

Supplementary text

Maximum entropy: detailed

A maximum entropy model ultimately takes information from data based on observations and maximizes entropy within the means of the environmental constraints (Jaynes, 1957; Elith et al., 2011). Using presence and absence (or random background) data, we calculated the conditional density of covariates ($f_1(z)$) and the marginal density of covariates ($f(z)$), respectively (Phillips and Dudík, 2008; Elith et al., 2011). With the following formula,

$$f_1(z) = f(z)e^{n(z)}, \quad (1)$$

where $n(z) = \infty + \beta \cdot h(z)$,

if we let ∞ be a normalization constraint, β a vector of coefficients, and $h(z)$ a vector of features, the raw output estimates the $f_1(z)/f(z)$ ratio where by covariate values are rescaled such that $f_1(z)$ sums to 1, and constraints are applied to the means of the features based on the means of the covariates (Elith et al., 2011). Next, an error bound smooths this output and prevents overfitting and limits the output probabilities (Elith et al., 2011). The distance between the conditional covariate density and the marginal density is the relative entropy, and by estimating the log of the raw output ratio,

$$n(z) = \log(f_1(z) / f(z)), \quad (2)$$

the probability of a species presence is presented on an interpretable 0–1 scale, where 0.5 reflects the prob-

ability of presence at the sites, where environmental conditions are ‘typical’ for presence (Phillips and Dudík, 2008; Elith et al., 2011).

With each additional informative covariate, the data set is further constrained. This information gain leads to a decrease in uncertainty and the probability distribution moves away from uniform and toward that of the data from observations (Cover and Thomas, 1991). The logistic output from a maximum entropy model is the probability distribution; it reflects the sum of all constraints (the realized niche) and the relative suitability of all locations on the basis of conditions prevailing in areas under occupation (Phillips et al., 2006).

Literature cited

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