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Preliminary Assessment of the Termite Distribution in Portugal

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Abstratct. Although extensive references can be found on the presence in the last 50 years of subterranean termites, particularly *Reticulitermes lucifugus* (Rossi), in Portugal, their exact distribution and importance have never been critically evaluated. Termites were found to be widespread in the country and are probably the most serious wood destroying insects in buildings. To provide a future working tool that would permit an evaluation of the probability of termite infestation within a given area, an attempt was made to model the probability of the presence of *R. lucifugus* to a set of environmental variables. Logistic regression was the chosen statistical method. Four variables were found to explain, in part, the distribution of the data. The overall effect of changes in environmental variables on the probability of termite occurrence is inferred from the model.
Key words: *Reticulitermes lucifugus*; modelling; logistic regression

Sumário. Embora existam várias referências da presença de térmitas subterrâneas em Portugal, particularmente de *Reticulitermes lucifugus* (Rossi), a sua exacta distribuição e importância não foram ainda avaliadas. As térmitas encontram-se dispersas por todo o país e são, provavelmente, os insectos degradadores de madeira mais relevantes em termos de construções. Com vista ao desenvolvimento de uma ferramenta de trabalho que permita avaliar a probabilidade de infestação por térmitas numa determinada área, procedeu-se à modelização da presença de *R. lucifugus* em função de um conjunto de variáveis ambientais, através de uma regressão logística. Foram encontradas quatro variáveis como sendo as mais explicativas da distribuição dos registos. O efeito global das alterações das variáveis ambientais na probabilidade de ocorrência de térmitas pode ser inferido a partir do modelo.
Palavras-chave: *Reticulitermes lucifugus*; modelização; regressão logística

Résumé. Bien que de nombreuses références puissent être trouvées sur la présence des termites souterrains, en particulier le *Reticulitermes lucifugus* (Rossi), au Portugal, leur exacte distribution et importance n'ont pas encore été évaluées. Les termites sont répandus dans le pays et sont, probablement, parmi les insectes détruisants le bois les plus sérieux du bâtiment. Pour fournir un futur outil qui permettrait une évaluation de la probabilité de l'infestation de termite dans une zone donnée, une tentative a été faite de modeler la probabilité de la présence de *R. lucifugus* à un ensemble de variables environnementales. La régression logistique était la méthode statistique choisie. Quatre variables se sont avérées les plus explicatives pour la

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distribution des données. L'effet global des changements des variables environnementales sur la probabilité d'occurrence de termites peut être déduit du modèle.
Mots-clés: *Reticulitermes lucifugus*; modelant; régression; logistique

Introduction

The distribution of termites was extensively discussed by a number of authors in the second volume of "Biology of Termites" (KRISHNA and WEESNER, 1970) and lately by EGGLETON (2000). The great majority of termites live in tropical and subtropical regions, though they extend into warmer temperate zones of the world like southern Europe. Several factors are suggested to explain this special distribution but the absence of a sufficiently high temperature for long periods of the year seems to be chiefly responsible for the absence of termites in certain parts of the world. However, anthropogenic climate changes and the increased use of centrally heating explains the establishment of *Reticulitermes flavipes* (Kollar) in more northerly cities like Toronto or Hamburg or of *Reticulitermes lucifugus* (Rossi) in Saunton, North Devon, U.K. (VERKERK and BRAVERY, 2000).

Up to now, in mainland Portugal, only two species of termites, both wood--feeders and building pests, have been reported (*e.g.* SARAIVA, 1957; FRANCO, 1965; CLÉMENT, 1986; HARRIS, 1970): one is the drywood termite, *Kalotermes flavicollis* Fabricius and the other is the subterranean termite, *Reticulitermes lucifugus*. Recently *K. flavicollis* has been observed by the authors in several regions of the central and southern parts of the country, namely in the Portuguese cities of Beja, Évora and Lisboa. However there is still no basis to assess it severity as a pest of construction timber.

Both of the principal species are present throughout southern Europe and the Mediterranean countries, reaching the borders of Turkey and Iran in the East (HARRIS, 1970), together with *R. santonensis* (de Feytaud) in southern France and northern Spain. Moreover, MATEUS and GOES (1953) reported the presence in Portugal of another dry wood termite and also a building pest, *Cryptotermes brevis* (Walker) though in the island of Madeira.

In Portugal, *R. lucifugus* is by far the most destructive species (FRANCO, 1965) with a wide distribution, apparently without latitudinal, longitudinal or altitudinal patterns (FRANCO, 1965; NUNES *et al.*, 2000). In particular the region of Lisbon and its surroundings is considered severely infested (NUNES *et al.*, 2000).

