SPATIAL HABITAT MODELING OF HAWAIIAN FOREST BIRD DENSITIES FOR ESTIMATION OF POPULATION SIZE AND DISTRIBUTION

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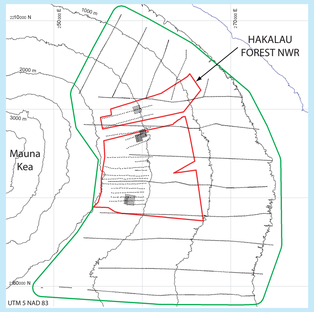
INTRODUCTION

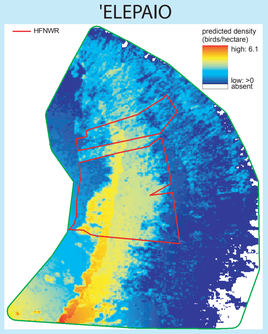
- The Hawai'i Forest Bird Interagency Database Project (HFBIDP) is an ecological study of the Hawaiian avifauna developed by the USGS Pacific Island Ecosystems Research Center. The HFBIDP has produced a database containing more than ¾ million records from over 400 forest bird surveys since the mid-1970s on the major Hawaiian Islands.
- We used GIS to integrate information on species densities at surveyed locations with habitat data derived from remote sensing and field sampling. We then developed predictive models at the landscape level of the distribution and population sizes of the Hawaiian avifauna.
- Results are presented for 8 native and 4 alien bird species from 66 variable circular plot surveys conducted in 1977 and between 1987-2000 in a 64,843-hectare study area on northeastern Hawai'i Island that encompasses the Hakalau Forest National Wildlife Refuge (HFNWR).

STUDY AREA

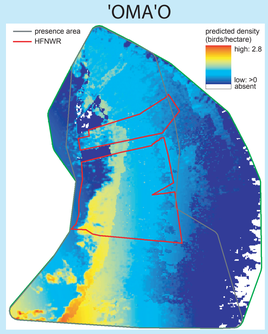
SURVEY TRANSECTS



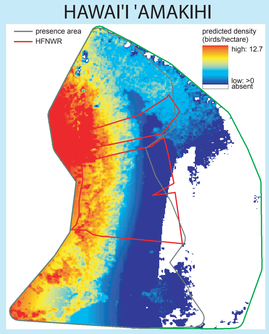
'ELEPAIO



'OMA'O



HAWAI'I 'AMAKIHI



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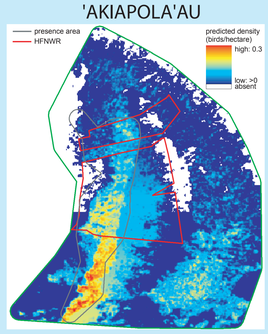
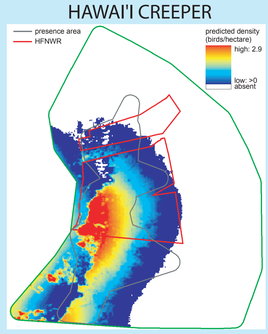


HAWAI'I CREEPER



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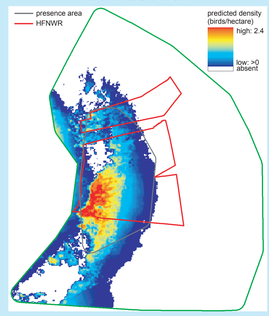

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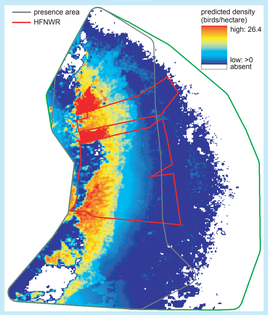

