Spatial Designation of Critical Habitats for Endangered and Threatened Species in the United States

Aarthy Sabesan
Nagendra Singh
Mark Tuttle

ABSTRACT. Establishing biological reserves or "hot spots" for endangered and threatened species is critical to support real-world species regulatory and management problems. Geographic data on the distribution of endangered and threatened species can be used to improve ongoing efforts for species conservation in the United States. At present no spatial database exists which maps out the location of endangered species for the US. However, spatial descriptions do exist for the habitat associated with all endangered species, but in a form not readily suitable to use in a geographic information system (GIS). In our study, the principal challenge was extracting spatial data describing these critical habitats for 472 species from over 1000 pages of the Federal Register. In addition, an appropriate database schema was designed to accommodate the different tiers of information associated with the species along with the confidence of designation; the interpreted location data was geo-referenced to the county enumeration unit producing a spatial database of endangered species for the whole of US. The significance of these critical habitat designations, database scheme and methodologies will be discussed.

Aarthy Sabesan, Geographic Information Science and Technology Group, Oak Ridge National Laboratory, Oak Ridge, TN 37763 (E-mail: s.aarthy@gmail.com).

Nagendra Singh, Geographic Information Science and Technology Group, Oak Ridge National Laboratory, Oak Ridge, TN 37763 (E-mail: singhn@ornl.gov).

Mark Tuttle, Geographic Information Science and Technology Group, Oak Ridge National Laboratory, Oak Ridge, TN 37763 (E-mail: tuttlema@ornl.gov).

Prepared by Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, Tennessee 37831-6285, managed by UT-Battelle, LLC for the U. S. Department of Energy under contract no. DEAC05-00OR22725.

Journal of Map & Geography Libraries, Vol. 4(2), 2008
Available online at http://jmgl.haworthpress.com
doi: 10.1080/15420350802142694

KEYWORDS. Endangered species, threatened species, Geographic Information System, spatial database, critical habitat

INTRODUCTION

There have been five major extinctions in geological history all attributed to natural causes such as climate change and volcanism. In the last 500 years around 844 species have died out and more than 16000 are known to be endangered (Pickrell, 2006). The concerns of a sixth extinction (Wilson, 1992), not from natural causes but from human activities like exploitation of land and species and increasing pollution (Eldredge, 2001), seem a certainty today. Extinction rates are now 100 to 1000 times than pre-human stages (Pimm et al., 1995). Increased concern over the global extinction of biodiversity has channeled efforts towards species conservation. The Endangered Species Act (ESA) (Wilcove et al., 1992) of 1973 was enacted by the U.S. Fish and Wildlife Services (FWS), to shelter and protect imperiled species in their natural habitat. For any species to get protection through the ESA it must first be placed on the Federal list of endangered and threatened wildlife and plants. The use of GIS in protection and conservation of species was emphasized by Scott et al. (1987). A handful of works have mapped and studied the geographic distribution of these endangered species. Dobson et al. (1997) mapped the geographic distribution of endangered species using a sorting algorithm to locate biodiversity hotspots for the U.S. Flather et al. (1998) mapped hot spots based on an upper percentile of sample units and described their characteristics. Godown and Peterson (2000) have mapped the distribution of endangered bird species in the U.S. while Orme et al. (2005) have created a global hotspot of extant bird species. Spatial designation of species-rich areas can be used as a first approximation to delineate biodiversity hot-spots (Scott et al, 1993) and hot-spot based biodiversity conservation efforts have proven quite effective (Flather et al. 1998). Hence, establishing biological reserves or hot spots for endangered and threatened species is increasingly recognized as a fundamental requirements to species conservation and restoration efforts.

One of the objectives of the ESA is the designation of critical habitat using the latest available techniques (Smallwood et al., 1999) which is the focus of this study. This work attempts to create a comprehensive database of endangered and threatened species for the whole of US at a county level. No such database currently exists for the US at the county level and some of the previous (Dobson et al., 1997; Flather et al., 1998) related works focus on the physical geography of the locations of endangered species. The database comprised a county-level spatial designation of the occurrence of critical habitats for endangered or threatened species in the United States. The species habitat attributes could be grouped based on state, county, species category (mammals, birds, reptiles, amphibians, fish, clams and crustaceans, arachnids, insects, flowering plants and ferns) and species name.

