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# Understanding and predicting time-lags in the response of birds to agricultural intensification using qualitative models.

Fernando Goulart, Paulo Salles and Carlos H.Saito

goulart.ff@gmail.com, psalles@unb.br, saito@unb.br
Institute of Biological Sciences, University of Brasilia
Campus Darcy Ribeiro, Brasilia, 70.910-900, Brazil

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## Abstract

Ecological systems hardly immediately respond to disturbance. Time-lags are common from the population to the ecosystems level. In a pioneer work, Tilman and colleagues modeled the impact of habitat loss on multiple species based on their competition ability. Results showed that there is an ecological debt defined as the present ecological cost of former habitat destruction. Taking this insight one step further, it has been shown that some ecosystems, such as in the case of the Atlantic Forest hotspot, the ecological debt have not been paid for bird species. This may explain why, even thought having less than 7% of forest cover, no extinction of avian species have been recorded for the biome. Considering that the threshold for habitat loss (minimum area for species survival) is somewhere around 40% of the original area, we shall expect extinctions in the near future. As experimental designs for studying time-lags are often unfeasible, modeling the ecological debt is necessary for ecologists and managers to understand, predict and take conservation actions before it`s too late.
Considering that agricultural intensification is one of the major threats to biodiversity, the work described here explores time-lag responses related to agricultural intensification-induced decline of bird species using qualitative reasoning models. Aware that effect of agricultural intensification on both farmland and nearby natural patches is slow and have non-trivial dynamics, we built a qualitative model to understand and predict the time-lag between causes and the effects on the community.
Qualitative reasoning (RQ) is an area of Artificial Intelligence (AI) engaged in describing physical and biological systems in order to derive behavior from system structure, and in doing so, to ground the dynamics of such systems in causal relations, when numerical data and precise information about the reality are unavailable. According to Forbus' Qualitative Process Theory, the behavior of a given system is determined by active processes. They are seen as mechanisms that affect objects' properties, the effects of which propagate to other compartments of the system over time and space. Therefore, the consequences of processes being active may be explained by means of causal relations involving relevant quantities. The model presented in this paper shows a landscape in which forest patches (source and target) are embedded in an agricultural matrix in which intensification takes place. In order to capture relevant elements of the system being modeled, a qualitative model is built around entities (the objects) and quantities (object properties). This way, Target forest patch properties are represented by the quantities *species variation rate*, *species richness* and *abiotic border effect*. Farmed matrix, by the quantities *bird predation and parasitism*, *spatial heterogeneity*, *food*

*resources*, *tree density*, *microclimatic alteration*, *nest site abundance*, *species variation rate*, *species richness* and *permeability*. Intensive Agriculture, by *agricultural intensification rate*, *mechanization level* and *pesticide*; Forest Species source, by *propagules quantity*; and Emigration, by *migration rate*.

Permeability is defined in terms of physical and biological characteristics that facilitate or render the flux of propagules (fruits, seeds, larvae etc.) and individuals through it. In the model described here, permeability should be equal or greater than a threshold value as a condition for propagules to cause positive influence on *species variation rate* of natural patches. Although many variables affect *permeability* such as *spatial heterogeneity*, *bird predation* and *tree density*, the model assumes that *permeability* changes in the same direction as *tree density*.

Intensification leads to the decline of matrix *species richness* (farm-birds) directly by the use of *pesticides* and indirectly by decreasing *tree density* and increasing *mechanization level* which leads to *nest site abundance* decrease. Pesticides also affect *species variation rate* indirectly by decreasing *food resources*. Forest patches species decline occurs because many of these species feed on the matrix and thus are affected by decrease of food resources. Decrease in permeability prevents colonization from forest species source and rescue effect leading forest *species richness* to decline.

Time-lags are also explained by the functional response of bird populations to food resource. Typically, consumption increases but rapidly decelerates and reaches a plateau with no change in consumption over wide high abundance of food resources. In the model, if the quantity *food resources* is lower than or equal to the value *medium*, then it affects positively *species variation rate*. If *food resources* is greater than *medium*, the model assumes it doesn't affect *species variation rate*. A number of model fragments represent similar trends for other variables. For instance, if *microclimatic alteration* is greater or equal to *medium*, than *microclimatic alteration* positively affects *border effect* in the forest patch, causing *species variation rate* of forest birds to decrease. This causal relation also induces a time-lag response.

In the model, relaxation time is the lag between intensification and the stabilization of *species variation rates* of both matrix and forest patches, which in turn lead to the stabilization of species richness in value small for both areas. Understanding time-lag in ecological responses should not be done without explicit representation of causality. Qualitative Reasoning appears as an important tool to support understanding, teaching and researching about time-lag.

In the present model both farmed matrix and target fragment took four qualitative time stages to happen. The quantification of this delay still uncertain and this depends on the intensification intensity, in the case of farm-land biodiversity and depends on the forest patch characteristics. One must notice that knowing the exact time-lag depends on the landscape and agricultural circumstances. For the moment, we argue that any study concerning agricultural intensification must be done under a specific time scale and that any study that do not consider a relaxed landscape (a system that still has an ecological debt to be payed) may underestimate the impacts of agricultural intensification on forest patch and matrix biodiversity. Considering that most studies don't consider the agricultural timing, most of known impact of intensification might appear to be smaller than it really is.

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