GIS and Avian Ecology
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GIS integrates extremely diverse data, tools and ideas into common frameworks for analysis and decision making. GIS is a powerful, evolving tool that is currently used in many fields of research. It is especially influential in the environmental field, as it provides extensive environmental data that can be modeled in coordination with multi-level parameters. Ecologists in particular have appreciated the value of spatial data, formerly obtained via the interpretation of aerial photography, as a tool for data analysis. The dynamic processes that take place on both a spatial and temporal scale for the landscape have a direct link to the species that inhabit that landscape. Ecology is the scientific study of the distribution and abundance of life and the interactions between organisms and their natural environment (Begon et al. 2006). GIS provides a system to perform ecological analysis on categorical and quantitative data beyond what was formerly possible using historical approaches, information and perspectives on how a species relates to its environment both over time and at differing scales.

The numerous applications of GIS in avian ecology is illustrated by its many uses, which range from very simple map overlays of species and habitats, to complex spatial and temporal modeling approaches involving the statistical analysis of data in combination with GIS multi-layering capabilities. As with any animal species, birds have direct spatial and temporal relationships with their habitat. Avian ecology is just one of many disciplines of ecology where GIS is an important tool. Some avian studies that incorporate GIS models are used to predict future populations of birds, or the species composition in a particular area of interest. Other GIS models are used to show basic changes of avian populations over time, or map the presence/absence of a particular species across a landscape.

An overwhelming number of avian studies that incorporate GIS use the software to calculate a habitat suitability index (HSI) and to create habitat quality maps for a particular species of interest. HSI’s are usually calculated by layering environmental variables over points where a bird species has been detected. These points are often buffered, and subsequent analysis determines landscape and environmental characteristics present most often among the points. The points containing key habitat characteristics are given a high HSI in a GIS layer, as they appear to be most important to that species. Thus, HSI (raster pixel) values can be interpolated across the landscape and help to determine potential habitat to be surveyed. Instead of searching many sites for a species, GIS allows digitally displayed spatial relationships to determine sites that have the combination of environmental characteristics correlated with a selected species in order to predict potentially suitable habitat for that species (Isaac et al. 2008). HSI Maps are used to determine where to focus surveys over the landscape, saving both time and money.

GIS can be especially helpful in interpolating values across a landscape from known sites; however, one provision to this process is that the level of accuracy and detail is greater with more data points. The reliability upon the data portrayed through the interpolation and other analyses is a limiting factor when using GIS. This method has been tested with respect to bird distributions using GIS and Bayesean Theory by
The authors’ Bayesian rule-based approach allows for the determination of the distribution of a number of bird species based on the probability of encountering a species, and the known preferences of a species (Tucker et al. 1997). The project investigators successfully identify quantifiable habitat preferences and other distribution factors of three bird species and develop map layers in a GIS using Bayesian formulas, distribution factors, and satellite base-maps. However, accuracy of results is questionable for analyses that contain few known data points that the interpolation is based on.

The effects of scale are also important considerations when planning a GIS analysis. Scale-related error can arise from defining the scale of the study itself. Differences in accuracy on natural resource maps occur due to scaling factors (Miller et al. 1989). For example, Miller et al.’s paper presented a cartographic modeling technique for measuring relations between environmental characteristics and rare species distribution patterns in Tanzania. The authors digitized rare bird distribution data for Tanzania and statistically analyzed the patterns in relation to geographic and environmental variables using the GRID software system. However, the only elevation data for Tanzania was a 10 minute Digital Terrain Model (DTM) and the 10 minute elevation data was at too small a geographic scale to be of use analytically. In addition, the authors found that precipitation data was inaccurate at several locations. The incomplete and inconsistent data coverage limited the scope of this study. Studies intended to show a relationship the presence or abundance of avian populations with landscape-scale habitat characteristics are particularly vulnerable to incorrect scale selection, because habitat characteristics are variable depending on the spatial resolution (Mitchell et al. 2001). Some data gathered by Miller et al. were accurate on a regional scale, but the associated data were not reliable at finer scales of resolution, which is required when attempting to accurately tie environmental data to avian use of a small area. The methods used for analysis of this study required environmental data at a scale consistent with the scale of precision necessary for the recorded biological data. Most data used in avian studies are suitable for landscape level analysis, but the finer resolution required for a more detailed analysis isn’t yet available for many locations.