MATERIALS AND METHODS

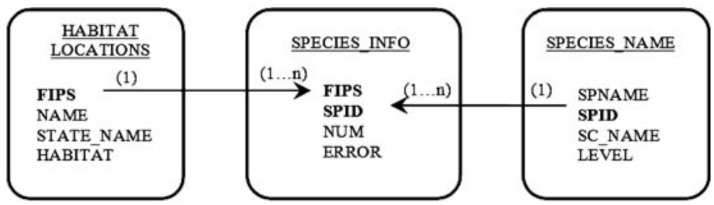
The main thrust of this study was to create a spatial database of the EPA-specified 472 endangered and threatened species from CFR documents, and successfully determine critical habitat boundary information for each of these species. The main work involved spatially mapping these boundaries into a uniform GIS layer using information from the CFR documents which was available in various forms. This included textual description of the habitat, a cartographic boundary or both. Typically, when location information was in the form of a description, it was represented in the CFR by a series of geographic coordinate values describing the designated boundary. Often, a specific habitat was contained by multiple polygons, requiring multiple listings of coordinate pairs. Using these coordinate values was significantly more challenging because these descriptions contained coordinate values from a variety of coordinate systems. Geographic coordinates (both in the form of decimal degrees and degrees/minutes/seconds) were used to describe the boundary of some critical habitat designations, whereas Universal Transverse Mercator (UTM) coordinates or state plane coordinates were used for other critical habitat designation. In no cases where coordinate values were provided in the CFR was the actual coordinate system identified; thus requiring an unacceptable risk of incorrectly interpreting the correct coordinate system. These inconsistencies rendered automated text recognition techniques impractical for interpreting the spatial designation for each species. In nearly all the CFR listings for each species, the text included the state and county or counties that contained the critical habitat even in instances where coordinate listing were included.

The challenge was to formulate a habitat location-county association for each species for each location. This data was extracted from over 1000 pages of document obtained from the CFR, which was available in one of the formats mentioned above. To account for errors in the final county level designation of each species a confidence value was assigned to each association. The confidence value of the habitat location-county association is an indicator of the clarity of the CFR location information and habitat boundary descriptions. The confidence values ranged from 1 to 10 and indicate depreciating levels of confidence in the species-county association. Confidence levels were assigned based upon a subjective analysis of each CFR citation and the spatial reference information contained therein. Specifically, if the CFR text contained actual county names, then the confidence level was the highest. If a cartographic description was extracted from the CFR and used, then a lower confidence level was assigned based largely on the quality of the graphic and the ease with which the graphic was georeferenced. The lowest designation were assigned to those habitats that required the use of coordinate values in combination with either a cartographic description or a county name(s) included in the CFR citation. In nearly every instance of this circumstance, there was some level of disagreement between the various descriptions.

To organize the location information together with the species attribute information, an appropriate database was developed. Based on the data provided by the EPA, an ESRI® shapefile summarizing critical habitats on a U.S. County level for each species was created. Individual counties were identified by the Federal Information Processing Standards (FIPS) codes for states and counties. Two database files, SPECIES_INFO and SPECIES_NAME, were created separately and linked to the shapefile via the key attribute. In reality, more than one endangered/threatened species could be located in an individual county and hence a one-to-many relationship exists between a county and its associated species. The attributes of the files and their cardinal relationship are shown in Figure 1.

In the SPECIES_INFO look-up table, multiple records were created to accommodate all the species associated with a particular FIPS code or county. Because of the one-to-many relationship, the linkage of records between the HABITAT_LOCATIONS and SPECIES_INFO look-up table required a 'relate' operation. The SPECIES_INFO data is logically associated to spatial data by the shared attribute, the FIPS code. The related tables can then be used for selections or data queries. Owing to the many-to-one relationship between the SPID attribute in SPECIES_INFO data table and the SPID attribute in SPECIES_NAME data table, a composite join was performed to link these two data tables. To spatially visualize the attributes of SPECIES_NAME data table, the one-to-many relationship between the tables had to be reduced to a one-to-one relationship. This was achieved by using the NUM attribute in SPECIES_INFO table. Records were selected

FIGURE 1. Database design to accommodate habitat and species attribute information.