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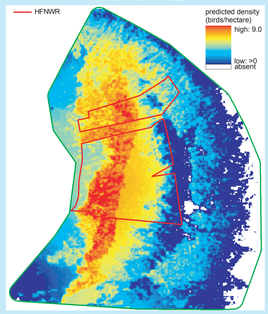
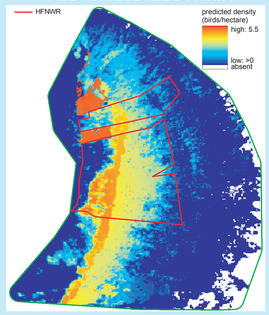
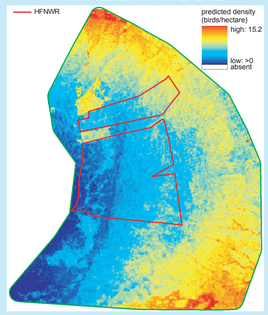


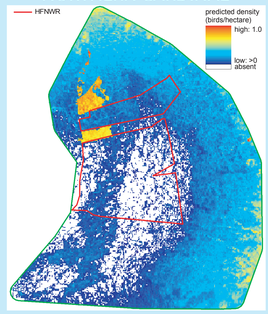
RED-BILLED LEOTHRIX



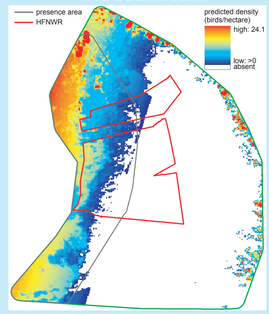
JAPANESE WHITE-EYE



NORTHERN CARDINAL



HOUSE FINCH



METHODS

- Survey stations were linked to habitat information derived from digital elevation models, rainfall and temperature isopleth interpolation, and land-cover classification of Landsat 7 imagery. Classified imagery provided data on dominant vegetation composition and structure, including canopy closure, canopy height, and the 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 invasive species such as banana poka (*Passiflora mollissima*) and guava (*Psidium* spp).
- Bird densities were calculated with the program DISTANCE from counts (i.e., abundance) sampled with variable circular plot (VCP) methodology (Buckland *et al*. 2001). VCP uses radial distances from observer to birds to calculate detection probabilities. Detection probabilities, in turn, determine the effective area sampled from which bird densities are derived (i.e., density = count / area).
- Regression was used to model observed density and habitat associations, and to predict density. The models used an autoregressive method that incorporated a spatially-dependent covariance structure, thereby accounting for fine-scale autocorrelation in density and habitat variables (Lichstein *et al*. 2002). Coarse-scale autocorrelation was controlled with trend surface terms (i.e., standardized geographic coordinates).
- Univariate correlation was used to characterize simple habitat associations.
- Estimates of densities and standard errors were generated with autoregressive models for all 1-hectare cells within the study area, and summed to estimate population size. The population estimate was limited to a species' "presence area" if the current regional distribution was smaller than the study area.

Significant positive or negative correlation ($p < 0.01$) between species' density and habitat variable.

Habitat Variables	Native Species [a]								Alien Species [a]			
	ELEP	OMAO	HAAM	AKIP	HCRE	AKEP	IIWI	APAP	RBLE	JAWE	NOCA	HOFI
OHIA	+	+	–	+	+	+	+	+	+		–	–
KOA		+	+			+	+	+			+	–
GRASS	–	–		–	–	–	–	–	–			+
EXOTIC	–	–					–	–		+	+	+
CLOSED	+	+	+	+	+	+	+	+	+	–		–
OPEN	–	–	–			–	–	–	–	+	+	
SPARSE	–	–	–			–	–	–		+		+
HIGH	+	+		+	+	+	+	+	+	–	+	–
MID	–	–	–					–	–	+	–	
LOW					–							
TREE FERN	–	–	–		–		–	–	–	+		–
MATTED FERN	–	–	–	–		–	–	–	–		–	
PASSIFLORA	–	–	+	–	–	–	+		+	+	+	
PSIDIUM	–							–	–	+	+	
RICHNESS	–	–	+		–	–	+	–	–	+	+	+
SLOPE	–	–	+								+	+
TEMPERATURE	–	–	–		–	–	–	–	–	+	+	–
RAINFALL	–	–	–	+			–	–	–	+		–
ELEVATION	+	+	+		+	+	+	+	+	–	–	

