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Shedding light on typical species: implications for habitat monitoring

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Abstract

Habitat monitoring in Europe is regulated by Article 17 of the Habitats Directive, which suggests the use of typical species to habitat conservation status. Yet, the Directive uses the term "typical" species but does not provide a definition, either for its use in reporting or for its use in impact assessments. To address the issue, an online workshop was organized by the Italian Society for Vegetation Science (SISV) to shed light on the diversity of perspectives regarding the different concepts of typical species, and to discuss the possible implications for habitat monitoring. To this aim, we inquired 73 people with a very different degree of expertise in the field of vegetation science by means of a tailored survey composed of six questions. We analysed the data using Pearson's Chi-squared test to verify that the answers diverged from a random distribution and checked the effect of the degree of experience of the surveyees on the results. We found that most of the surveyees agreed on the use of the phytosociological method for habitat monitoring and of the diagnostic and characteristic species to evaluate the structural and functional conservation status of habitats. With this contribution, we shed light on the meaning of "typical" species in the context of habitat monitoring.

Keywords

diagnostic and characteristic species, habitat monitoring, keystone species, Natura 2000, plant community, structure and functions, typical species, 92/43/EEC Directive

Introduction

In the Anthropocene, many ecosystems are increasingly at risk due to the concurrent action of a set of drivers such as habitat loss, fragmentation, invasive species and pollution, that are altering ecosystem structure and functioning, while threatening their long-term persistence and capability to provide essential ecosystem services (IPBES 2019). Accordingly, monitoring changes in natural ecosystems is a top priority in global conservation agendas to anticipate ecological tipping points, ultimately preventing ecosystem collapse (Balmford 2005; Jongman 2013; Gigante et al. 2018), as already pointed in the Biodiversity Strategy (https://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm).

In Europe, ecosystem monitoring is regulated by the Habitats Directive (Art. 17 of the 92/43/EEC), and it is mostly done at the habitat level (Lengyel et al. 2008a; 2008b; Campagnaro et al. 2019), a key component of biodiversity (Legg and Nagy 2006; Bunce et al. 2013; Proença et al. 2017). The Habitats Directive requires the Member States to report, every six years, on the conservation status of natural and semi-natural habitats listed in Annex I (European Commission 1992), to verify the effectiveness of EU policies in terms of biodiversity conservation (Evans and Arvela 2011; DG Environment 2017). According to this Directive (European Commission 1992), largely considered as the cornerstone of Europe's nature conservation, the status of a habitat type is defined based on four criteria: area, range, structure and functions, future prospects.

While habitat area, range and future prospects are assessed at biogeographical level, the "structure and functions" parameter can be monitored at the local level starting from field data, trying to minimise the degree of subjectivity (Carli et al. 2018; Tsiripidis et al. 2018). Whereas structures describe the physical components of a habitat type (e.g., trees in a woodland), functions highlight the ecological processes occurring at various temporal and spatial scales (Evans and Arvela 2011; DG Environment 2017). However, the evaluation of the "structure and functions" parameter strongly relies on the assessment of conservation status of typical species; indeed, according to the Habitats Directive, for a habitat type to be considered in favourable conservation status, both its structure and functions and its typical species should be at a favourable conservation status (European Commission 1992). Following Evans and Arvela (2011), typical species "should be selected to reflect favourable structure and functions of the habitat type", meaning that they should be at the same time: i) good indicators for favourable habitat quality; ii) exclusive of the habitat or present over a large part of the habitat range; iii) sensitive to changes in the conditions of the habitat. Despite that, the Habitats Directive itself uses the term "typical" species but does not provide a definition, either for its use in reporting or for its use in impact assessments. Some Member States proposed to start from vegetation databases, with data recorded on the field, to define typical species lists (Maciejewski 2010; Tsiripidis et al. 2018). Recently, a list of statistically-derived characteristic species combinations for EUNIS habitat types have been published (Chytrý et al. 2020).

