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5.8 Selecting critical areas for monitoring the impact of ammonia on biodiversity

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Summary
- The main impact of atmospheric ammonia (NH₃) is known to occur at short distances (less than 500 m). Therefore, for successful development and implementation of policies aiming at preventing the impacts of NH₃ on biodiversity of Natura 2000 sites, it is necessary to make use of a high spatial resolution mapping. However the available information of NH₃ emission and deposition is clearly of an insufficient resolution for this purpose, at least in Portugal.
- Our objective was to provide a practical method for selecting critical areas for monitoring the impact of NH₃ in plant and animal biodiversity within Natura 2000 sites. Lichen functional-diversity is a good indicator of NH₃ impact at small spatial scales, when a single source of disturbance is present. However, because Natura 2000 sites are large areas and contain multiple sources of disturbance, lichen-functional diversity may not be the most appropriate indicator since it responds to other factors besides NH₃. Therefore, we propose to use total nitrogen concentration in lichens, [N], as a method for selecting critical areas of NH₃ impact in Natura 2000 sites.
- A first question that was addressed was: what are the [N] concentration in lichens reflecting? For that we tested if: i.) [N] was reflecting atmospheric NH₃ deposition (by relating it with agriculture land-use); ii.) was [N] reflecting NOₓ (by relating it to industrial and urban land-uses).
- The [N] in lichens was shown to be very significantly related to agriculture areas and not to urban or industrial areas thus showing that N concentration in lichens is most probably reflecting the NH₃ emissions. In this way we propose here to apply the N concentration in
lichens as a detailed ecological indicator for selecting critical areas for the impact of NH$_3$ on biodiversity.

- Furthermore, we applied this indicator to two Natura 2000 sites by mapping [N] in lichens. By doing so we could select the critical areas for the assessment of the impact of atmospheric NH$_3$ deposition on plant diversity in Mediterranean Natura 2000 sites. Further studies on the impact of plant diversity can now be focus in high NH$_3$ deposition areas.

5.8.1 Introduction

In Mediterranean landscapes a large variety of land-cover types occur in small areas (Blondel and Aronson, 1999). Besides, areas dedicated to Nature Protection are surrounded by centuries old human-matrix. Among important sources of disturbance in Natura 2000 sites we can find agriculture. Those activities are major sources of atmospheric NH$_3$ in Europe (EPER, 2004; Galloway et al., 2003). Moreover, the deposition of N is related to biodiversity loss (Phoenix et al., 2006; Suding et al., 2005) and is considered not only a major threat to global biodiversity but also one of those threats that are expected to increase worldwide (SCBD, 2006). Thus, biodiversity within protected areas might be highly threatened by atmospheric NH$_3$. However in Portugal the spatial resolution of the available emission and deposition mapping is clearly insufficient to allow an adequate selection of the areas under the greater risk of NH$_3$ impact (Martins-Louçã, this volume).

Therefore the main goal of this work was to provide a practical method for selecting critical areas for monitoring the impact of NH$_3$ on biodiversity within Natura 2000 sites. To do so we used lichens, poikilohydric organisms resulting from the symbiosis of a fungus and a photosynthetic partner. Lichens are considered one of the most sensitive communities of organisms in the ecosystems, due to its particular physiological characteristics such as the absence of a protective cuticle. Lichens are the most sensitive group of organisms to N and its functional biodiversity changes with NH$_3$ atmospheric deposition (Pinho et al., 2009). However the application of lichen diversity in this case is problematic, since it responds to a series of other factors. In fact, lichens have been shown to be sensitive to a large number of factors including pollutants, with both human and natural origin and microclimate changes (Geiser and Neitlich, 2007; Giordani et al., 2002; Pinho et al., 2004; Pinho et al., 2008a) and therefore have been used as biomonitors of complex environmental changes such as habitat fragmentation, habitat stability and influence of forest management (Coxson and Stevenson, 2007; Edman et al., 2008; Nascimbene et al., 2007; Ranius et al., 2008). More specifically, we propose to use lichens as nitrogen biomonitors (Gaio-Oliveira et al., 2001). This is so because total N in lichens has been shown to increase in NH$_3$ rich areas (Pinho et al., 2008b) and increased N concentration in lichens and plant tissues has been associated to higher N availability (Adrizal et al., 2008; Boggs et al., 2005; Fluckiger and Braun, 1998; Gaio-Oliveira et al., 2001; Pocewicz et al., 2007).