[a] Species acronyms - **native species**: ELEP - 'Elepaio (*Chasiempis sandwichensis*), OMAO - 'Oma'o (*Myadestes obscurus*), HAAM - Hawai'i 'Amakihi (*Hemignathus virens*), AKIP - 'Akiapola'au (*Hemignathus munroi*), HCRE - Hawai'i Creeper (*Oreomystis mana*), AKEP - Hawai'i 'Akepa (*Loxops coccineus*), IIWI - 'I'iwi (*Vestiaria coccinea*), and APAP - 'Apapane (*Himatione sanguinea*); **alien species:** RBLE - Red-billed Leothrix (*Leiothrix lutea*), JAWE - Japanese White-eye (*Zosterops japonicus*), NOCA - Northern Cardinal (*Cardinalis cardinalis*) and HOFI - House Finch (*Carpodacus mexicanus*).

RESULTS

- The native species are generally associated with closed canopy, high stature native forest with 'ohi'a (*Metrosideros polymorpha*) and koa (*Acacia koa*) components.
- The alien species occupy a variety of niches and are associated with both forest and non-forested habitats, often in areas with an exotic plant component.
- The banana poka, an invasive vine that produces copious nectar and fruit, is associated with high densities of native birds such as the nectarivorous 'I'iwi and alien omnivores such as the Red-billed Leothrix, Japanese White-eye, and Northern Cardinal. Dense growths of the tree-strangling vine are negatively associated with densities of other native birds such as 'O'mao and 'Akepa.
- Positive association of native species with elevation is the result of range contractions caused by high incidence of avian malaria at low to mid-elevations. Negative correlations of density with tree fern, matted fern, temperature, and rainfall reflect the inverse of the association with elevation. Positive correlation with slope reflects the concentration of populations at higher (and steeper) elevations.
- HFNWR includes portions of the regional populations of three endangered species: 'Akiapola'au (50%), Hawaii Creeper (49%) and Hawaii 'Akepa (72%).

Population and standard error estimates derived from predicted densities.

Species	Population Size	Standard Error	Extent (km^2) *
'ELEPAIO	138,930	605	648
'OMA'O	57,533	191	473
HAWAI'I 'AMAKIHI	200,760	990	416
'AKIAPOLA'AU (E)	1,585	44	108
HAWAI'I CREEPER (E)	17,842	221	167
HAWAI'I 'AKEPA (E)	8,311	144	108
'I'IWI	285,422	1,267	384
'APAPANE	255,898	1,037	648
RED-BILLED LEIOTHRIX	82,006	480	648
JAPANESE WHITE-EYE	460,373	1,417	648
NORTHERN CARDINAL	8,677	93	648
HOUSE FINCH	64,799	568	201

* Area encompassed by either the 648 km^2 study area or species' presence area (i.e., area of occurrence).
(E) Federally listed as endangered.

DISCUSSION

- Analyses are updates of the initial study carried out a quarter century ago by Scott *et al*. (1986).
- Density predictions generated for 1-hectare cells permitted the characterization of local habitat conditions. This approach is an improvement over previous methods of extrapolating densities from survey stations to strata that are presumed to possess homogeneous habitat conditions.
- Autoregressive modeling effectively addresses fine-scale spatial autocorrelation in bird density and habitat variables. It avoids overstatement of explanatory variable significance in models that assume independent errors and provides adjusted regression coefficients.
- Parts of the regional population of species of concern lie outside of the protection afforded by the HFNWR and are vulnerable to habitat degradation.
- Native habitats harbor widespread and large populations of alien bird species. The competitive effects of these species upon native birds are poorly understood.

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