Critical Habitat Mapping

The loss of habitat that supports the various life stages of threatened and endangered species is an important factor that contributes to the continued decline of those species. As such, once a species is listed under the Endangered Species Act the designation of critical habitat becomes a key tool used to support recovery efforts and goals established for the listed species. Critical habitat is defined as the area that provides the various resources that will facilitate a species’ persistence, and may include food, cover, nesting, and migration routes (Gregr et al. 2001). However, before it is possible to designate critical habitat for a listed species, that habitat must first be identified. This identification of critical habitat often presents an entirely new set of challenges particularly when working with threatened and endangered species that are often already rare and thus difficult to observe. I compared multiple studies describing the methods by which habitat for threatened and endangered species was identified. Through my research I found many commonalities among the methods described as well as the discussion of advances that will improve our ability to precisely map critical habitat. However, I also found shortcomings of the methodologies employed and challenges associated with properly defining critical habitat.

In general, I found that the process by which critical habitat is determined and mapped is not widely available for most species and no systematic process to define critical habitat exists that can be applied across species or taxa. When consulting governmental resources, final rulings published in the Federal Register regarding critical habitat often include text stating that multiple experts were consulted and contributed to the critical habitat designation. However, final rulings seemed to rarely include specific information on how that critical habitat boundaries were determined. This lack of transparency has led to negative public sentiment and low public confidence in the critical habitat designation process and has resulted in a series of lawsuits in which courts have repealed critical habitat designations. These court decisions have not only been costly for federal agencies charged with protecting species, but they may also discourage the future designation of critical habitat. As such, a process of critical habitat mapping that is transparent, uses the best available science, and can be justified in a court of law is critical to ensuring that habitat is protected for our most vulnerable species (Turner et al. 2004).

Despite these setbacks, there have been many efforts to determine critical habitat for a variety of species from many taxa. Early determinations of critical habitat used extensive field surveys in combination with qualitative assessments of habitat importance. The qualitative nature of habitat assessments led to low confidence in habitat boundaries, while field surveys can be both time consuming and expensive and often limit one's
ability to survey large areas. Currently, however, this approach to habitat mapping is being replaced by the application of some combination of GIS, remote sensing, field sampling, and statistical modeling to produce the best possible delineation of predicted critical habitat with reduced financial and time costs.

The most common method of determining critical habitat that I found begins with the determination of species density. In the case of the Smalltooth Sawfish, density was found by using encounter records submitted by fishermen that were analyzed using a spatial analyst density tool in ArcView 9.3. For the Desert Tortoise, extensive field surveys were conducted in survey plots established using Landsat Thematic Mapper-based surface features of vegetation. For five species of whales, density was found by using kill data from the mid 1900’s, and interpolation was performed using a TIN that displayed whale distribution as well as bathymetric data. Density of the Woodland Caribou was calculated by collecting point data from GPS radio-collared females over 11 winters. These initial methods of collecting density and distribution data will ultimately influence the quality of the model and resultant critical habitat delineation that is produced and some methods are clearly more desirable than others. For instance the use of GPS radio collars will likely produce more quantifiable and unbiased location data for a species whereas encounter or kill data reported by fishermen is potentially biased based on where fishermen are most actively fishing.

The next step in determining critical habitat often includes the extraction of habitat variables as data layers that can be inserted into a statistical model for analysis. This allows the ecological modeler to determine the suite of environmental variables that will predict the most favorable habitat conditions for the plant or animal being studied. In many cases, those habitat predictor variables included bathymetric information or topographic information such as slope, elevation, erosion, deposition, distances to water sources, and aspect, as well as soil, vegetation, and climatic variables. These habitat variables were generally extracted from digital elevation models (DEMs), although recent advances have made light detecting and ranging data (LiDAR) available, which has allowed scientists to extract vegetation structure and height and high-resolution elevation data as habitat variables. These advances vastly improve the habitat variables entered into the statistical models and allow scientists to make more precise and detailed critical habitat delineations. Additionally, the use of LiDAR data allows scientists to observe fine details of physical and biological variables across large spatial scales without the need for intensive field studies and validation.

Once the various habitat predictor variables and species density data have been analyzed using a statistical model, areas containing the suite of environmental variables shown to be most associated with high densities of plants or animals can be displayed using GIS and considered for critical habitat designation. In general there remains a need to validate the predictions of critical habitat through field surveys. This allows the researcher to verify the accuracy of their critical habitat predictions and ensure that the designation of critical habitat will contribute to species recovery goals. Ultimately, if the
model used to delineate critical habitat is based on empirical and unbiased data, and clear and justifiable habitat boundaries can be established, the critical habitat designation can be an effective tool in the management of high quality habitat for threatened and endangered species.
Annotated Bibliography


Anderson et al. describe an interdisciplinary study that combined traditional field data collection methods with satellite imagery to model potential habitat for Desert Tortoises. Through intensive field work, the relative density of tortoises were found and inserted into a regression-tree model along with 11 spatial data layers including elevation, vegetation communities and cover, soils, and topography. The resultant model showed the suite of landscape features that coincided with tortoise densities. While important habitat variables were defined through this model, they remain specific to the study site, and may not necessarily be useful in predicting critical habitat for the entire range of the desert tortoise. As such further studies incorporating a larger spatial area should be conducted.