In Italy, the evaluation of structure and functions of habitat types, has usually been carried out relying on typical species, identified by experts. They are summarized in the "physiognomic reference combination" on the online italian version manual for the interpretation of habitats (Biondi et al. 2009; Biondi 2013). Additionally, Gigante et al. (2016) pointed out some criteria for selecting the typical species *sensu* Habitats Directive, partially overcoming the lack of a unique definition. They suggested that typical species can be recognized only in species-poor habitats or when habitats are characterised by a low number of physiognomy-shaping genera and species; however, in the case of species-rich habitats, the whole floristic pool should be considered as the best proxy for assessing the conservation status, thus overcoming the use of typical species. These criteria are explained, and the resulting species lists proposed, in Angelini et al. (2016).

In the first place, it is not clear yet to what extent phytosociology and other disciplines, such as functional ecology, can be used to identify typical species. Diagnostic and characteristic species, as defined in the phytosociological method (Braun-Blanquet 1932), can be used to identify typical species following the second criterion ("species only found in the habitat or which are present over a large part of the habitat's range"; Evans and Arvela 2011). On the other hand, they may not meet the other two criteria, i.e., they may not be good indicators of habitat quality and changes. At the same time, typical species selected only through a functional approach can eventually warn about habitat quality and changes, while failing at distinguishing one habitat from another. As a consequence, the use of different approaches and definitions might lead to inconsistencies in the evaluation of habitats' conservation status.

A further potential approach that might be valuable for habitat monitoring advocates the use of keystone species, widely applied in ecology, as typical species. Keystone species play critical ecological roles that are of greater importance than one would predict from their abundance (Power et al. 1996); indeed, they have a disproportionate impact, in relation to their number or biomass, on the organization of a biological community. The loss of a keystone species may have far-reaching consequences for the community (Primack 2018). Therefore, these species have exceptionally large effects on communities and ecosystems through processes such as trophic interactions, habitat modification, and mutualism (Grime 1998; de Visser et al. 2013).

An additional issue is the spatial scale at which typical species should be identified. By definition, typical species should be exclusive of a given habitat, but they should reflect favourable structure and functions (Evans and Arvela 2011; Oosterlynck et al. 2013). Yet, it might not always be possible to identify unique links between habitats and functions, as the realization of some functions strictly depends on the co-occurrence of multiple habitats interconnected at the landscape scale (e.g., Betts et al. 2019; Hackett et al. 2019).

The Italian Society for Vegetation Science (SISV) is not novel to collectively contribute to aspects related to habitat monitoring (Gigante et al. 2016; 2018). In October 2020, an online workshop was organized by SISV to shed light on the diversity of perspectives regarding the concepts of "typical", "diagnostic", "characteristic" and "keystone" species, to discuss the possible implications for habitat monitoring. Specifically, the workshop addressed the following questions: (i) Are diagnostic and characteristic species informative about the structural and functional conservation status of habitats? In other words, might we use them as typical species? (ii) Are diagnostic and characteristic species used to assess conservation status dependent on specific habitats? (iii) Diagnostic, characteristic and typical species: how much do they overlap (conceptually and practically)? (iv) What about keystone species? Might they be used as typical species too? (v) Does scale matter for the definition of typical species?

This study aims to provide insights on these topics, by combining different points of view of researchers and professionals of vegetation science to give a shared interpretation on typical species and the implications for habitat monitoring.