Unfortunately, in Portugal as in other countries, there is a lack of systematic studies on the distribution of termites. To understand the range of termites' infestation problems it is essential to look at their distribution systematically, and the knowledge of the ecological requirements of each species is also needed. With this knowledge, the occurrence and severity of potential problems can be predicted to some extent and hopefully the appropriate management activities can be put in place.

Materials and methods

The collection of data regarding termite occurrence was based on an extensive bibliographic review (SEABRA, 1907; SEABRA, 1939; NEVES, 1950; SILVA, 1952; MATEUS and GOES, 1953; NEVES, 1956; VIEIRA, 1956; MARQUES, 1957; RIBEIRO, 1957; SARAIVA, 1957; CABRAL,

1959; MENDES, 1959; SEMEDO, 1961; FRANCO, 1965; CABRAL, 1985), plus all confidential reports from the Timber Division of LNEC. The review also took into account reports from companies active in termite control and unpublished observations of the authors.

To model the probability of presence of *R. lucifugus* infestation, a logistic regression was performed. This model is used to describe the relationship of several independent variables to a dichotomous dependent variable requiring fewer assumptions than discriminant analysis (HOSMER and LEMESHOW, 1989; TABACHNICK and FIDELL, 1989; KLEINBAUM, 1994).

Lacking other criteria, the Portuguese mainland was simply divided into 50x50km cells, using the Universal Transverse Mercator (UTM). All the parameters considered were compiled for each cell.

The dependent variable was derived from records of *R. lucifugus* as explained above. The majority of data available were of detected and communicated infestations. Accordingly, a positive record actually means the presence of the species but we can not assume that the absence of records in a given cell would mean the absence of termites (*i.e.* an event not occurring). In order to look at the distribution of termites infestations, 60 sites of termite presence were compared with 40 areas of absence (corresponding to areas without records), obtained randomly.

For the selection of independent variables, an evaluation of available data as ecological predictors of the presence of *R. lucifugus* was first carried out. The chosen variables were put into classes being all the analysis based on the new discrete variables. This is presented in Table 1.

The statistical analysis was performed in SPSS for Windows Advanced Statistics 7.0. The multivariate analysis was performed by submitting all the variables to the forward stepwise method, in order to obtain a more parsimonious model. Removal testing was based on the probability of the Wald statistic. The major and minimum limits considered for entry and removal of variables were suggested by HOSMER and LEMESHOW (1989) (p<0.15 for enter and p>0.20 for removal), as the usual *p-value* of 0.05 is too restrictive.

The significance (p<0.001) of the logistic model was established from the likelihood ratio statistics, by comparing the deviancies for the model fitted only to intercept β_0 and for the model of interest (HOSMER and LEMESHOW, 1989).

Results

Reports made before January 2001 constituted 586 records of termite occurrence. Although records could be found since the beginning of the 20th century, the majority of data come from the last 10 years. Termites can be found in every district of mainland Portugal and on the island of Madeira.

The species of termites found were, as expected, *Cryptotermes brevis* (Kalotermitidae) on the island of Madeira only; *Kalotermes flavicollis* (Kalotermitidae), and *Reticulitermes lucifugus* (Rhinotermitidae).

Concerning *K. flavicollis* 60 occurrences were recorded, both in forests and in houses, all in mainland Portugal (Figure 1a) with particular concentration in the region around Lisbon. Due to the small size of the sample, no attempt was made so far to model the distribution of this species.

Table 1 - Independent variables, number of classes considered, minor, and major values observed

Variables*	Number of classes	Minor value	Major value
Annual Average Temperature (ºC)	3	< 10.0	> 15.0
Annual Average Humidity (% at 9 TMG)	5	< 65	> 85
Total rainfall (mm)	4	< 500	> 1600
Days of rainfall (number)	3	51 to 75	101 to 110
Days of Frost (number)	5	0 to 5	> 70
Annual Insolation (hours)	5	< 1900	> 2800
Annual Evapotranspiration (mm)	5	< 400	> 800
Altitude (m)	4	0	> 700
Cambisoils (%)	5	0	> 75
Leptosols (%)	5	0	> 75
Luvisols (%)	5	0	> 75
Pódzols (%)	5	0	> 75
Regosols (%)	5	0	> 75
Solonchaks (%)	5	0	> 75
Forestry area (%)	9	< 10	> 200
Urban area (%)	8	< 5	> 150
Agricultural area (%)	10	<10	> 150
Buildings (number)	11	< 2000	> 100000
Familiar houses (number)	12	< 2000	> 400000
Human population (number)	12	< 2000	> 400000

* The data were collected from INE (National Statistic Institute) and DGA (General Environmental Department)

R. lucifugus was found to be distributed from north to south Portugal (Figure 1b), its presence being recorded in 498 different locations (although 215 of those were found in Lisboa and 37 in Porto). It is worthwhile to notice that 11% of the records found for this species were on areas considered as National and
even World Heritage sites.

