical support for model 2 in comparison with model 1, which would be selected as the better model.

Discussion

As expected, the model representing closer proximity to cropland and contaminated sites was selected as the best model. These were very promising results based on the limited data, indicating deformity may be correlated to environmental factors. Proximity to water seemed to have no influence on model prediction. This variable may be insignificant because it merely represents the pathway, rather than the point source, of contaminants. This indicates that with more occurrence data and inclusion of additional environmental factors as predictor variables this method could provide valuable insight into the cause of deformity, as well as other wildlife problems relating to contamination.

Limitations

This study and its results demonstrate the potential for spatial and statistical analysis to discern patterns in the occurrence of bird beak deformity. However, the study was constrained by several limitations:

1. Limited deformity occurrence data restricted the ability to fully examine the problem in terms of spatial analysis. With greater number of occurrences, the landscape scale would become a more valuable scale in which to study this subject.
2. Locations of occurrences were not as accurate as they need to be for more precise spatial analysis. This was due to limited information provided on the specific locations where deformity observations were made. Those georeferenced locations may have biased the statistical results by showing an occurrence in greater or lesser proximity to one of the environmental variables
3. Further analysis incorporating the number of documented deformities per location would provide additional insights. This would allow weights to be assigned to occurrences and potentially increase the predictive power of the model.
4. Buffers used for determining proximity were set at arbitrary distances and only used as values for this initial study to examine the potential of this method. There was no biological significance in the specific distances. Additional spatial analysis would require researchers to determine appropriate distances at which negative impacts would be significant.
5. Spatial variables were limited by availability of digital data the study area. This includes land use for the entire intended study area, as well as digital data regarding specific chemical use. More available data and at finer scales would have allowed this method to produce more useful and accurate models.

Recommendations

In order to fully understand this epizootic as a potential widespread problem, there needs to be consistency in data collection and collaboration by researchers. This is necessary to understand any possible agents causing these deformities. One widely used research method in ornithology is bird banding. This is a valuable method, particularly in this case where a bird, in-hand, can provide more specific physiological data than other ornithological research methods. Bird banders have the opportunity to document each deformity they encounter and compile databases for analyses at regional and potentially international scales. More investigation into contaminants as a causative factor would also be an important component of any future research and such variables could be included in any spatial analyses.

This study indicates that a spatial analysis with landscape perspectives can serve as a valuable tool for examining the causes and distribution of bird beak deformity as an environmental problem. However, in order for its potential to be fully realized, some issues need to be addressed. There needs to be more openness with data sharing among the scientific community. The current paradigm that data should be kept private by the researchers hinders progress overall. In the context of this study, data sharing could significantly benefit this project. With more occurrence data included in the analysis, this model could provide a more accurate prediction and serve as a stronger tool in guiding research towards possible environmental correlates.

Bird beak deformity may be caused by a variety of factors, one of which may be environmental contamination. Spatial analysis can be a valuable method in identifying environmental correlates to deformity and could possibly help predict areas that are susceptible to deformity. With more solid empirical data for deformity occurrences and spatial digital data on a finer scale, this method may prove to be beneficial to researchers by inspiring new ideas and directions to in which investigate towards the goal of understanding the causes of bird beak deformity.

Table 1: Model 1 parameter estimates, where buffers from Crops and Superfund were at 10 km and Water at 5km

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test			Goodness of Fit
			Lower	Upper	Wald Chi-Square	df	Sig.	
Intercept	-1.951	.6123	-3.151	-.751	10.159	1	.001	
Crops	-.743	.2822	-1.297	-.190	6.942	1	.008	
Water	.940	.3786	.198	1.682	6.169	1	.013	
Superfund	1.692	.5337	.646	2.738	10.048	1	.002	
Akaike's Information Criterion (AIC)								32.025
Finite Sample Corrected AIC (AICC)								32.205

Omnibus Test

Likelihood Ratio Chi-Square	df	Sig.
24.646	3	.000

Table 2: Model 2 parameter estimates where buffers from Crops and Superfund were at 20 km and Water at 10 km