Methods

Survey data collection

We aimed to acquire a consistent overview regarding specific topics' opinions such as "diagnostic", "characteristic" and "typical" species for habitat monitoring throughout the whole potential audience of Italian scientists and professionals dealing with vegetation science. To this aim, before the workshop, SISV organisers sent out a tailored survey addressing confirmed workshop participants (hereafter, 'surveyees'). Surveyees included persons with a very different degree of expertise in habitat monitoring, spanning from students and young scientists to experienced professionals and recognized vegetation scientists. The survey was composed of 8 questions with hybrid possibilities of multiple-choice, binary and open answers (see Tab. 1 for the questions and possible answers). The first three questions (i.e., Q1-Q3) were intended to account the different levels of expertise among surveyees and their agreement on the methods used for habitat monitoring. Q1 aimed at a self-evaluation of experience degree, and Q2 asked whether the surveyee had previously used the phytosociological method in habitat monitoring; Q3 investigated the opportunity of using the phytosociological method to perform habitat monitoring. Questions Q3 to Q8 (except for Q6) were developed in a "Likert scale" (Likert 1932) with 5 ordered and symmetric levels of agreement, ranging from "strongly disagree" to "strongly agree". In addition, since some questions might have required further explanation than a categorical choice, we accompanied all questions by the possibility of adding a brief description. This strategy allowed us to (i) have a general overview of the surveyees' opinions, (ii) synthesize the open questions prior to the workshop, and (iii) during the workshop, start the discussion based on the already-retrieved data, thus optimizing the limited online time at disposal, and making the whole debate more focused and effective.

Workshop structure

During the workshop, the results of the survey were presented in raw form (i.e., with no statistical analysis), and discussed among participants. Starting from this discussion, we attempted to find shared views and solutions to the raised issues. To this end, several contributions and case studies presented by the participants helped to shed light through direct monitoring experiences. We summarize the main conclusions together with the most relevant issues emerged during the debate.

Data analysis

We analyzed the results of all the questions (Q1-Q8) by means of a Pearson's Chi-squared test with simulated p-value (based on 9999 randomizations) to verify that the answers diverged from a random distribution. Then, we checked the effect of the surveyees' experience on the answers Q3-Q8. We used an Asymptotic Linear-by-Linear Association Test (Agresti 2002), to verify whether these answers (Q3-Q8) were influenced by the ordered level of surveyees' experience (i.e., whether increasing levels of expertise affected the surveyees opinion). This test allows comparing data expressed in any ordinal (i.e., ordered) scale. We used two-tailed tests, with no specific direction of the relationship among expertise and answer output. Moreover, we evaluated with a Pearson's Chi-squared test with simulated p-value (based on 9999 randomizations) whether having already used the phytosociological method to perform habitat monitoring affected the surveyed opinion on the other questions (Q3-Q8).

Table 1. Questions and possible answers provided to the surveyees. The Q3-Q8 answers followed the "Likert scale" (Likert 1932).

N	Question	Possible answers				
Q1	Level of expertise on habitat monitoring	No experience	Little experience	Medium experience	Solid experience	
Q2	Did you already use the phytosociological method to perform habitat monitoring?	Yes	No			
Q3	Do you agree with the use of phytosociological method to perform habitat monitoring?	Strongly disagree	Disagree	Neither agree nor disagree	Strongly agree	Agree
Q4	Are diagnostic and characteristic species informative about structural and functional conservation status of habitats?	Strongly disagree	Disagree	Neither agree nor disagree	Strongly agree	Agree
Q5	Is the use of diagnostic and characteristic species for assessing conservation status dependent on specific habitats?	Strongly disagree	Disagree	Neither agree nor disagree	Strongly agree	Agree
Q6	Diagnostic, characteristic and typical species: how much do they overlap (conceptually and practically)?	Slightly	Moderately	Strongly		
Q7	Keystone species. Can keystone species be used as typical species?	Strongly disagree	Disagree	Neither agree nor disagree	Strongly agree	Agree
Q8	Does scale matter for the definition of typical species?	Strongly disagree	Disagree	Neither agree nor disagree	Strongly agree	Agree

Results of the survey

Overall, 73 people participated in the questionnaire survey and 104 in the workshop. Among surveyees, 17 (23%) stated to have solid experience in habitat monitoring, whereas a comparable number had little or medium experience (23 and 21, respectively; i.e., 32% and 29%; Fig. 1A). Only 12 (16%) participants had no experience. About 71% of the surveyees had already used the phytosociological method to perform habitat monitoring (Fig. 1B).

