

IV REUNIÓN BINACIONAL DE ECOLOGÍA

Interacción, Espacio, Tiempo

8 al 13 de agosto 2010
Buenos Aires, Argentina



CONFERENCIA PLENARIA

Miércoles 11 de agosto
19:30 hs

THE THREE PHASES OF ENSEMBLE FORECASTING OF NICHE MODELS: MAPPING UNCERTAINTIES IN SPECIES DISTRIBUTIONS UNDER CLIMATE CHANGES

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Species' geographic ranges are usually considered as basic units in macro-ecology and biogeography, yet it is still difficult to measure them accurately for many reasons. About 20 years ago, researchers started using local data on species' occurrences to estimate broad scale ranges, thereby establishing the niche modeling approach. However, there are still many problems in model evaluation and application, and one of the solutions is to find a consensus solution among models that is derived using different mathematical and statistical models for niche modeling, climatic projections and variable combination, all of which are sources of uncertainty during niche modeling. In this paper, we discuss this approach of ensemble forecasting and propose that it can be divided into three phases with increasing levels of complexity. Phase I is the simple combination of maps to achieve a consensual and hopefully conservative solution. In Phase II, differences among the maps used are described by multivariate analyses, and Phase III consists of the quantitative evaluation of the relative magnitude of uncertainties from different sources and their mapping. We show a new method developed for evaluating Phase III, based on a model II Analysis of Variance (ANOVA) applied to each geographical unit (grid cell), in which sources are different levels on uncertainty in ensemble forecasting and response is a modeled biological variable. We present several applications of the three phases, for both shifts in climatically suitable areas for different species and broad-scale patterns of species' turnover in the neotropics. In most cases, niche models are the main source of uncertainty, although climatic models and their interaction with niche usually possess clear spatial structure of ANOVA variance components.