FIPS – Unique identifier for each U.S. County

NAME – County name associated with the FIPS code

STATE_NAME – State name comprising the county

HABITAT – Binary denotation of existing habitat (1 implies the presence of habitat and 0 implies the absence of habitat)

ERROR – Ratings from 1 to 10 describe depreciating confidence of the interpreter in the particular county level designation

SPID – Assigned unique identifier for each species

NUM – Number of species associated with the FIPS code

SPNAME – Common name of the species

SC_NAME – Scientific name of the species

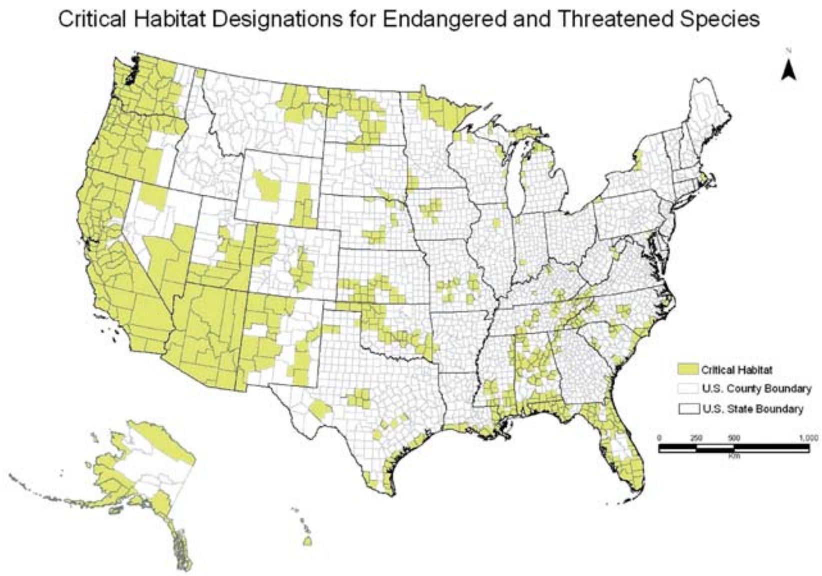
LEVEL – Endangered/Threatened (denoted as E and T respectively)

or filtered based on the NUM attribute to create a one-to-one relationship. Besides adding various species attributes to the database as explained in Figure1, a principal constituent information (PCE) document was also prepared which provides information about the environment needed by each species to thrive naturally.

RESULTS

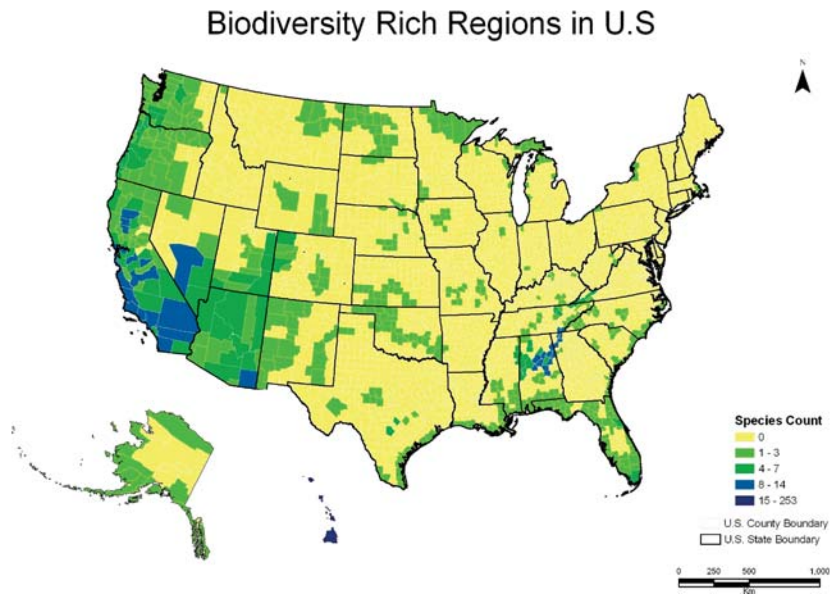
A county level spatial database of endangered and threatened species was created containing species attribute information. The geographic distribution of the species agrees well with some previous works (Dobson et al., 1997; Flather et al.) The main advantage of developing a database of this type is that it can be easily integrated into a GIS system and allows the user to do various types of analysis and queries. It also allows creation of a variety of maps with various themes like distribution of a