5.8.2 Aims and objectives

- The aim of this work was to provide a method with high spatial resolution for selecting critical areas for monitoring the impact of NH$_3$ on plant and animal biodiversity within Natura 2000 sites.
- For that we proposed to use total N concentration in lichens. We firstly tested if [N] was related to the area occupied by agriculture (a source of atmospheric NH$_3$) and artificial zones (a source of NO$_x$). Secondly we mapped [N] within the Natura 2000 sites.

5.8.3 Results and discussion

We found that [N] in lichens can be used as an ecological indicator to reflect NH$_3$ deposition in Natura 2000 sites with a high spatial resolution. The hypothesis was that this indicator would be useful for mapping critical areas of potential impact of NH$_3$ pollution, and to test this we first determined if [N] in lichens was related to human activities in neighboring areas, considering agriculture (emitting NH$_3$), industry and traffic (emitting NO$_x$).
In small areas, with a single source of disturbance, lichen biodiversity has been shown to respond accurately to NH\textsubscript{3}, leading to a change in lichen functional-diversity (Pinho et al., 2009). However, when dealing with Natura 2000 sites, normally occupying a regional area, we must consider the possible existence of multiple disturbance sources, many of which may be diffuse. In such areas, and more specifically in the studied area (Figure 5.13), nitrophytic and oligotrophic lichen species have been shown to respond to a large number of factors, including natural (such as the sea) and anthropogenic ones (such as industrial areas) (Pinho et al., 2008a; Pinho et al., 2008b). These may impede the use of biodiversity as an indicator of NH\textsubscript{3} pollution. In order to avoid the interference by other factors we used [N] in lichens to determine the critical areas of potential impact of nitrogen pollution, the usefulness of the use of nitrogen concentration as a biomonitoring tool having already been suggested by a preliminary work (Gaio-Oliveira et al., 2005). In this work, [N] was determined in the lichen species \textit{Parmotrema hypoleucinum} (J.Steiner) Hale, collected from 104 cork-oak woodland sites. First we determined if [N] was related to neighboring sources of atmospheric nitrogen, by performing a local correlation analysis (Figure 5.14). We considered neighborhood areas around sampling sites, with radius ranging from 50 to 6400 m (Pinho et al., 2008a). A local analysis was made using these areas, by relating [N] and area of agriculture and artificial land-cover, considering sites located at less than 10 km distance. This local correlation was preferred to a regional analysis because NH\textsubscript{3} pollution is known to be of short-range (Pinho et al., 2009; Sutton et al., 1998). The local correlation analysis was plotted for the study area (Figure 5.14), showing many very significant correlations between [N] in lichens and the area occupied by annual agriculture (mainly rice fields and cereals), as well as heterogeneous and other permanent agriculture (mainly small farms and orchards) (Figure 5.14). The results also showed that there was no significant correlation between [N] in lichens and artificial areas (mainly roads, urban and industrial areas) (data not shown), excluding NO\textsubscript{x} emissions as contributing to the [N] in lichens. Moreover the distance of influence, that for which the maximum correlation was observed (Pinho et al., 2008b), was found to be on average 1600 m for annual cultures and 1200 m for

Figure 5.13: Location of Natura 2000 sites in Portugal and of the studied region in SW Portugal. The labeled Natura 2000 sites are the ones included in this work. Main industrial areas are part of Sines industrial complex and include a power-plant, an oil refinery and other petrochemical industries.
5 New science on the effects of nitrogen deposition

Once we had determined that agricultural areas are the most likely cause for increased nitrogen concentration in lichens, we mapped [N] in the study region. This variable was analyzed by geostatistical techniques (CERENA, 2000), namely variogram interpretation used to interpolate [N] for the region using ordinary kriging (ESRI, 2008). By focusing on the Natura 2000 sites (Figure 5.14) we could observe that it presents a patchy distribution, highlighting the short-range nature of nitrogen pollution. Moreover this mapping also provides an efficient way to map the critical areas probably affected by nitrogen pollution, and should be considered critical areas.