Answers to all questions, except Q1, showed significant differences in the frequencies among the responses provided (Tab. 2).

Most of the surveyees (77%) agreed with the use of the phytosociological method to perform habitat monitoring, while very few (5.5%) disagreed (Fig. 1C). Also, the majority of the surveyees (59%) agreed that diagnostic and characteristic species are informative about the structural and functional conservation status of habitats, a substantial proportion was undecided (around 30%), while a smaller rate disagreed (about 11%; Fig. 1D).

Almost all surveyees (about 84%) acknowledged that the use of diagnostic and characteristic species for assessing conservation status is dependent on specific habitats (Fig. 1E).

The overlapping between diagnostic, characteristic and typical species was strongly recognized by 24% and moderately acknowledged by 71% of the surveyees (Fig. 1F).

The answers on using keystone species as typical species had an unclear pattern (Fig. 1G). About 50% of surveyees agreed that keystone species could be used as typical species. There was a substantial proportion of undecided (around 29%), and about 22% disagreed.

The scale for the definition of typical species resulted important (Fig. 1H), showing a widespread agreement among surveyees (68%), while 22% of the surveyees were undecided (22%) or disagreed (11%).

The Asymptotic Linear-by-Linear Association Test revealed that only Q5 was affected by the level of expertise of the surveyees, while for all the other answers, the association was not significant (Tab. 3). Particularly, experienced surveyees supported more consistently than others that the use of diagnostic and characteristic species for assessing conservation status depends on the study habitat (Fig. 2). Furthermore, we detected no effect of the previous use of the phytosociological method in habitat monitoring (Tab. 3).

Discussion from the workshop

The answers to the questionnnaire highlighted a substantially shared point of view on the debated topic, though diverging opinions on some specific issues emerged.

We present them by summarizing the main messages, highlighting pros and cons, and offering proactive ideas to shed light on the meaning and use of typical species for habitat monitoring.

Table 2. Results of Pearson's Chi-squared test with simulated p-value (based on 9999 randomizations) to verify that the answers diverged from a stochastic distribution.

Question	Chi Square statistic	p-value
Q1	4.53	0.216
Q2	13.16	<0.001
Q3	57.75	<0.001
Q4	66.47	<0.001
Q5	69.92	<0.001
Q6	47.75	<0.001
Q7	21.51	<0.001
Q8	31.22	<0.001

Table 3. Results of the Asymptotic Linear-by-Linear Association Test to verify whether contributors' answers were influenced by their level of expertise (Q1), and of the Pearson's Chi-squared test with simulated p-value (based on 9999 randomizations) for the effect of the previous use of phytosociological method in habitat monitoring (Q2).

	Test on the effect of Q1		Test on the effect of Q2	
	Test statistic (Z)	p-value	Test statistic (X^2)	p-value
Q3	-1.063	0.288	6.431	0.130
Q4	0.461	0.645	1.312	0.897
Q5	-2.774	0.006	3.667	0.303
Q6	-1.630	0.103	3.147	0.214
Q7	-0.450	0.653	3.547	0.494
Q8	-0.186	0.853	2.595	0.475

During the workshop, a large part of the discussion focused on the phytosociological method. Surveyees agreed that using the floristic-vegetation sampling, i.e., the phytosociological method *sensu* Braun-Blanquet (1932) and further updatings (Dengler et al. 2008; Biondi 2011; Guarino et al. 2018), to perform habitat monitoring, has undoubted strengths. The use of phytosociological relevés provides detailed information on the composition and structure of plant communities, it is widely used and allows cost-effective habitat monitoring. Indeed, the Italian manual for habitat monitoring suggested using it for field (Angelini et al. 2016). However, though the phytosociological relevé has wide approval among participants, its acceptance is not unanimous. The concerns are related to various aspects for which adequate solutions were proposed during the discussions. The phytosociological method does not consider other taxonomic groups (e.g., animal taxa) that, being involved in specific ecosystem functions, might provide crucial information on the conservation status of a habitat (Bland et al. 2016). Additionally, the participants to the workshop reported that the phytosociological method, in accordance with the original aim of the discipline, i.e., the description and typification of vegetation units (Braun-Blanquet 1932), is based on a partially subjective sampling protocol linked to the selection of physiognomically and structurally homoge-