FIGURE 2. Map showing critical habitat designation for endangered and threatened species in the U.S.



particular species by county, state, region etc. This can help planners to formulate conservation strategies and make policy decision for their conservation. The geographic distribution of the 472 critical habitats locations for endangered and threatened species is shown in Figure 2. Of the given 472 species, habitat-rich areas are concentrated along the west coast and the Hawaiian Islands. The greatest numbers of endangered and threatened species are found in the islands of Hawaii. The islands of Maui, Hawaii, Oahu and Kauai comprise the highest number of critical habitats. Following this are the California counties of Riverside, San Bernardino, San Diego, Tehama, San Luis Obispo and Santa Barbara. In the eastern United States, counties in Tennessee and Georgia are richer in terms of biodiversity than other regions. Also, the coastal regions of Texas, Mississippi, Alabama and Florida have a significant number of critical habitats for endangered and threatened species. The biodiversity rich regions in U.S. are shown in Figure 3. Improvements in our knowledge of species-richness may help in better delineating hot spots and support ongoing efforts to biodiversity conservation.

FIGURE 3. Map showing biodiversity rich regions in the U.S.



COPYRIGHT

REFERENCES

Dobson, A. P., J. P. Rodriguez, W. M., Roberts, and D. S. Wilcove. 1997. Geographic distribution of endangered species in the United Species. *Science* 275:550–553.

Eldredge, Niles. 2001. *The Sixth Extinction*. http://www.actionbioscience.org/newfrontiers/eldredge2.html#educatorresources (accessed Nov 11. 2006).

Flather, C. H., M. S. Knowles, and I. A. Kendall. 1998. Threatened and endangered species geography. *Bioscience* 48:365–376.

Godown, M. E., and A. T. Peterson. 2000. Preliminary distributional analysis of US endangered bird species. *Biodiversity and Conservation*. 9:1313–1322.

Orme,C. D. L, R. G. Davies, M. Burgess, F. Eigenbrod, N. Pickup, V. A. Olson, A. J. Webster, T Ding, P C. Rasmussen, R. S. Ridgely, A. J. Stattersfield, P. M. Bennett, T. M. Blackburn, K.J. Gaston, and I. P. F. Owensl. 2005. Biodiversity hotspots of species richness, threat, and endemism are not congruent. *Nature* 436:1016–1019.

Pickrell, J. 2006. Instant Expert: Endangered Species. http://www.newscientist.com/channel/life/endangered-species/dn9961 (accessed Nov 11, 2006).

Pimm, S. L., G. J. Russell, J. L. Gittleman, and T. M. Brooks. 1995. The future of biodiversity. *Science* 269:374–350.

Scott, J. M., F. Davis, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. Derchia, T. Edwards, J. Ulliman, and R. G. Wright. 1993. Gap analysis: A geographical approach to protection of biological diversity. *Wildlife Monograph 123*, Bethesda, MD: The Wildlife Society.

Scott, J. M., B. Csuti, J. D. Jacobi, and J. E. Estes. 1987. Species richness: A geographical approach to protecting biodiversity. *BioScience* 37:782–788.

Smallwood, K. S., J. Beyea, and M. L. Morrison. 2000. Using the best scientific data for endangered species conservation. *Environmental Management* 24:421–435.

Wilcove, D., M. McMillan, and K. Winston. 1993. What exactly is an endangered species? An analysis of the U.S. endangered species list: 1985–1991. *ConservationBiology* 7:87–93.

Wilson, E. O. 1992. *The Diversity of Life*. Cambridge, MA: Harvard Univ. Press.