Methods of avian data collection usually involve point counts along transects or routes. Resulting data is already associated with geographic points, and is therefore easily transformed into a GIS. Private data collected with GPS and heads-up digitized into a GIS is common among avian ecologists. This private data is used along with satellite (land cover) and physiographic data for analyses. Several sources of public spatial data are especially valuable to avian ecologists. One source is the North American Breeding Bird Survey (NABBS) provided online by USGS and the Pawtuxet Wildlife Research Center. This helpful resource can perform online mapping analyses, or distribute spatial data for download into a GIS. Species occurrence data are available online in each state from the Audubon Christmas Bird Counts, as well as from the Ornithological Information Service (ORNIS, supported by the National Science Foundation) and the Monitoring Avian Productivity and Survivorship (MAPS) Program. NASA’s Socioeconomic Data and Applications Center (SEDAC) also recently made raster datasets of species distribution maps available online. The extensive surveys from all these sources provide vital information about trends in bird distributions and populations (Tucker et al. 1997). Furthermore, satellite imagery and Digital Raster
Graphics (DRG), Digital Elevation Modules (DEM), as well as ortho-photography, are increasingly important to avian GIS analyses.

The future of GIS in ecology is a bright one. I believe that satellite imagery and analysis in GIS will also play a larger role as more data is made available, as well as radio-telemetry (as this technology decreases in cost over time). I also believe that the current trend toward ecosystem based management in natural resources will continue, and that GIS will have a critical role in the development of it. In order to create effective management plans for an entire ecosystem, GIS will be used to help organize and analyze the various layers associated with a range of species. GIS is an extremely useful tool that enables ecologists to take into account and address the important issues relating to management of our environment so that meaningful decisions can be made, and the use and effectiveness of GIS will only increase as time moves forward.

The cases presented above only highlight a few uses that may be employed to ecological studies. It does not matter whether the subject of study pertains to land use patterns, agriculture, land cover, vegetation, or wildlife distribution. The importance of GIS to an ecologist cannot be overlooked. However, it is important for ecologists to recognize certain errors that may be involved when using GIS for their studies. It is known now that there is difficulty in building predictive models at finer resolutions (Mitchell et al. 2001). Scaling up only blinds the conclusions to many details that may be important to the study itself. GIS software is able to adjust data layers according to appropriate coordinate systems, but further edits and calculations must be performed which can often take too much time and costs are too high. Inaccurate habitat variables are another source of error. In addition, the high mobility of birds and coarseness of satellite data also lead to difficulty in determining habitat area and boundaries and the spatiality of GIS presents a major limitation. However, it is important to note that although sources of error and difficulties with scale will be encountered, GIS should never be excluded from a study due to them.

Literature Cited

GIS and Avian Ecology: Annotated Bibliography


Bayliss et al.’s paper presented a conservation targeting approach for multi-species assemblages that used a unique combination of modeling techniques. This approach was utilized to identify sites with the highest habitat suitability for three wading bird species within the UK. The first model was generated from habitat association data using multilevel modeling techniques (variation in log odds between grid squares) and was generated from habitat association data from breeding bird surveys. The authors employed indicator kriging to interpolate pixel values from point survey data to account for the spatial aspect of species data while making population assumptions. These two models were combined using Baysean inference to refine the prior probability values, which produced a series of posterior values indicative of habitat suitability. The authors presented probability maps for all three species that were generated as a result of the multi-level, kriging and Baysean modeling approaches. This paper presented a unique and useful combination of modeling techniques that was very effective for habitat suitability investigation. By developing a multi-species approach consisting of three species with similar biology, a more comprehensive management plan can be developed than by only analyzing single species, and a more targeted approach to management than using a multi-species model whose species may not share the same habitat suitability traits.