The multivariate logistic model resulted in a final formulation comprising only 4 of the 20 variables considered (Table 2): human population, leptosols, insolation and days of rainfall.

Given the coefficients found for the most parsimonious model, the logistic regression equation for the probability of the presence of *R. lucifugus* can be written as:

Prob (*R. lucifugus* presence) = $1 / 1 + e^{-z}$;

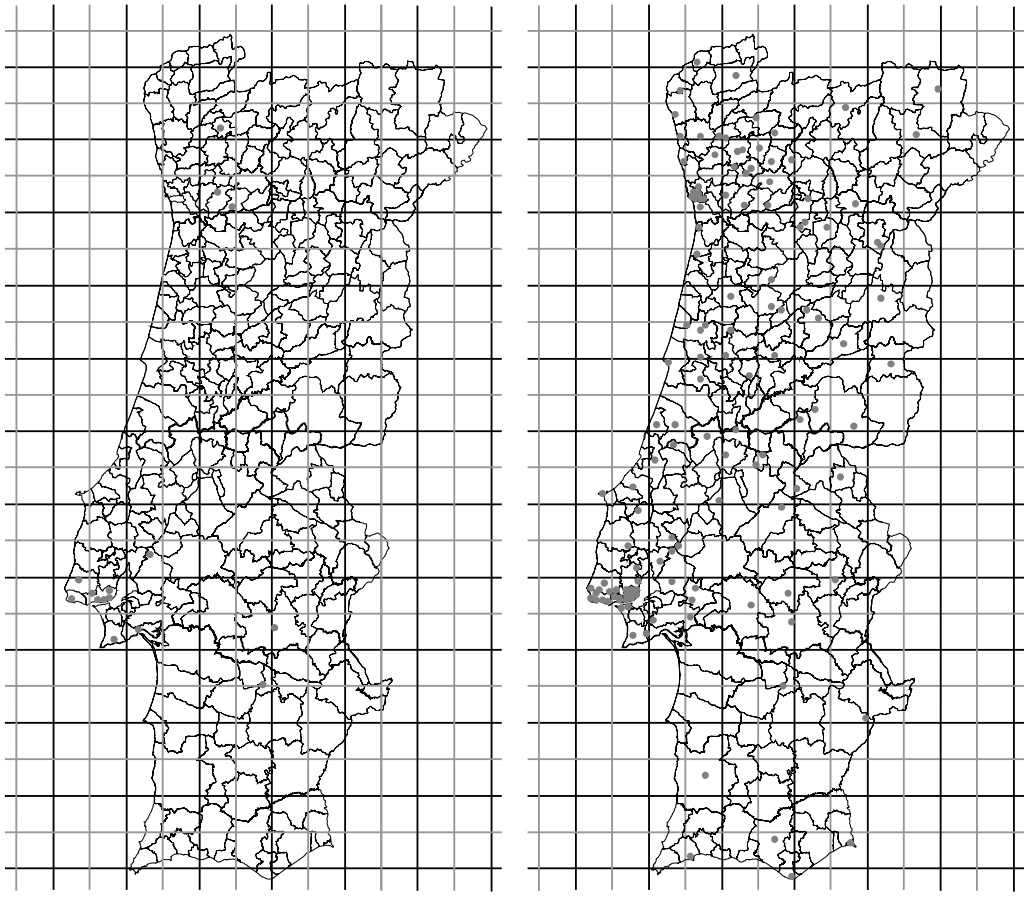
$Z^1 = -8.2253 + 0.5769(HP) - 0.5967(LS) + 1.0364(IS) + 0.9936(DR)$

According to this model, termite infestation is more likely in areas of high human population, with higher insolation and more days of rainfall. In sites with a high percentage of leptosols ("rocky" soils) the termite infestations are less likely to occur.

