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An integrated system for producing user-specific keys on demand: an application to Italian lichens

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Abstract — The identification of lichens is important in several applied fields, such as the biological monitoring of air pollution and the restoration of open-air stone monuments. This often creates relevant problems for non-specialists and technicians which are in charge of routinely applying lichen monitoring techniques. The coupling of a complex information system (ITALIC), together with a new software which can automatically produce identification keys for any subset of species included in a database (FRIDA), is an innovative approach in the field of identifying biodiversity. ITALIC is able to produce a list of species which potentially occur under a set of ecological and distributional conditions specified by the user. The list is automatically transferred to FRIDA, which generates a user-oriented interactive identification key limited to the species present in the "virtual habitat" created by the user. The new system has relevant applications, since it effectively supports the technical personnel of Environmental Agencies, Nature Parks, Cultural Heritage Conservation Agencies involved in lichen monitoring throughout the Country.

Index Terms — interactive keys, biomonitoring, restoration of monuments, lichens, identification.

1 Introduction

Lichens are a diverse and species-rich group of fungi living in close symbiotic relationship with algae or cyanobacteria. Many of them form crustose thalli whose identification usually requires the analysis of micro-morphological or chemical characters. However, the identification of lichens is important in several applied fields, such as the biological monitoring of air pollution and the restoration of open-air stone monuments.

Epiphytic lichens are highly sensitive to environmental changes and air pollution, and they are among the most widely used biomonitors in terrestrial environments [1]. Epi- and endolithic lichens are important in the biodeterioration

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of stone monuments [2], [3]. In Italy their identification is required for restoration programs, both in the planning phase and for monitoring the effectiveness of restoration practices [4]. The identification at species level often creates relevant problems to non-specialists and technicians which are in charge of routinely applying lichen monitoring techniques.

In Italy, the popularization of lichen biomonitoring was supported and encouraged by rendering available online information on lichens provided by researchers. The first relevant contribution was the Italian checklist by Nimis [5], which was the basis for the creation of ITALIC, the Information System on Italian Lichens [6], that is freely available online since 2003. ITALIC provides support to the identification process by offering the possibility to compare a given specimen with high-resolution pictures and ecological-distributional information. However, while helpful, this simple comparison is far from being enough for this difficult groups of organisms, especially for a layperson.

In this paper we present a system which is able to produce ”keys on demand”, by coupling lists of species for “virtual habitats” created by users in ITALIC with a software that automatically generates identification keys to the species in those lists.

2 Basic information contained in ITALIC

For each lichen species which occurs in Italy (ca. 2350 in total), ITALIC provides: 1) updated literature on the specimens recorded from each of the 20 administrative regions of the country, 2) a predictive map depicting its potential distribution in 9 bioclimatic regions of Italy, 3) high-resolution pictures, and 4) information on biological traits, ecological requirements, and commonness/rarity. Biological traits include: growth forms (crustose, narrowly-lobed foliose, large lobed foliose, fruticose, fruticose-filamentose, squamulose), photobiont type (Cyanobacteria, Trentepohlia, Chlorococcoid green algae), and reproductive strategy (sexual vs. asexual by soredia, isidia or thallus fragmentation). Ecological requirements are summarised by 4 ecological indicator values: pH, air humidity, solar irradiation and eutrophication. Each ecological indicator value is expressed on a 1-5 ordinal scale. An additional indicator, expressed on a 0-3 ordinal scale, describes the tolerance of a species to human disturbance (poleophoby or hemeroby). Information on altitudinal range and substrates (epiphytic, lignicolous, foliicolous, saxicolous, and terricolous) is given as well.

The commonness/rarity of a species is expressed by a scale with 8 classes, ranging from extremely rare to extremely common in each of the main bioclimatic areas of the Country. This parameter was assessed on the basis of: a) number of samples in the TSB lichen herbarium, b) number of literature records, and, c) expert judgement. The ‘extremely rare’ status is given only to taxa known from less than 5 localities in Italy, or to those which were not mentioned in the literature in the last fifty years. Recently-described or dubious taxa are excluded from this category. The species in the ‘extremely rare’ class are likely candidates for the ‘threatened species’ category of the IUCN criteria [7], and therefore important for conservation purposes.

3 Automatic generation of species lists for "virtual habitats"

By combining several morphological, ecological and distributional parameters, ITALIC permits to elaborate complex queries for reconstructing "virtual habitats" in different parts of the country, the output being in the form of lists of species which are most likely to occur under the specified conditions. The predictivity of these virtual lists was tested by Nimis & Martellos [8] using a multivariate analysis of a matrix of "virtual" and real relevés of epiphytic lichen vegetation. Virtual relevés were obtained by selecting administrative region, altitudinal belt, substrate, and appropriate values for each ecological indicator value according to the main features of the targeted habitats. The results showed that the "virtual relevés" are highly predictive models, indicating that ITALIC could be consistently used for generating a large number of lists of lichens potentially occurring under conditions specified by the user. In the framework of the "Carta della Natura" project, promoted by the Italian Institute for Environmental Protection and Research (ISPRA), we recently applied this approach for providing potential lists of lichens for each of the ca. 160 CORINE-Biotopes habitats inventoried for Italy at the 1:50.000 scale [9]. The lists were obtained by combining the most important parameters describing the distribution and the ecology of Italian lichens: regional distribution, bioclimatic region, substrate type, ecological indicator values. In a few cases, additional parameters, such as commonness/rarity and tolerance to human disturbance, were used as well. A qualitative evaluation of the predictivity of these lists was assessed by checking real species lists available for well-studied habitats such as coniferous alpine forests [10], [11]: a good correspondence between the two datasets was found. Despite the fact that more quantitative evaluations on a large dataset would be welcome to statistically confirm previous results, this experience supports the practical utility of using the automatic generation of species lists for applied purposes.