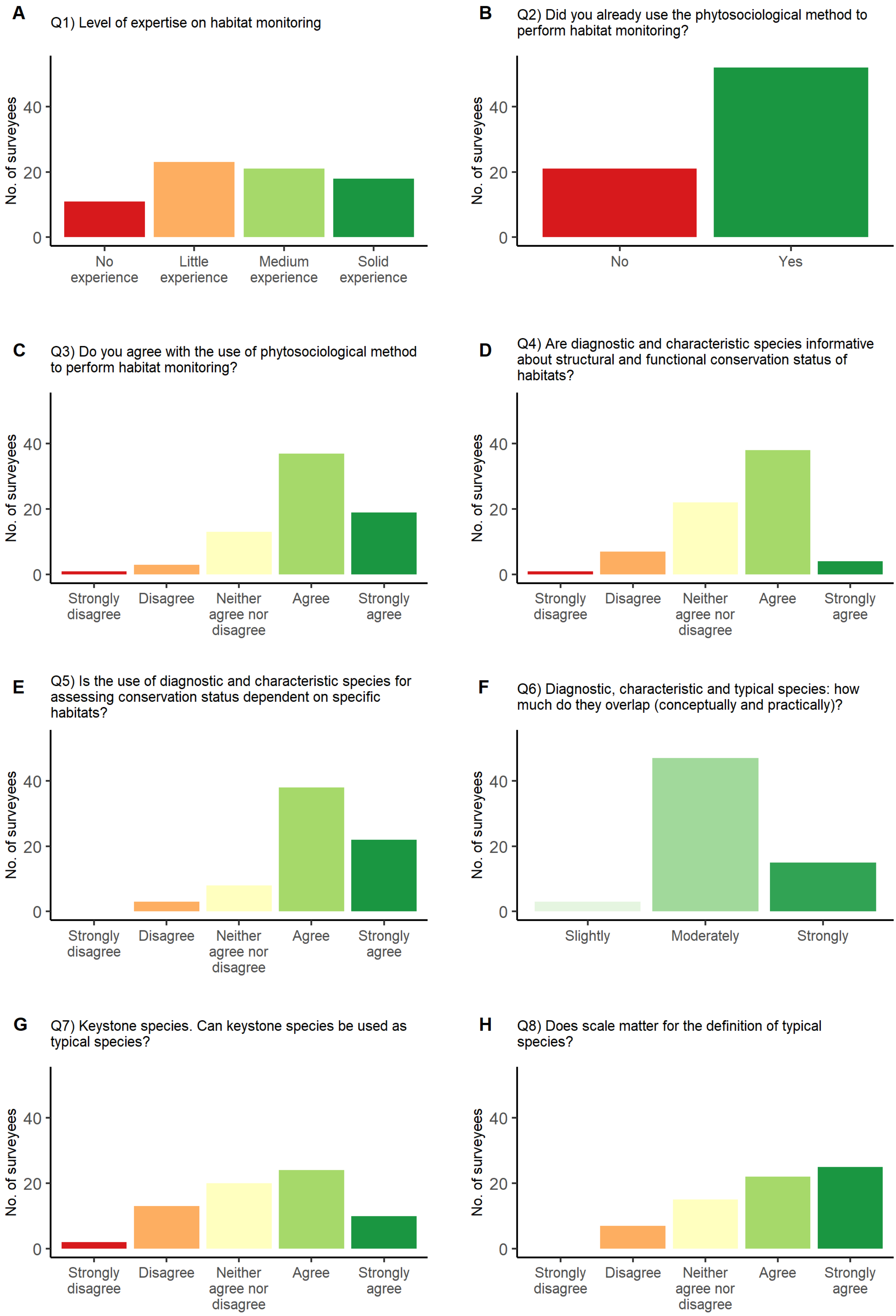

Figure 1. Barplots of the answers to the questionnaire.

