The Use of GIS in Studies of Amphibian Ecology and Conservation
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By their very nature, amphibians utilize a large part of the landscape, breeding in wetlands or streams and often spending the majority of their lives in the upland. Since many of these species are fossorial or too small for a transmitter, their upland habitat requirements and movements are far less studied than their wetland breeding sites. The use of GIS has allowed the incorporation of field studies and modeling to extrapolate findings to the broader landscape and to develop conservation strategies to ensure the persistence of these species.

Some studies have used radiotelemetry to follow individual movements for larger salamander species. In these studies, amphibian locations are recorded using GPS. The points are then entered into a GIS where estimates of total distances traveled, habitat preferences, and other factors affecting amphibian movement can be assessed (Berven and Grudzien 1990; Faccio 2003; McDonough and Paton 2007). This information for pond-breeding amphibians is often used to calculate the distances required for a terrestrial buffer around a pool to protect 95% of the breeding population (Semlitsch 1998; Faccio 2003; McDonough and Paton 2007).

Many other studies draw correlations between landscape characteristics and the presence or abundance of amphibian species in a breeding pool. GIS is often used to calculate the percent of forest cover, road density or number of wetlands within a specified buffer from the breeding pool. Porej et al. (2004) found that wood frog and spotted salamander presence was positively associated with the amount of forest cover within 200 m, and wood frog presence was also positively correlated with the amount of forest within the broader landscape (1 km). Houllahan and Findlay (2003) found effects of forest cover extending out 3 km from pools on amphibian diversity in southeastern Ontario. Guerry and Hunter (2002), Rubbo and Kiesecker (2005), and Skidds et al. (2007) also found a positive association between wood frog and spotted salamander presence and forest cover. Homann et al. (2004) identified thresholds of forest cover for spotted salamander and wood frog occurrence. Hermann et al. (2005) also found critical values at which amphibian species richness at a pool increased or decreased depending on the amount of surrounding forest cover. Guerry and Hunter (2002) found a positive correlation between spotted salamanders and the adjacency of the breeding pool to the nearest forest patch. Burne and Griffin (2005) found the presence of another breeding pond within 1 km of a pool had a positive association with species richness.

Amphibians are theorized to act as metapopulations, which require successful dispersal among subpopulations for rescue effects and recolonization of pools that become extirpated (Marsh and Trenham 2001). To sustain amphibian populations, seasonal pools need to be located in landscapes that provide habitat connections between wetlands (Semlitsch 1998; Snodgrass et al. 2000; Semlitsch 2002; Gibbons 2003; Petranka et al. 2003; Burne and Griffin 2005; Regosin et al. 2005). Kolozsvary and Swihart (1999) found the presence of three ranid frog species to be positively associated with the proximity of wetlands.

Roads and certain anthropogenic landscapes (e.g., agricultural lands, large open habitats) may act as barriers to migration and sources of mortality (Egan and Paton...
Regosin et al. 2005; Houlan and Findlay 2003; Findlay and Houlan 1997). Houlan and Findlay (2003) documented a negative effect of road density around a breeding site on amphibian species richness. In an Ontario study, Findlay and Houlan (1997) found a decrease in herptile species richness with increasing paved road density at least 2 km from wetlands. In the agricultural prairie ecoregion of Minnesota, Lehtinen et al. (1999) found that amphibians were impacted by road density and wetland isolation. In a Maine study, deMaynadier and Hunter (1998) found wood frogs and spotted salamanders to be relatively sensitive to silvacultural edges as old as 11 years. The abundances of both species were negatively affected at least 25-35 m into the undisturbed forested patch. These studies provide a good basis for the initial investigations into how habitat fragmentation impacts amphibian species richness, presence and abundance.

GIS can calculate many of the parameters for habitat fragmentation analysis, but programs, such as FRAGSTATS have been created to better portray habitat configuration. FRAGSTATS requires the input of data layers from GIS to complete its analysis. In this way, GIS has become integrated into this kind of analysis. Martin and McComb (2003) used FRAGSTATS on an Oregon landscape. The authors calculated multiple indices relating to patches, edges, patch shape, and core area. For instance, they calculated the percent of the landscape that the largest patch comprises, the number of patches in 100 ha, and the total perimeter of a patch divided by the total area. They were then able to relate the presence of species in various patches to these indices. Four amphibian species in the study were associated with one or more of these pattern metrics.

GIS has also become integral to modeling amphibian movements. Some of these models are relatively simple such as the one conducted by Dayton and Fitzgerald (2006). In this model, the authors used digital elevation models, digitized soil survey maps, and drainage channel maps to rank areas for habitat suitability for four species based on past studies on the species’ biology. The ranking included giving each attribute a score and totaling scores across attributes for a habitat suitability score. The authors then used field data from amphibian surveys to validate or reject their model. For two species, the model had considerable agreement between actual and predicted species presence.

