Spatial modeling of Hawaiian forest bird densities

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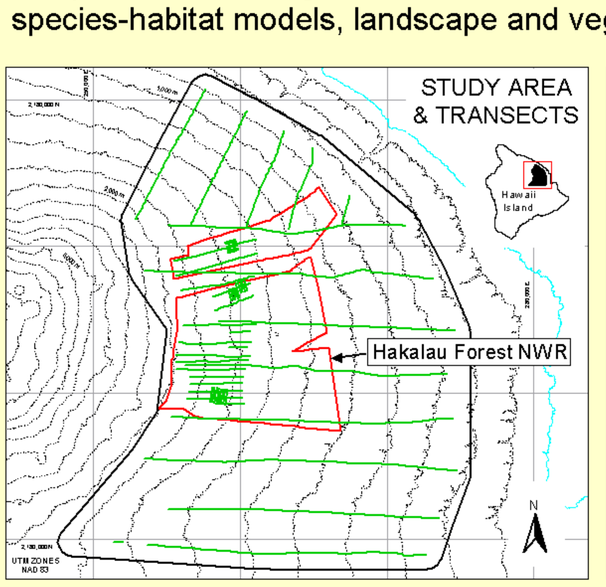
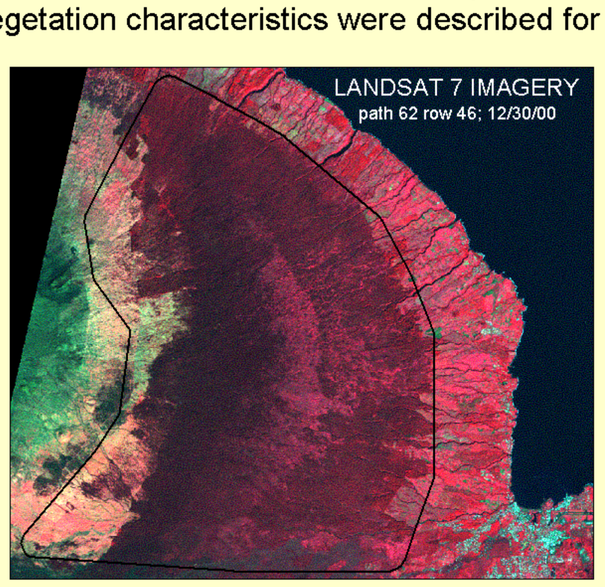
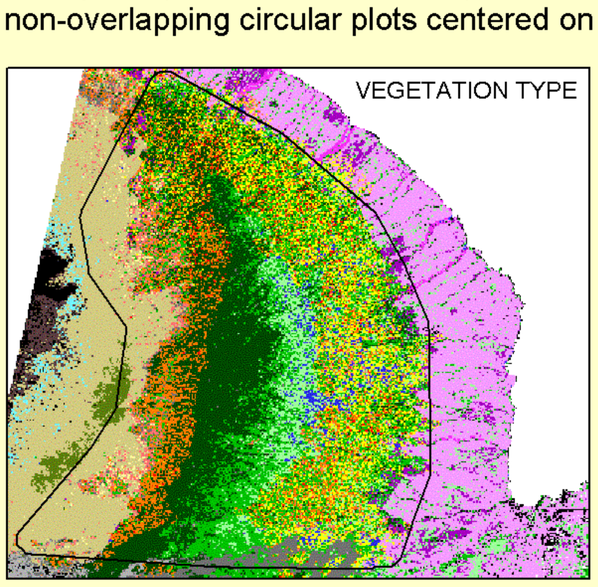
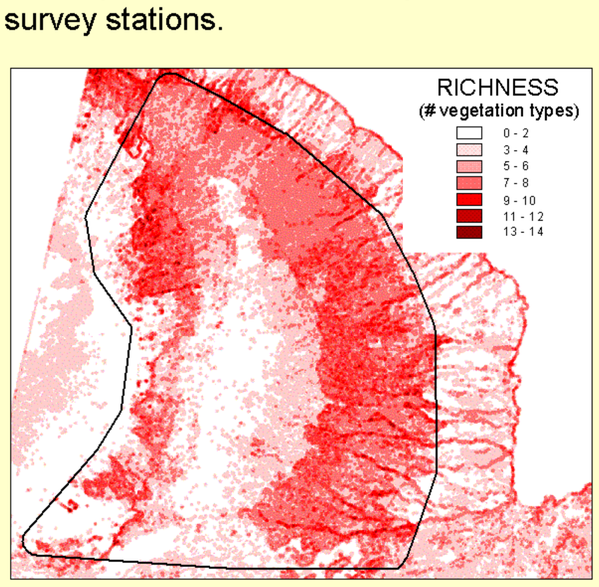
INTRODUCTION: The Hawaiian avifauna has experienced numerous extinctions, population declines and range contractions since human settlement of the islands. Many agencies have expended considerable effort to survey and monitor bird distribution, abundance and trends. However, a comprehensive synthesis of the survey results has not been produced. Toward this end, the Hawaii Forest Bird Interagency Database Project (HFBIDP) has developed a centralized and relational database of survey data for 81 species collected in Hawaii since the mid-1970s. The database contains more than ¾ million records from over 400 surveys on all the major Hawaiian islands. GIS analysis integrated information on species abundance and habitat characteristics at the landscape level, and has been used to determine which characteristics play a role in regulating the distribution and population sizes of the Hawaiian avifauna.