neous sampling sites. A further limitation of the method highlighted during the workshop is represented by the use of the Braun-Blanquet scale (Westhoff and van der Maarel 1973; Dengler et al. 2008), which may not be sufficiently sensitive in detecting changes in species abundance over time (Londo 1976). Lastly, the phytosociological method requires specialized personnel, which restricts its applicability to specifically trained operators. To overcome these issues, many suggestions arose during the discussion. Part of them were of technical nature and can be more or less easily implemented. The use of a probabilistic sampling design, such as the stratified random sampling design, could substantially increase the objectivity of the monitoring (McGarvey et al. 2016; Corona et al. 2020; Maccherini et al. 2020), while the inclusion of other taxa and of other survey approaches (e.g., the dendrometric survey of forest vegetation; De Cáceres et al. 2019; Yao et al. 2019) can provide valuable information on the habitat conservation status. Nevertheless, a probabilistic sampling design might not be effective for habitats characterized by a limited distribution and/or a linear surface which could be underrepresented. The recently proposed Habitat Monitoring National Plan, which tries to find a cost-effective solution between totally random and opportunistic sampling, seems to go in the direction of an intermediate solution. Similarly, an intermediate solution emerged during the workshop: first, localize and map the Habitat types through the phytosociological method, and then use a random sampling design to perform vegetation surveys and following monitoring. However, the use of permanent plots for biodiversity monitoring also represents a solid opportunity. As to the lack of sensitivity of the Braun-Blanquet scale, workshop participants proposed using a more detailed scale (i.e., 1-100%), which can more effectively detect habitat changes (Dengler et al. 2016). Yet, specialized personnel is indispensable, and it is necessary to entrust monitoring to adequately trained personnel.

Besides the methodological aspects, the workshop addressed substantial conceptual issues, such as selecting typical species *sensu* 92/43/EEC among the diagnostic and characteristic species. Diagnostic and characteristic species were originally defined for diagnostic purposes, i.e., for identifying and classifying syntaxa (Poldini and Sburlino 2005). As such, it is still unclear whether they are suitable for evaluating habitat conservation status. Indeed, diagnostic and characteristic species can be considered as typical species, and thus be used for habitat monitoring purposes only when their relationship with habitat structure and functions is ascertained (Evans and Arvela 2011). Moreover, it should be recalled that diagnostic species are context-dependent (Chytrý et al. 2002).