Other models can become slightly more complicated. In a Minnesota study of wood frog, Boone et al. (2006) created a model to predict amphibian movements between breeding ponds. The authors used data layers for factors believed to influence wood frog movements. Satellite imagery provided data for leaf-on greenness, spring wetness, and fall brightness. The authors also used a digital elevation model to calculate slope. These data layers were used in combination with a random walk model known as IMove. The authors were able to add data layers to the program to improve the predictability of the model. Based on the parameter value within a cell, the amphibian would be more or less likely to move into a cell. Based on probabilities and set amphibian affinities for cell attributes, the model creates a path for amphibians across the landscape. The model was able to explain 77% of the variation of wood frog movements seen in the field over three years of surveys. This model could be applied to other areas to explain connectivity between pools and the likelihood of amphibians traversing roads. The increase in predictive ability brought about by the use of GIS in
modeling is incredible. This model would probably never have been done without GIS. Compton et al. (2007) created a resistant-kernel model based on the resistance of amphibians of crossing particular land uses. Potential vernal pools, roads, rivers, and land use data were used in this model. The authors were interested in the connectivity between breeding ponds in this study. To investigate this, they modeled the probability of amphibian movement between breeding sites based on resistance values and dispersal capabilities. The model was completed for the entire state of Massachusetts. The authors hope the model results will be used to focus efforts for conservation.

Other models have been used to predict the effects of landscape change on amphibian populations. In Indiana, Gustafson et al. (2001) modeled amphibian species under different forest harvesting regimes. GIS data was used in a program called HARVEST to model forest harvesting and regeneration over a 150-yr period. The authors predicted salamander abundances to be influenced by stand age and site moisture. The authors calculated slope using digital elevation models and aspect to estimate site moisture. HARVEST provided stand age. Based on these two criteria, the authors modeled abundances of salamanders for four different forest harvesting regimes. The simulations can be used to help managers decide on forest management plans. Rustigian et al. (2003) conducted a similar experiment to predict salamander abundances in two watersheds given three different future land use scenarios. The future land use scenarios included one with bioreserves, one designed to protect water quality, and another designed to increase agricultural production. The landscapes were created in GIS and input into PATCH, a demographic model. The authors also used random walk models for juvenile amphibians moving across the landscape. The GIS layers enabled the use of multiple modeling programs in this study. From this modeling, the authors were able to predict changes in abundances, upland and breeding habitat, and nearest neighbor distances. The authors were then able to select the scenario that best supports amphibian abundance and diversity.

GIS is an essential tool for amphibian studies. With satellite imagery coming in at smaller pixel sizes and with the use of infrared imagery, small vernal pools (breeding sites) will be able to be picked up from photointerpretation with increased accuracy. Recently with the addition of new data at small pixel sizes, modeling capabilities have increased. By being able to use imagery to gain estimates on parameters such as site wetness, studies are able to save considerable field work and spend more time on other aspects of their work. Many studies are now being conducted that would not be possible 10 years ago. In future years, I predict that we will learn a lot about amphibian ecology and be able to apply much of our findings to conservation because of GIS technology.
Other Literature Cited


Annotated Bibliography


In this Minnesota study of wood frog movements, the authors chose eight vernal pools and captured frogs moving in and out of each pool over three years. To explain the movements of frogs between pools, the authors employed Landsat tasseled cap images to portray brightness, greenness, and wetness, 30m resolution USGS digital elevation model to calculate slope, and National Wetland Inventory maps to locate wetlands. The authors used IMove, a correlated random walk diffusion model, to estimate wood frog movements based on habitat attributes. Each attribute in a cell is given a suitability score, which corresponds to the likelihood of an animal moving to that cell. Using this, the model created estimates of animal movements based on the different parameters. The results were compared with field study findings. The authors found that slope and spring wetness described 77% of the variation in actual wood frog movements between ponds. Using three satellite images, the authors were able to determine brightness, greenness and wetness. The study would have been impossible without the use of this imagery.


Compton et al. wished to establish estimates of the connectivity between vernal pools in the state of Massachusetts. Since amphibians are believed to act as metapopulations they rely on movement of individuals between pools for rescue effects and recolonization of habitat. Therefore the connectivity of upland habitat between breeding pools is key for a regional population’s survival. The authors used GIS data for potential vernal pools (obtained from infrared aerial photographs), land use, roads, streams, and slope. In order to establish connections between pools, the authors had to first estimate the probability of movements between pools based on the resistance values of various land uses for the movement of amphibians. The authors used the resistance values with maximum dispersal estimates to model connectivity between pools. Connectivity was modeled at three scales: local, neighborhood, and regional. Each pool was given a score based in its connectivity. This analysis will be used to determine high priority pools for conservation.