In this article Bradbury et al. explore the capacity of airborne LIDAR to augment field sampling when modeling critical habitat for avian species. This review looks at two studies that used Airborne LIDAR to collect vegetation height data for crops and woodlots at a high vertical resolution over large spatial areas. The vegetation data served as a predictor of habitat quality and was then used in statistical models to accurately show the distribution of two species of breeding birds, Sky Larks and Blue Tits, and thus provide conservationists with a more sophisticated tool to predict critical habitat for these species. This article is effective in demonstrating the capacity for LIDAR to support field studies through the measurement of vegetation structure, an important facet of habitat modeling. While this article explores studies completed in the UK, the application of LIDAR collected data in habitat mapping is applicable for mapping critical habitat for species in the US.


DeCesare et al. used a statistical model to assess resource selection across different spatial scales in order to determine the effects of human impacts on the threatened
Woodland Caribou and to map critical habitat for this species. This study used location data collected from GPS collared females over 11 winters in combination with resource variables taken from Digital Elevation Models (DEM) and anthropogenic variables including clear cuts, and linear features (hiking trails, pipelines). These data and variables were used to develop a multi-scale logistic regression model to determine which variables had the largest impact on caribou populations and at which scale. The models showed resource selection probability functions, which were then assigned to each pixel in the study area. These pixels displayed the probability that caribou would use each pixel and served as a basis for critical habitat mapping. DeCesare et al. found that variables affected the caribou at different spatial scales and the use of this integrated scale model allowed them to determine the most important suite of variables at each scale. The methods used by DeCesare et al. seemed to be the most sophisticated in determining which variables affected the distribution of species and was the most effective in predicting critical habitat for species at a variety of spatial scales.


In this study, Gregr and Trites attempted to map critical habitat for 5 species of highly migratory whales off the coast of British Columbia. To do so, position information from whale kills as well as habitat variables including bathymetric data were analyzed using a statistical model to identify variables that would predict whale occurrence and thus critical habitat. Cause and effect software was used to create the habitat model, and the data from this model was mapped using interpolation into a TIN surface. The predictive power of the model was tested and shown to accurately predict locations of whale occurrence, allowing Gregr and Trites to determine critical habitat for the 5 whale species. While the model’s predictive power in general was shown to be high, the edges of the TIN that lacked sufficient sample data led to a decrease in predictive power, reducing confidence in the outer boundaries of the mapped critical habitat. In order to increase the confidence and predictive power of the model and thus the accuracy of the TIN surface, additional point and location data for whales should be recorded and incorporated into the TIN surface.


In this article Norton et al. discuss the process by which critical habitat was identified for the Smalltooth Sawfish off the coast of Florida. A key tool in the recovery of this species is the conservation of nursery habitat, which allows recruitment of juveniles into adult age classes, and helps to sustain population levels. However, little research had been
conducted on this species and the spatial extent of nursery habitats was undefined. Researchers mapped the density of juveniles with the Spatial Analyst Density tool in ESRI ArcView 9.3 and then determined the biological and physical characteristics of high-density areas. Those characteristics, including shallow waters, red mangrove shorelines, and euhaline areas were used to identify areas designated as critical habitat. While this method did result in the mapping of 3,401.3 km$^2$ of critical habitat, the predictive powers of those habitat characteristics were not validated through field sampling efforts leaving this method vulnerable to doubt. Additionally, the point data for Smalltooth Sawfish occurrence was based on sightings by the public, which may also introduce bias into the study and result in the skewed importance of habitat characteristics used to delineate the critical habitat.


In this study Sellars and Jolls, determined that LIDAR data could be used to identify habitat variables and to predict potential habitat for a federally threatened annual plant, *A. pumilus*. To do so, topographic variables taken from high resolution LIDAR Digital Elevation Models (DEMs) were identified in areas containing high densities of *A. pumilus*. The habitat variables and point data were then modeled using a logistic regression model, which determined the most important combination of variables that would predict ideal habitat. The model was tested and accurately predicted areas containing the threatened species. This study demonstrated the capacity of LIDAR data and statistical models to predict potential habitat for threatened plant species, tools that are conventionally used to predict wildlife habitat.


In this article, Turner et al., seek to define the true critical habitat boundaries for Nelson’s Bighorn Sheep through the application of quantitative methods based on empirical data. To do so point data of Bighorn Sheep distribution was modeled along with 6 habitat predictor variables taken from available Digital Elevation Models (DEM) in a logistic regression model. An unsupervised classification was used to classify the habitat based on the variables and correctly predicted the presence and absence of sheep throughout the landscape. This study was both timely and important, as Turner et al. were able to refine the boundaries for the designated critical habitat and quantitatively justify the designation of critical habitat for this endangered species.