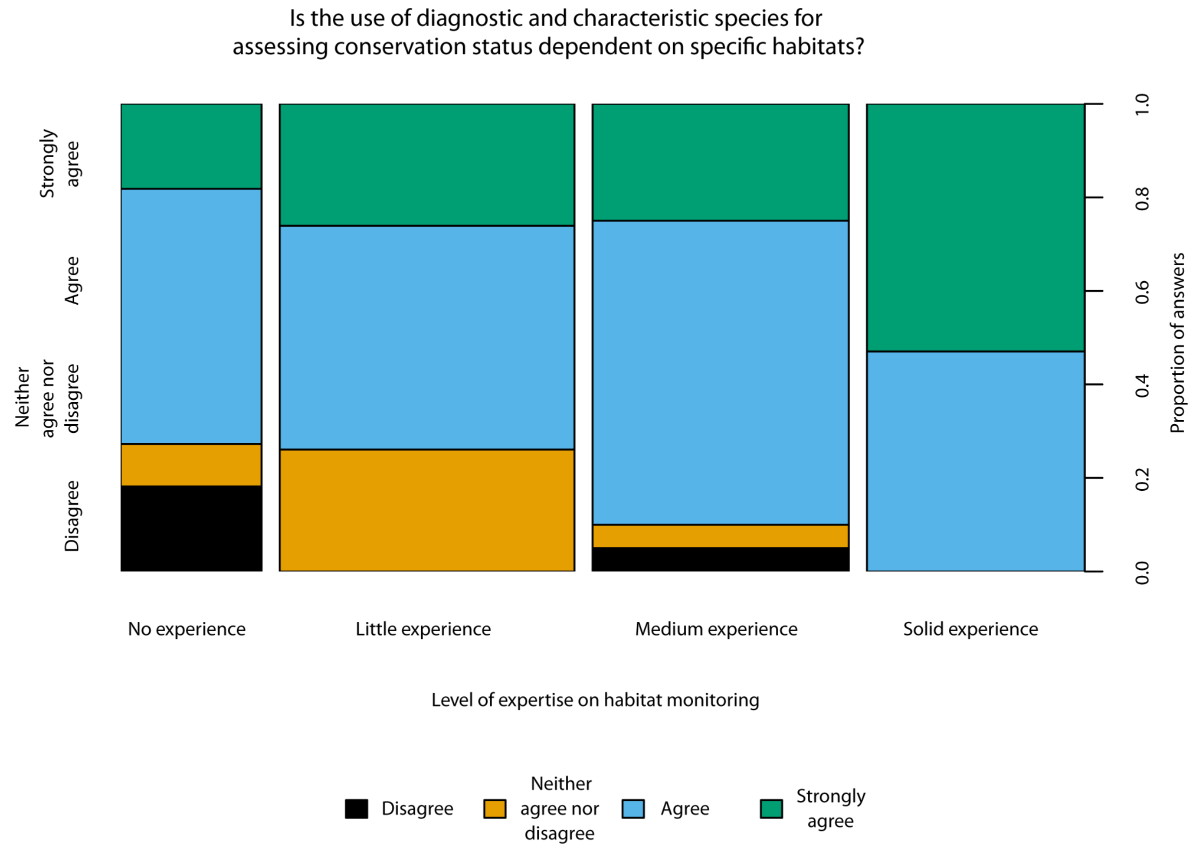

Figure 2. Spine bar plot of the ordered association between Q5, shown on y axis, and the level of experience of the surveyees. The widths of the bars correspond to the relative frequencies of surveyees for each level of expertise.

According to the mass ratio hypothesis (Grime 1998), ecosystem functioning is mainly determined by the most abundant species (and their features); therefore, the overlap between "diagnostic", "characteristic" and "typical" species is driven by their abundance. Yet, some participants expressed their concerns about the difficulty of using diagnostic species to evaluate the conservation status of species-rich habitats, characterized by a considerable species evenness. In this context, a paradoxical question arises: how do we consider a habitat where diagnostic and characteristic species are present but typical species lack? In other words, where is the boundary between a degraded habitat in unfavourable conservation status and a shift to another habitat?