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test			Goodness of Fit
			Lower	Upper	Wald Chi-Square	df	Sig.	
Intercept	-1.391	.3856	-2.147	-.635	13.012	1	.000	
Crops	-.001	.2866	-.563	.560	.000	1	.996	
Water	.323	.3090	-.282	.929	1.095	1	.295	
Superfund	1.473	.3766	.735	2.211	15.304	1	.000	
Akaike's Information Criterion (AIC)								47.910
Finite Sample Corrected AIC (AICC)								48.090

Omnibus Test

Likelihood Ratio Chi-Square	df	Sig.
21.475	3	.000

Table 3: Probabilities for Model 1 scenarios

Variables	P(No Deformity)	P(Deformity)	Odds of No Deformity	Odds of Deformity	Odds Ratio
None Present	0.48	0.52	0.94	1.06	1.13
SF only	0.15	0.85	0.17	5.78	33.38
W only	0.27	0.73	0.37	2.72	7.42
CL only	0.66	0.34	1.98	0.51	0.26
All Present	0.12	0.88	0.14	7.04	49.50
CL, W	0.44	0.56	0.77	1.30	1.68
CL, SF	0.27	0.73	0.36	2.75	7.55
W, SF	0.06	0.94	0.07	14.79	218.77

Table 4: Probabilities for Model 2 scenarios

Variables	P(No Deformity)	P(Deformity)	Odds of No Deformity	Odds of Deformity	Odds Ratio
None Present	0.60	0.40	1.50	0.67	0.45
SF only	0.26	0.74	0.34	2.91	8.48
W only	0.52	0.48	1.08	0.92	0.85
CL only	0.60	0.40	1.50	0.67	0.44
All Present	0.20	0.80	0.25	4.02	16.15
CL, W	0.52	0.48	1.09	0.92	0.85
CL, SF	0.26	0.74	0.34	2.91	8.47
W, SF	0.20	0.80	0.25	4.02	16.18

References

Bowerman, W.W. 1994. Observed abnormalities in mandibles of nesting Bald eagles, *Haliaeetus leucocephalus*. Bulletin of Environmental Contamination and Toxicology 53(3):450-457.

Burnham, K. P. and D. R. Anderson. 2002. Model Selection and Multimodel Inference. Springer-Verlag, New York.

Center for Disease Control (CDC). 2011. Retrieved on September 26, 2011 from http://www.cdc.gov/exposurereport/data_tables/chemical_group_0802.html.

Craves, J.A. 1994. Passerines with deformed bills. North American Bird Bander 19(1):14-18.

Custer, T.W., C.M. Custer, R.K. Hines, S. Gutreuter, K.L. Stromborg, P.D. Allen and M.J. Melacone. 1999. Organochlorine contaminants and reproductive success of Double-crested cormorants from Green Bay, Wisconsin, USA. Environmental Toxicology and Chemistry 18(6):1209–1217.

D'Agostino, R.B. 1971. An omnibus test of normality for moderate and large size samples. Biometrika 58(2): 341-348.

U.S. Environmental Protection Agency (EPA). 2011. Retrieved on September 28, 2011 from http://www.epa.gov/pesticides/factsheets/chemicals/ddt-brief-history-status.htm.

U.S. Environmental Protection Agency (EPA). 2011. Retrieved on August 15, 2011 from http://www.epa.gov/enviro/geo_data.html.

Fox, G.A., B. Collins, E. Hayakawa, D.V. Weseloh, J.P. Ludwig, T.J. Kubiak and T.C. Erdman. 1991. Reproductive outcomes in colonial fish-eating birds: a biomarker for developmental toxicants in Great Lakes food chains. II. Spatial variation in the occurrence and prevalence of bill defects in young Double-crested Cormorants in the Great Lakes, 1979-1987. Journal of Great Lakes Research 17:158-167.

Gilbertson, M., R.D. Morris and R.A. Hunter. 1976. Abnormal chicks and PCB residue levels in eggs of colonial birds on the lower Great Lakes (1971-73). The Auk 93(3):434-442.

Gochfeld, M. 1975. Developmental Defects in Common Terns of Western Long Island, New York. Auk: 92(1):58-65.