Dayton and Fitzgerald used GIS to create habitat suitability models for four species of amphibians in the Big Bend National Park. The model used digital elevation models (DEM), digitized soil survey maps, and drainage channel maps. The authors used Arc View Spatial Analyst to generate slope and distance to drainage channels layers. The authors assigned suitability values for each of the seven model variables. The values were totaled for a prediction of quality habitat. During seven years of field surveys, researchers recorded species breeding in pools on the reserve using a GPS. The accuracy of the model was tested by overlaying the GPS points of each species’ breeding pools over the predicted habitat suitability maps. Between 59 and 89% of all breeding pools for each species were located in “Very High” suitability habitat. This was an interesting case where field data was used to validate their model. The results also stress the importance of models for individual species. For specific species, this relatively simple model provides a valuable framework for conservationists and biologists.


The authors used digital elevation models and stand age maps in GIS. The authors developed GIS functions to identify ridge tops and valley bottoms and to create layers representing each pixel’s distance to the nearest ridge or valley. This information was then used to calculate slope. Depending on the slope facing, each pixel was assigned a value for site moisture, which is an important determinant of amphibian presence. The authors used data from amphibian captures in different aged forest stands to develop a model of amphibian occurrence according to stand age. These two factors, stand age and site moisture, were melded together for a predictive model of amphibian abundance in a new GIS layer. The program HARVEST was used to generate different landscape composition based on different forestry plans. By examining different scenarios, the authors were able to elucidate the effects of increased harvest activities on amphibian abundance and on the mean distance amphibians have to travel to recolonize extirpated sites. This later factor can be particularly important for amphibians, which are believed to form metapopulations. The amount of calculations conducted for each 30-m pixel for three areas within the Hoosier National Forest would have been horribly time-consuming without GIS. The measurements of distances between each pixel and the nearest features or travel distances for salamanders to recolonize areas would have been impossible without GIS. This study utilized many uses of GIS and combined it with another useful program (HARVEST) to create an interesting predictive model useful for managers.

Herrmann, H.L., K.J. Babbitt, M.J. Baber, and R.G. Congalton. 2005. Effects of landscape characteristics on amphibian distribution in a forest-dominated landscape. *Biological*
In a study of 61 palustrine wetlands in New Hampshire, Hermann, Babbitt, and Congalton examined the influence of forest cover, wetland cover, and river and road density at multiple scales (100-1000m) surrounding a breeding pond on species richness. The authors delineated forest and non-forest areas using black and white USGS National Aerial Photography Program 1:40,000 photos. They also used National Wetlands Inventory maps. This data set often has a minimum polygon size of 1 acre, which may not be appropriate for species that can breed in small isolated wetlands.

The article drew correlations between various landscape measures and species presence, but failed to consider the configuration of these features.


In this study of Oregon amphibian species, Martin and McComb compared capture rates of amphibians in different forest types and patch sizes. The study area was divided into different forest types using GIS. The authors then picked study sites based on the number of forest types and size of patches. They trapped amphibians in each study area. Based on the numbers found in each area for a species (standardized for sampling effort) the authors determined whether a species selected, avoided, or showed neutrality toward each forest types. Using GIS, the authors then created new maps of the study areas for each species with the three categories: selected, neutral, and avoided. This process would have used the entire budget to group these data for 30 sites 250-300ha in size for 9 different species preferences. Using the new maps and the original maps, the authors employed FRAGSTATS, which requires input of data from GIS, to calculate edge indices, patch indices, shape indices, and core indices. Through this process, the authors were able to elucidate the effects of various landscape metrics on amphibian abundances and to establish habitat associations.


In an Iowa study, Rustigian et al. compared the effects of three prospective land use scenarios on four amphibian populations in two watersheds. GIS coverages of future and current land use were used and dry years were estimated by eliminating seasonally wet areas as potential habitat. Each habitat was assigned a value according to habitat preferences. The land use coverages were then converted to grids with a 3 m pixel size for use in PATCH. PATCH is a demographic model that requires the input of raster landscape maps as well as information on each species to be modeled (i.e. habitat-use patterns, maximum dispersal distances, survival rates, and fecundity estimates). The
model output predictions of percentage of area available for habitat, percent of occupied sites, and mean number of breeders at sites. The model provides a way for planners to examine land use choices in light of the long term effects on biodiversity. The accuracy of the model is questionable in some ways, however. The use of 3-m grids from land use data that is surely not at 3-m resolution for entire watersheds appears to be stretching the data beyond its uses. This study does again emphasize the prevalence of GIS in research today as it provides the required format for information input into modeling programs, such as PATCH.