Figure 5.14: Local correlation analysis between [N] in lichens and: i.) neighboring annual agriculture (left) and ii.) neighboring heterogeneous and other permanent agriculture (right). This is the result of a moving window analysis that correlates two variables using as samples all sites at a distance of 10km from each sampling site. A significant correlation indicates that, within a 10km radius neighborhood, the two variables are significant correlated. In the maps not-significant correlations (n.s.) are marked with small dots, significant ones with larger circles. The magnitude of the correlation (R) is given on the legend, and varied between 0.35 and c. 1.00. The two biplots are example of correlation for two sites, marked with a darker symbol in the maps above. More details on this type of analysis can be found in (Pinho et al., 2008a).

heterogeneous and other permanent agriculture (average values of all sites). This distance is in agreement with other studies that have shown that most nitrogen deposition and its effects on biodiversity occur less than 1 km from sources (Pinho et al., 2009; Sutton et al., 1998). Taken together, these results have shown that [N] in lichens can be used to map areas under the impact of agriculture NH3, even if other sources of disturbance are present.
Nitrogen deposition and Natura 2000

In this way we reduce cost focusing the plant and animal diversity monitoring in high impact NH3 deposition areas.

In the Natura 2000 site “Costa Sudoeste” (Figure 5.13, right) most nitrogen is probably being emitted by vegetables, as well as by grain cultivation sites located in the nitrogen hot-spot areas (Figure 5.14, right). Of special concern is the Natura 2000 site “Comporta/Galé” (Figure 5.15, left), characterized by costal dunes habitats and costal lagoons. Up-stream of those lagoons there are rice cultures, known to be important sources of NH3 (Yan et al., 2003). Rice fields are the probable source of N leading to accumulation in lichens (Figure 5.14). Within this Natura 2000 area there are two Special Protection Areas (Birds Directive), one of which, “Lagoa de Santo André”, is located in the area with higher Nitrogen concentration (Figure 5.15). This area is likely to be under strong nitrogen-pollution and should be particularly monitored for its impacts.

Aiming in the future at establishing precise boundaries for the critical areas outlined in Figure 5.15, we aim at calibrating [N] in lichens with a legal-bounded variable, namely i.) loss of biodiversity (e.g. loss of endangered plant species) or ii.) exceedance of critical levels of measured NH3. Within the legal limits the criteria for protection level given by the chosen boundaries is a matter of decision makers choice.

5.8.4 Conclusions

• Although lichen-diversity is a good ecological indicator of NH3 impact on ecosystems, in areas with multiple sources of disturbance, it responds also to factors other than NH3, such as industrial and urban pollution. Therefore in such areas lichen diversity is not a good indicator of atmospheric NH3.
5 New science on the effects of nitrogen deposition

- Nitrogen concentration in lichens was shown to be highly significant related to agricultural areas, and not related to artificial ones, being therefore a good measure of NH$_3$ atmospheric deposition, even in areas with multiple disturbance sources.
- By mapping nitrogen concentration in lichens, we could provide criteria for selecting critical areas with potential risk for biodiversity from NH$_3$ pollution within Natura 2000 sites.

References


**Acknowledgements**

Pedro Pinho for the PhD grant from the Portuguese Foundation for Science and Technology, FCT-MCTES (BD / 17880/ 2004). SinesBioar project (LIFE00 ENV/P/000830) for funding this work and COST 729 (Assessing and Managing nitrogen fluxes in the atmosphere-biosphere system in Europe) for travel funds.