A plot showing the odds change produced by incremental changes in the

[1] See Table 2 for variables code

different independent variables (Figure 2) is a convenient way of representing the results of the logistic regression, as it makes them easier to interpret.



a) *K. flavicollis* b) *R. lucifugus*

Figure 1 - Sites of termites occurrence in mainland Portugal. The gridlines are based on UTM coordinates.

Table 2 - Estimated logistic regression coefficients (β), Standard error of β (S.E. β), Wald statistic and Odds ratio (ψ) for the model considered as the most parsimonious.

Variables	**Coef.**	**S.E.**	**Wald test**		**Odds ratio**	
	β	β		*p*	ψ	90% CI
Human Population (HP)	0.577	0.157	13.462	0.000	1.780	(1.375 , 2.306)
Leptosols (LS)	-0.597	0.215	7.663	0.005	0.551	(0.386 , 0.785)
Insolation (IS)	1.036	0.392	6.980	0.008	2.819	(1.479 , 5.374)
Days of Rainfall (DR)	0.994	0.534	3.455	0.063	2.701	(1.121 , 6.506)
Constant (β_0)	-8.225	2.779	8.760	0.003		

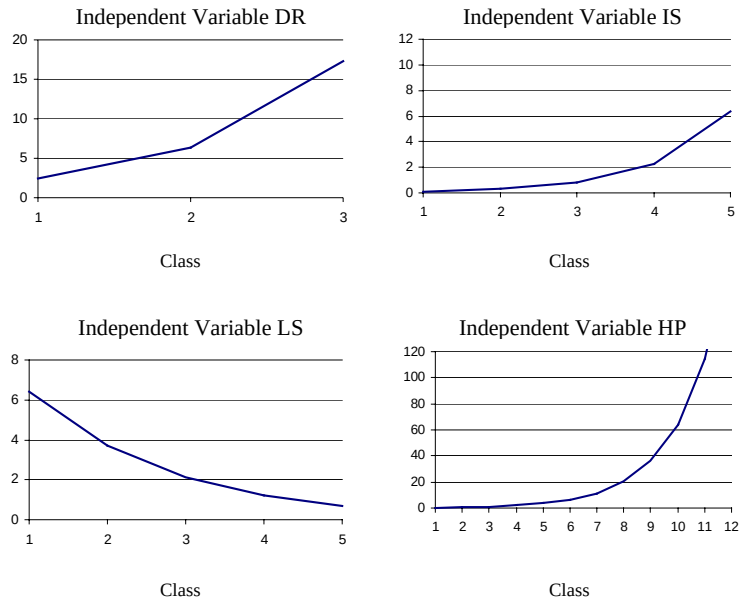


Figure 2 - Plots of odds with increasing classes of the independent variable under scope, keeping all other variables at their mode values. (DR) Days of Rainfall; (IS) Insolation; (LS) Leptosols; (HP) Human Population

The likelihood ratio statistic was significant (χ^2 =50.194; d.f.=4). Of the 100 cases introduced, the model identified correctly 83% of termite infestation cells and, at the same time, only misclassified 11% of the random cells. Considering the distribution data of all the cells determined, the model identified correctly 65% of termite infestation cells, the majority of misclassifications being due to the "absences" class (almost 50% of the "absences" were predicted, by the chosen model, as presences).

Discussion

The species with the most extensive distribution and the one that causes the most serious problems to timber in service in Portugal is *Reticulitermes lucifugus*, and was therefore the main focus of this work. The presence of this termite was registered from north to south, without a defined pattern. This is indicative of its universal occurrence throughout the country. Records of termites occurrence do not directly translate into distribution. The majority of reports are from the cities of Lisboa and Porto, and the almost complete absence of data from the inner parts of the country may reflect the great influence of factors such as development, richness and risk awareness, on the infestation occurrence data. Though risk awareness is extremely difficult to quantify, further efforts will have to be made, mainly on sampling procedures, to better take into account the remaining factors.

The model developed here has to be seen as a preliminary analysis. It is based on relatively large cells with low resolution for the organisms under consideration. An analysis of multicollinearity was lacking and being some of the variables used intrinsically interdependent, this could lead to some spurious considerations. One way to compensate for unavoidable intercorrelation of the data would be the use, as independent variables, of the axis obtained from an ordinary principal components analysis (PCA) as performed by PALMA *et al.* (1999).

The model did not address directly the question of termite distribution, nor the habitat selection by the termites. The clear association of our data with human variables should not be forgotten.

Nevertheless, the results show a close agreement between the predicted distribution of infestation sites of termites based on environmental criteria and their actual reported occurrence.

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