Handel, C.M., L.M. Pajot, S.M. Matsuoka, C. Van Hemert, J. Terenzi, S.L. Talbot, D.M. Mulcahy, C.U. Meteyer, and K.A. Trust. 2010. Epizootic of beak deformities among wild birds in Alaska: An emerging disease in North America? Auk 127(4):882-898.

Ludwig J.P., H.J. Auman, D.V. Weseloh, G.A. Fox, J.P. Giesy, and M.E. Ludwig. 1995.

Evaluation of the Effects of Toxic Chemicals in Great Lakes Cormorants: Has causality been established? Colonial Waterbirds Special Publication: The Double-Crested Cormorant: Biology, Conservation and Management 18(1):60-69.

Ludwig, J.P., H. Kurita-Matsuba, H.J. Auman, M.E. Ludwig, C.L. Summer, J.P. Giesy, D.E. Tillitt, and P.D. Jones. 1996. Deformities, PCBs, and TCDD-equivalents in Double-crested Cormorants (*Phalacrocorax auritus*) and Caspian Terns (*Hydroprogne caspia*) of the upper Great Lakes 1986–1991: Testing a cause-effect hypothesis. Journal of Great Lakes Research 22:172–197.

Monks, V. 1994. Dioxin's toll on wildlife. National Wildlife 32(5):8.

Norman, S.A. 2008. Spatial Epidemiology and GIS in Marine Mammal Conservation Medicine and Disease Research. EcoHealth 5:257–267.

Ohlendorf, H.M., D.J. Hoffman, M.K. Saiki, and T.W. Aldrich. 1986. Embryonic mortality and abnormalities of aquatic birds: Apparent impacts of selenium from irrigation drainwater. Science of the Total Environment 52:49-63.

Pratt, R.M., L. Dencker, and V.M. Diewert. 1984. 2,3,7,8-tetrachlorodibenzo-p-dioxin-induced cleft palate in the mouse: evidence for alterations in palatal shelf fusion. Journal of Teratogenesis, Carcinogenesis and Mutagenesis 4:427-436.

Ramey, C.A., K.H. Mills, J.W. Fischer. 2010. Evolving Analyses of the Shoshone River Skunk Rabies Epizootic in Wyoming. Proc. 24th Vertebr. Pest Conf. Univ. of Calif., Davis: 322-332.

Ryckman, D.P., D.V. Weseloh, P. Hamr, G.A. Fox, B. Collins, P.J. Erwins, and R. J. Norstrom. 1998. Spatial and temporal trends in organochlorine contamination and bill deformities in Double-crested Cormorants (*Phalacrocorax auritus*) from the Canadian Great Lakes. Environmental Monitoring and Assessment 53:169-195.

Savage, L.T., R.M. Reich, L.M. Hartley, P. Stapp, M.F. Antolin. In press. Climate, soils and connectivity predict plague epizootics in black-tailed prairie dogs (Cynomys ludovucanus). Ecological Applications.

US Fish and Wildlife Service (USFWS). 2000. Retrieved on September 26, 2011 from http://www.fws.gov/pacific/ecoservices/envicon/pim/reports/contaminantinfo/contaminants.html.

US Fish and Wildlife Service (USFWS). 2000. Retrieved on April 2, 2011 from http://www.fws.gov/pacific/ecoservices/envicon/pim/reports/contaminantinfo/contaminants.html.

U.S. Department of the Interior, U.S. Geological Survey (USGS). 2012. Retrieved on August 14, 2011 from http://www.mrlc.gov/index.php.

Van Hemert, C., and C.M. Handel. 2010. Beak deformities in Northwestern crows: Evidence of a multispecies epizootic. Auk 127(4):746-751.

Yamashita, N., S. Tanabe, J.P. Ludwig, H. Kurita, M.E. Ludwig, and R. Tatsukawa. 1993. Embryonic abnormalities and organochlorine contamination in Double-crested cormorants (*Phalacrocorax auritus*) and Caspian terns (*Hydroprogne caspia*) from the Upper Great lakes in 1998. Environmental Pollution 79(2):163-173.