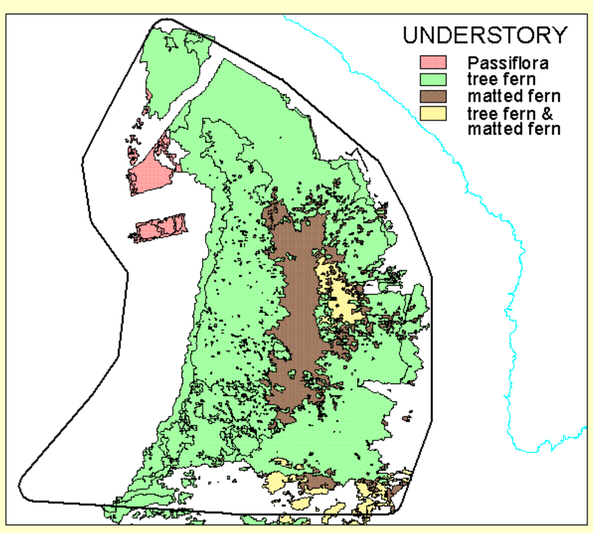
METHODS and RESULTS: Survey sites across the islands were digitally mapped and linked to habitat information derived from digital elevation models, rainfall and temperature isohyet interpolation, and land-cover classification of Landsat 7 imagery. Classified imagery provided data on vegetation composition and structure, including canopy closure, canopy height, and the diversity (i.e., richness) of land-cover types. Aerial photo interpretation was used to determine the presence of understory components including native tree-ferns and matted-ferns and the invasive species banana poka (*Passiflora mollissima*). To minimize spatial autocorrelation problems in species-habitat models, landscape and vegetation characteristics were described for non-overlapping circular plots centered on survey stations.