Importantly, workshop participants recalled the need of reporting, when tracking habitat conservation status, the occurrence of invasive, ruderal and in general of all those species indicating negative changes in habitat conditions (Evans and Arvela 2011). This is particularly important when dealing with invasive alien plants referred to as transformers, for their remarkable ability to deeply change the abiotic and biotic characteristics of affected ecosystems (Pyšek et al. 2004; Guarino et al. 2021), driving to a shift of structure and functions regulated by plant traits (Dalle Fratte et al. 2019), ultimately leading to the total disappearance of natural habitats. Hence, their presence, especially when still limited or even confined to nearby areas, should be carefully assessed in habitat monitoring activities. Notable examples in that regard are *Acacia* spp., *Ailanthus altissima*, *Carpobrotus* spp., and *Robinia pseudoacacia*, which have been increasingly reported in Italian Natura 2000 habitats in the last few years (Lazzaro et al. 2020). Moreover, in a recent study, Viciani et al. (2020) identified 27 vascular and one bryophyte phytosociological classes, hosting 194 low rank alien-dominated syntaxa, comprising in most cases strongly anthropogenic or highly disturbed habitats. According to these authors, regressive changes in vegetation structure and floristic composition of plant communities due to alien species invasion could be efficiently described and classified using a syntaxonomic frame (e.g., *Conyzo canadensis-Oenotheretum biennis* Biondi, Brugiapaglia, Allegrezza et Ballelli 1992). Similarly, a growing bulk of data concerning aquatic habitats (e.g., macrophyte-dominated ones) show the progressive replacement of native dominant species by invasive taxa such as *Elodea* spp., *Lagarosiphon major*, *Lemna minor*, and *Nelumbo nucifera* in several lakes, rivers and wetlands across Italy (Bolpagni et al. 2017).

Another open issue regards the conceptual and factual overlap between typical and keystone species. Keystone species have a disproportionate impact on biological communities, which means that their contribution to the maintenance of an ecosystem structure and functioning is more significant than we could infer from their abundance only (Power et al. 1996; de Visser et al. 2013; Primack 2018). Although most of the participants agreed in the questionnaire on the use of keystone species as typical species, caution has been claimed during the discussion, likely due to a lack of sufficient clarity on the concept of keystone species, and issues related to their identification. In this respect, it should be noticed that keystone species might not necessarily be plants and, given their substantial contribution to ecosystem functioning, they might not be exclusive of single habitats (Hackett et al. 2019), so that a systemic view appears increasingly critical when evaluating habitat conservation status.

During the workshop, the need for a broad perspective in habitat monitoring also emerged, especially when discussing the importance of the scale, which was deemed crucial in the definition of typical species by the majority of the surveyees. Ecosystem functioning is based on ecological mechanisms and processes mostly trespassing the borders of single habitats (Gonzalez et al. 2020). In agreement with this view, to correctly define typical species, which need to be informative of a habitat's structure and functions, a deeper knowledge about spatial, functional and trophic interactions among neighboring habitats might be required.

Finally, it should be noted that defining a list of species that "reflect favourable structure and functions of the habitat type" (Evans and Arvela 2011) implies a thorough understanding of the structures and the functions characterizing each habitat, which might not always be available.

Conclusion

With this contribution, we attempted to shed light on the meaning and interpretation of typical species in the context of habitat monitoring. To this aim, we combined different perspectives belonging to researchers and professionals in vegetation science. In particular, most of the surveyees and participants to the workshop agreed on two issues: i) the phytosociological method is adequate for habitat monitoring and ii) diagnostic and characteristics species are informative about the structural and functional conservation status of habitats. The definition of typical species useful for habitat monitoring should be accompanied or even preceded by the parallel identification of the habitats' structures and functions. Accomplishing these two tasks calls for a multidisciplinary approach that can be implemented only by combining different scientific knowledge and expertise. Although many open issues remain unsolved, this study represents a first attempt to provide a shared view of key concepts for habitat monitoring and conservation.

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Competing interests

The authors have declared that no competing interests exist.

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Authors' contribution

G.Bo., E.F., L.L. M.G.S. joint first authorship.

S.B. conceived the idea of the workshop. S.B., G.Bo., E.F., L.L., M.G.S. conceptualization of the manuscript. A.T.R.A, M.A., S.P.A., S.B., G.Bo., M.Cac., V.D.C., E.F., A.R.F., D.G., L.L., G.R., M.G.S., G.T., B.V., D.V. organized the workshop. S.B., G.Bo., M.Cac., D.G., E.F., L.L., M.G.S. structured the workshop sessions. G.Bo., E.F., L.L., M.G.S. drafted the original manuscript, with contribution of A.T.R.A., S.B., D.G. All the co-authors commented on the manuscript.

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