Butler et al.’s paper was a detailed and impressive work. The authors relay a detailed methodology about how their analysis used GIS components for their data analyses on waterfowl abundance and distribution in Alaska. The authors discuss their data collection, processing and mapping methods, results, and accuracy, as well as compare their adopted three-dimensional (3D) mapping method to other analysis methods in GIS. The objective of this work was to provide refuge managers with geographic waterfowl population data at high resolution by developing GIS techniques for mapping bird distribution, density, and changes in density based on aerial surveys. The best facets of this paper are the description of the process of converting observation location data into 3D density and distribution maps, and discussion that follows about the factors affecting this type of map development and interpretation. Butler et al.’s method for analyzing and graphically representing waterfowl location data was ahead of their time, and increased the use, effectiveness, and application of multi-species aerial surveys in Alaska. Their detailed methods and discussion sections make their GIS analyses easily adoptable for other natural resource managers in Alaska, or anywhere in the world.


This study used GIS to analyze current breeding sites for the powerful owl, an apex predator in Australia, to find potential nesting sites of the species missed by conventional surveys. The
Authors used GIS datasets from the Department of Suitability and Environment (DSE), VICMAP, and private corporations. Habitat data layers were gathered according to important ecological variables for powerful owls in the literature and include dense vegetation, proximity to water, slope, and managed land. The current nest locations’ coordinates were determined using a Garmin GPS and used as a layer of data in the GIS. These nest locations were clipped for a 1 km radius around each of the 15 breeding locations. The authors performed an overlay analysis to intersect combinations of the common ecological variables and determine the habitat suitability. Isaac et al. used the attribute classes found in greatest number around of urban fringe breeding sites, and the attribute found in the least number of urban fringe breeding sites to produce a base area of predicted breeding habitat for powerful owls with the intersection of permanent water source (buffered at 40 m) and dense vegetation. Patches that didn’t conform were removed from the map and the remaining patches contained characteristics that were most likely to indicate potential breeding sites. Comparisons between these results and historical records were used to test the validity of the output and indicated that predictive mapping provided a useful representation of potential breeding areas for powerful owls in Australia’s urban and urban-fringe environments. I believe that this paper was influential because it proved that GIS is an important tool for ecologists as population and urban sprawl are increasingly affecting species in their natural environments.


Lauver et al.’s paper presented a test and analysis of a spatially explicit habitat suitability model for loggerhead shrike, a grassland bird species of special concern. The authors interpreted high quality digital photographs to delineate land cover classes, hedgerows, and tree counts, and entered them into a GIS as individual data sets. A previously developed habitat model was then employed that produced a GIS database predicting low, moderate, and high quality shrike habitat. Using this model, the authors then predicted the distribution and amount of available suitable habitat, tested the model with independent observations, and determined landscape features most important in predicting shrike presence. The authors did an excellent job discussing the history of habitat suitability index (HSI), explaining the specifics of ‘head’s up’ digitizing, and the benefits and trade-off of using remotely sensed data or photo interpretation. Their model can easily be applied to other areas of the country with different habitats not as dominated by grassland because of its use of general land cover types in the GIS. I think the paper was great overall, but could have been improved with the addition of a few more figures and a detailed description of the statistical methods used in their analysis.


In this paper, Li et al. used a GIS to record information about crested ibis and spatial data to assess habitat quality this endangered bird in Yang County in China. Nest locations were mapped with GPS from 1981 to 2002, and were imported into the GIS database. In addition, the authors used four layers of data for their analysis: vegetation, topography, rivers and reservoirs, and human disturbance. These layers were created by digitizing existing maps and converting them into raster data using the grid module of ArcInfo. Within each layer, different habitat suitability index (HSI) values were placed within each 500 m² pixel. These values were based on the opinions of six ibis experts for the habitat’s suitability for crested ibis based on all four layers of data. The most interesting part of the project analysis was that they found that crested ibis are highly correlated with their calculated suitability index, and appeared important in
determining the distribution of crested ibis. The biggest critique about the paper I have is that calculating this HSI from the opinions of four people used is not very objective or accurate, which the authors admit to in the discussion. Perhaps a better method would have been to use statistical data from crested ibis field research available in the literature to calculate their HSI values. In addition, the paper does not mention anything about accuracy arising from the digitized maps. The author’s methods have some faults, however, this paper does provide an important base of information for determining potential habitats of crested ibis and how to support larger populations in the wild, and was an interesting paper to read.


