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# Improving the analyses of nestedness for large sets of matrices

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## Abstract

Nestedness is a property of binary matrices of ecological data and quantified by the matrix's temperature, $T$. The program widely used to calculate $T$ is Nestedness Temperature Calculator (NTC). NTC analyses matrices individually, turning the analysis of large sets time-consuming. We introduce ANINHADO, a program developed to perform rapid and automatic calculation of $T$ over 10,000 matrices. ANINHADO can be useful to minimize the time spent in analysis and to compare real data against a variety of null models that typically generate a large number of replicates.

*Keywords:* Biogeography; Community assembly; Ecological networks

## Software availability

Name of software: ANINHADO
Developers: Paulo Guimarães and Paulo R. Guimarães Jr.
Platform: MS-DOS under Windows.
Contact address: Instituto de Biologia, UNICAMP, CP 6109, Campinas, SP, Brazil
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Availability: http://www.guimaraes.bio.br

Environmental scientists have been studying systems to discover for the patterns of the underlying processes. Many of these patterns are described in binary or presence/absence matrices (Bascompte et al., 2003). Nestedness is a pattern (Fig. 1), which characterizes distributions of species within a habitat (Atmar and Patterson, 1993), parasites among hosts (Worthen and Rohde, 1996), and interactions in ecological networks (Bascompte et al., 2003).

The degree of nestedness of a matrix can be quantified by the matrix's temperature ($T$), a measure of how the presence/absence pattern departs from perfect nestedness (calculated by NESTEDNESS TEMPERATURE CALCULATOR (NTC), see Atmar and Patterson, 1993). Nevertheless, as the studies about nestedness have increased, some analyses cannot be optimally performed using NTC, leading to the necessity of new tools. Here we introduce ANINHADO, a program developed to attend to one of these needs: the rapid, automatic calculation of $T$ for many matrices.

NTC is a Visual Basic package downloadable at http://aics-research.com/nestedness/tempcalc.html. It implements a good graphical user interface, intuitive menus, it includes background information about the nestedness theory and it also allows hypothesis testing: the observed value of $T$ can be compared with the expected one under the assumption that presences were randomly assigned to any cell within the matrix. The graphical user interface and the supporting documentation about nestedness theory make NTC a convenient tool for users willing to analyze a limited number of matrices. However, the user needs to load and calculate $T$ from each matrix individually, making the calculation of $T$ time-consuming when there are many matrices to examine.

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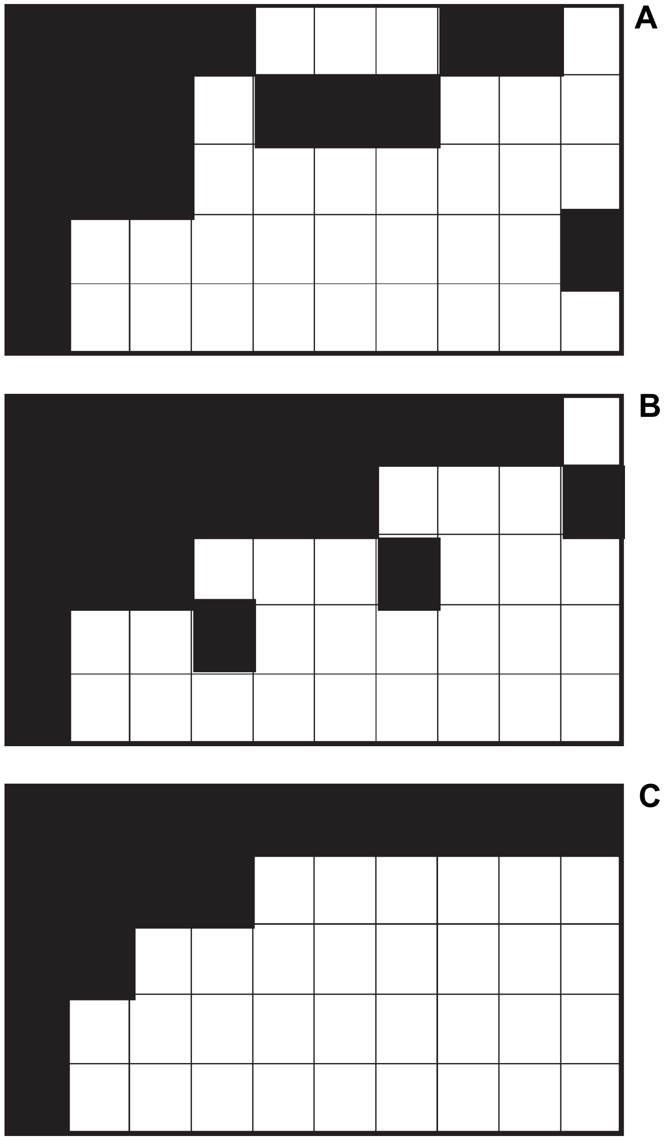

Fig. 1. Hypothetical matrices describing presences (black squares) of species (rows) in locations (columns). Nestedness occurs when presences in a row/column is often a subset of presences recorded in rows/columns with more presences. The matrices vary in their degree of nestedness: low (A), high (B), and perfect (C).

Table 1
Performance of NTC and ANINHADO using a Mobile Intel Pentium 4, 2.8 GHz CPU processor

| | NTC | ANINHADO |
|---|---|---|
| Matrices/run | One | 10,000 |
| Matrices/min | ∼8 | >80 |
| Automatic processing | No | Full |

The C++ software ANINHADO was developed to perform rapid, automatic calculation of $T$ of many matrices (Table 1). ANINHADO analyzes a set of user-specified matrices and generates a file containing their names and respective $T$ values. Moreover ANINHADO does not require the user‘s interaction during its execution, and it is therefore possible to perform other tasks in the computer during the analysis.

The automatic processing capabilities and speed of ANINHADO are also an asset when the user is interested in analyzing sets of real matrices or when testing null models other than the one implemented in NTC (Bascompte et al., 2003). The null model approach is based on the comparison of real data with an empirical distribution obtained from the analysis of thousands of algorithm-generated matrices that deliberately exclude an influence (Gotelli and Graves, 1996). As a consequence, the rigorous characterization of the expected $T$ for an alternative null model will consume hours of continuous work in NTC, but only few minutes in ANINHADO. Additionally, ANINHADO generates empirical distributions for four pre-determined null models, allowing users not familiarized with programming to compare their data against alternative hypotheses.

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