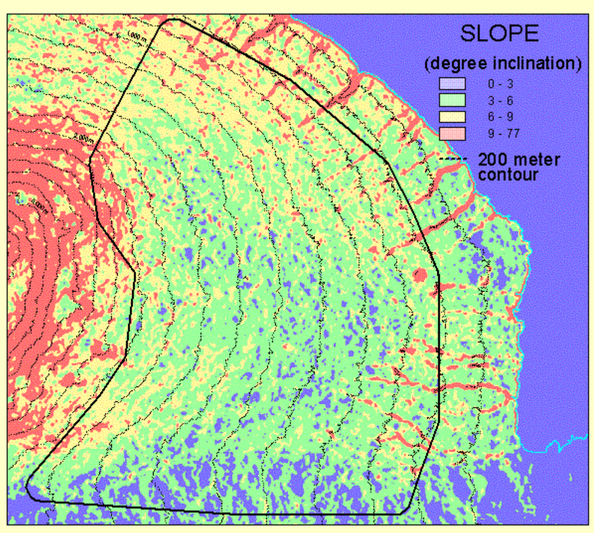


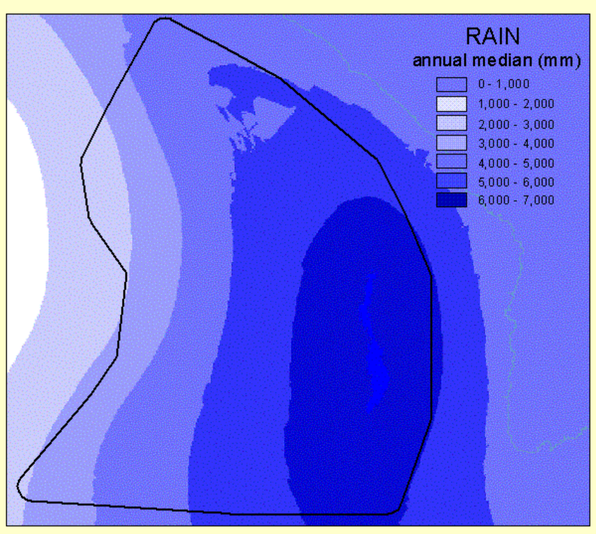


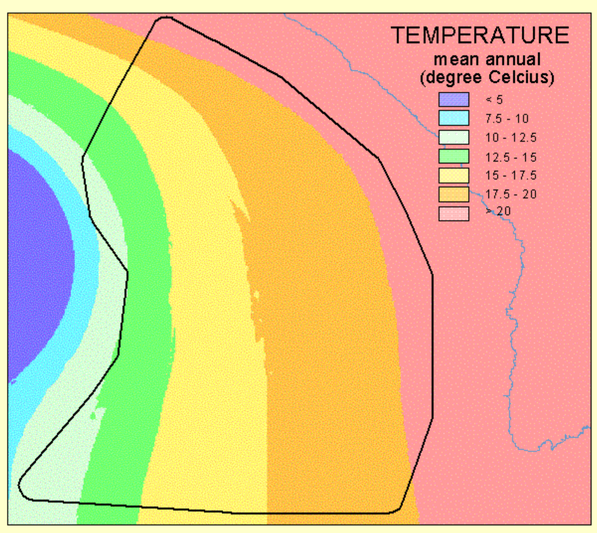






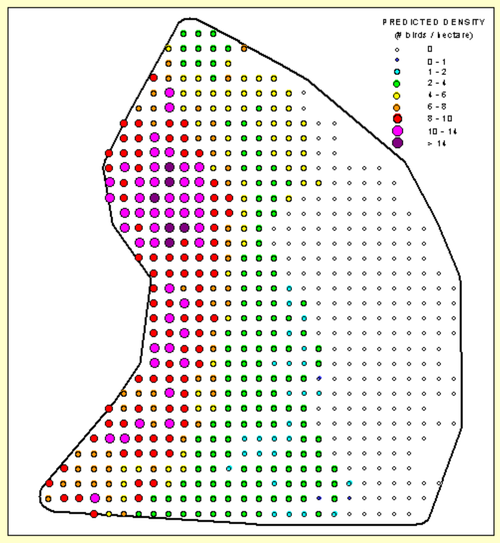




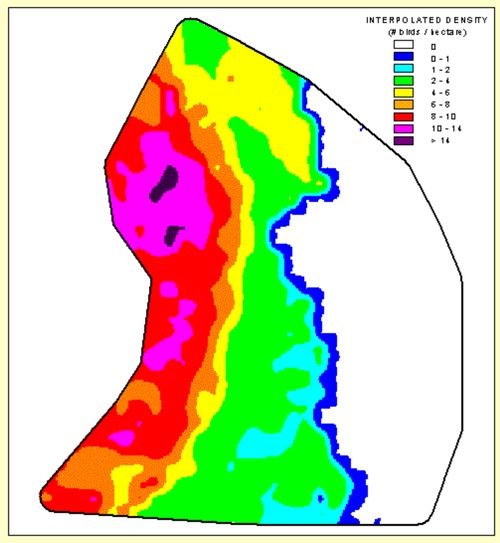


Point estimates of bird densities were developed with the program DISTANCE from bird counts surveyed with variable circular plot methodology. Regression was used to model density and habitat associations, and to predict density in unsurveyed habitat for an entire study area. Predicted densities were developed for a regular lattice of points from which interpolation was used to generate density surfaces. Density surfaces served as maps of predicted species distribution, and yielded estimated population sizes from area-based sums of densities. Correlation analyses supplemented regression models for the purposes of interpreting species-habitat associations.

species-habitat model applied to predict densities



predicted densities are interpolated to produce density surface



DISCUSSION: The HFBIDP has initiated the first synthesis of more than 25 years of survey data, and is generating new or revised population estimates and distribution maps essential for the management and conservation of the Hawaiian avifauna. In addition to corroborating habitat associations identified by earlier studies, the species-habitat models developed in this study are used for predicting densities in unsurveyed areas. The predictions are subsequently used to generate density surfaces for assessing the spatial distribution of bird species, and to provide area-based measures of abundance from which population estimates are derived. The calculation of the variance associated with a population estimate obtained from interpolation remains problematic (Royle et al. 2002).

Model predictions derived from a regular lattice of points spaced 1 kilometer apart permit the characterization of *local* habitat conditions. A regular lattice of point predictions has the added benefit in that it does not produce the surface distortions and high variance typical of interpolations from irregularly spaced survey stations.

Interpolation of *predicted* densities generates surfaces that more accurately depict species-habitat relationships than interpolation methods based only on observed densities at scattered survey stations. This approach specifically incorporates into predictive models the habitat characteristics that contribute, in part, to regulating local and regional abundances. It also avoids the problems of interpolating observed densities across areas of unsuitable habitat.

FUTURE RESEARCH DIRECTIONS: Conditional autoregressive modeling is currently being developed for use in addressing fine-scale spatial autocorrelation in bird density and habitat variables. Other techniques (such as weight-of-evidence logistic models for absence-presence data) are also being evaluated for use in predicting distributions, especially for rare species for which observed densities are highly variable. In addition, bootstrap methods are being investigated as a means of obtaining the variance of a population estimate.

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