Miller et al.’s paper presented a cartographic modeling technique for measuring relations between environmental characteristics and rare species distribution patterns. The authors digitized rare bird distribution data for Tanzania and statistically analyzed the patterns in relation to geographic and environmental variables using the GRID software system. The authors performed analysis on two datasets to measure the difference of small and large area size, and so each dataset became identified with an area of 69 Km² and 607 Km², respectively. However, due to limitations of the software, all areas in the small and large datasets were not of equal size. In the small dataset, 85.5% of the areas covered 69 Km², and 55.6% of the areas covered 607 Km² in the large dataset. The authors discovered that only the vegetation and soils data were accurate enough to represent natural resource distribution patterns, and their analysis cautions future users to always check the accuracy of spatial data before proceeding with analyses in little biologically known regions of the world. This work was important because it demonstrated a simple modeling technique applicable for predicting rare species patterns in areas of the world that aren’t extensively mapped, and pointed out important accuracy considerations for future applications of the model. However, a complete lack of statistical analysis on their resulting figures made me doubt some of the conclusions made in their discussion.


An incorrect choice of scale can lead to misinterpretations of spatial data. This is especially important when studies are intended to correlate presence of abundance of animal populations with landscape-scale habitat characteristics because these characteristics vary widely with scale. Mitchell et al. developed and compared three statistical models for predicting presence of selected bird species inhabiting a managed forest in South Carolina. The first model was based only on microhabitat characteristics, the second model was based on landscape characteristics (summary statistics of forest age and type calculated at different spatial scales) derived from GIS data, and the third model that combined microhabitat and landscape characteristics. These landscape models were developed for predicting the presence of selected bird species and evaluating landscape scales relevant to birds. The landscape models, used at various scales, worked as well or better than traditional microhabitat approaches as predictors of the presence of forest birds. This method was very interesting to read about because it proved that using landscape data (which is readily available in GIS
databases) to predict distributions of birds instead of using microhabitat data (which requires intensive field sampling and can be difficult to model spatially for an entire forest) can have as much accuracy as traditional methods. However, this can only be used as a coarse-grained predictor of presence/absence of a bird species, and is not sufficient for predicting population dynamics. This paper was quite detailed and informative and showed that certain trade-offs in accuracy or precision must be made when using microhabitat or landscape characteristics to model animal populations. Scale choice should be project-specific and accuracy needs and scale should be determined before a project is undertaken.


In this article, Stralberg et al. discuss how GIS, habitat mapping, statistical modeling and simulation were used to evaluate the interrelated and conflicting habitat needs from a variety of bird species to create management priorities for wetland restoration in San Francisco Bay. The authors developed a first-generation habitat conversion model (HCM) that could be used to estimate quantitative and qualitative effects of habitat conversion on bird populations. Their initial comparison of tidal marsh and salt pond bird use included a GIS-based analysis of site-level habitat characteristics, pond/marsh habitat configuration and surrounding landscape characteristics. This article demonstrated how an integrated model using existing field and GIS data sets could be used to conduct a series of statistical analyses and identify important site and landscape level habitat requirements for wetland associated bird species. This paper was very well-written and supported by figures and tables. I especially enjoyed their section entitled Future Directions, where they outlined future versions of the HCM, where GIS could be used for making predictions of intra-site variations in bird use, extrapolating bird distributions to a broader area with a spatially explicit model, as well as to simulate changes over time and model avian response to those changes.


Tucker et al.’s work is detailed and well-written account of combining Bayesian modeling with GIS analyses. Investigators often identify quantifiable habitat preferences and other distribution factors of the bird species and develop map layers in a GIS using Bayesian formulas, distribution factors, and satellite base-maps. The Bayesian rule-based approach allows for determining distribution of a number of bird species based on probability of encountering a species and known preferences of a species. Tucker et al.’s models use available data from ornithological literature to define habitat preferences and life-history characteristics of the birds, and combine it with satellite and physiographic data. Model predictions were calculated at the landscape scale using a raster-based GIS. This work brought up important considerations when using GIS, such as the reliability of data when using interpolation methods and other analyses.