4 FRIDA: from a morpho-anatomical database to interactive identification keys

In the last decade, our research team has developed original software for automatically generating interactive identification tools. A first phase of the research was conducted in the framework of the national project *Dryades,* and then continued in the European project *KeyToNature*. The most important software is FRIDA [12], a package which permits to generate interactive identification keys from a database of morpho-anatomical characters, starting from any list of species. The huge floristic information contained in several local checklists or vegetation studies can thus be easily used for generating new and original identification keys. For example, we used the detailed floristic information provided by Poldini [13] for the area of the natural reserve of the Val Rosandra (Trieste, NE Italy), and by Festi & Prosser [14] for the Paneveggio-Pale di San Martino Natural Park (Trento, NE Italy), to generate digital keys to the 988 and 1451 species of vascular plants known to occur in these two areas, respectively. In the last years, the continuous development of FRIDA, and of other original

software produced in the framework of *Dryades* and *KeyToNature,* permitted to greatly improve both the morpho-anatomical databases and the identification keys, which are now available in different and user-friendly layouts, such as those running on iPhones and other portable devices.

5 A STEP FURTHER: THE COMBINED USE OF ITALIC AND FRIDA FOR GENERATING INTERACTIVE IDENTIFICATION KEYS ON DEMAND

Here we provide an example of the high informative and applicative potential which derives from the combined use of an ecological-distributional database (ITALIC) with a morpho-anatomical database (FRIDA). The great novelty is that it is now possible to obtain from ITALIC lists of species potentially occurring under specified conditions, which are used for "feeding" FRIDA to generate personalized, user-oriented interactive identification key on demand.

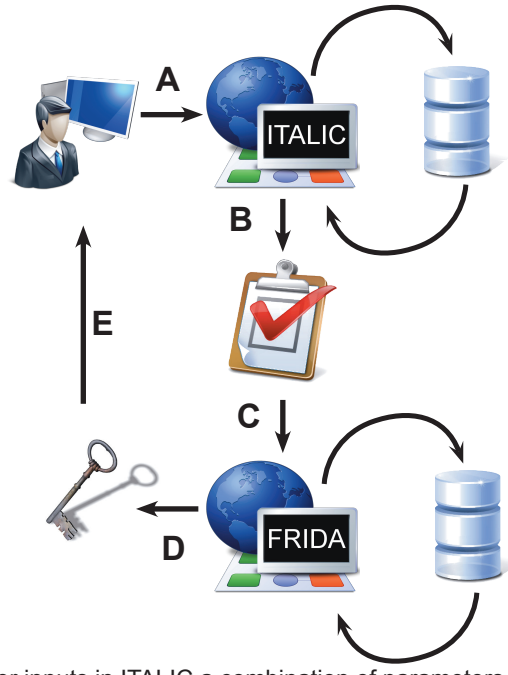

Fig. 1 – A) The user inputs in ITALIC a combination of parameters defining a "virtual habitat", B) ITALIC produces a list of species which are likely to occur under the specified conditions, C) the list is automatically sent to FRIDA, D) FRIDA produces an interactive key to the species in the list, E) the key, in its various versions (online, stand-alone for CD-ROM and for mobile devices) is forwarded to the user.

This novelty can have relevant applicative implications. For example, forest managers, which are in charge of monitoring epiphytic lichen diversity in spruce forests of the Italian administrative region Trentino-Alto Adige, could obtain their potential species list by selecting the administrative region, the 'subalpine' bioclimatic belt, 'epiphytic' lichens growing on 'acid bark' (pH indicator value

1-2), in ‘mesic’ (air humidity indicator value 2-4), ‘shaded’ (indicator value for solar irradiation 2-3), and ‘non-eutrophicated’ (indicator value for eutrophication 1-2) conditions. An interactive identification key to these species, including high-resolution pictures and ecological notes, is immediately created by FRIDA, and can be used for routine activities.

Similarly, managers in charge of monitoring the effectiveness of a restoration program on a Greek temple near the town of Agrigento (Sicily, S Italy), could obtain the list and the identification key for the species potentially occurring in that environment. They should just select ‘Sicily’, ‘dry-mediterranean’ bioclimatic region, ‘saxicolous’ lichens growing on limestone (‘basic’ substrata, indicator value for pH 5), in ‘dry’ (air humidity indicator 4-5), and ‘sun-exposed’ (indicator value for solar irradiation 4-5) conditions.

The digital identification keys are immediately ready to be used online. However, when identification has to be carried out in the field, the Web could be not the best medium for a key. For this reason, several accessory tools were developed, which permit the storage of the keys as stand-alone packages on different media, such as mobile devices (iPhones and other smartphones), as well as on paper, in the form of printable, illustrated field guides.

6 Conclusion

The identification of lichens is often difficult, both in the field and in the laboratory, and requires a long period of study and training. The new digital keys “on demand”, being restricted to a relatively small number of species potentially occurring in a given habitat and/or in a given area, are generally much more user-friendly. They proved to be a valuable support for the technical personnel of Environmental Agencies, Nature Parks, Cultural Heritage Conservation Agencies, etc. Within *KeyToNature* we have produced free of charge hundreds of mini-keys for schools using the same approach. However, the potential market for such a service in the field of practical applications is quite high: we have already received dozen of requests by institutions and companies which are ready to pay for having the possibily of generating “their own” keys on demand.

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