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POLICY PERSPECTIVE

Mismatch between Habitat Science and Habitat Directive: Lessons from the French (Counter) Example

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Abstract

The European Habitat Directive encompasses a conservation policy devoted to conserve habitats rather than single species. This ambition has strong ecological justifications, and inspires other initiatives such as the IUCN red list of ecosystems. Evaluating this policy is therefore pivotal to identify and reproduce best practices. However, the habitat aspect of this policy has so far not been systematically assessed. To make up for this lacuna, we take advantage of decision-aiding methodologies to introduce a new normative framework. According to this framework, a conservation policy is positively evaluated if it contributes to conservation, is science-based, operational, and legitimate. Based on an exploration of the published literature and unpublished reports and databases, we identify knowledge gaps plaguing the European habitat conservation policy. We argue that, due to these knowledge gaps, the contribution of this policy to the conservation of habitats is unproven, it is not science-based, not operational and not legitimate. Our study draws heavily on the French implementation. Analyzing this example, we highlight knowledge gaps that carry lessons for European conservation policies as a whole, but also for conservation initiatives focused on habitats in a broader geographical and political context. We then identify concrete means to strengthen habitats conservation policies.

Introduction

Natura 2000 (N2000) is the world's largest network of conservation sites (Evans 2012), covering more than 18% of the European Union (EU) land's area. The Birds and Habitat Directives (BD and HD; Supporting Information [SI], SI-Table 1-B1-B2) require that Member States codify European protections in National laws and actively implement them within this network. The corresponding conservation actions focus on "Species of Community Interest" (SCI) and "Habitats of Community Interest" (HCI) listed in annexes of the Directives (HCI are presented in "EUR28": SI-Table 1-A1; SI-Table 4).

The habitat aspect of this policy embodies the largely justified ambition to overcome species-focused approaches by targeting ecosystems (Keith *et al.* 2013). Beyond the acknowledged importance of assessing public policies (Ferraro & Pattanayak 2006, SI-Table 1-D1), its evaluation therefore has a particular significance for conservation. However, although several studies address the impact of N2000 on various taxa (birds: Pellissier et al. 2013; Sanderson et al. 2015; terrestrial vertebrates: Maiorano et al. 2015; bats: Lisón et al. 2013)), its habitat aspect has not been systematically assessed (SI-Table 1-A2).

We address this lacuna through an analysis mostly focused on France, used as an example to draw lessons for Europe as a whole. Indeed, according to the subsidiarity principle (SI-Table 1-B3), N2000 is orchestrated at EU-scale, but Member States implement it as they see fit. This diversity of implementations provides opportunities to learn from local experiences, which is our approach here.

Table 1 Indeterminacy of translation between the functional ecology literature and HCI practice

The ontology of functional ecology		The ontology of HCI practitioners
Reference	Categories used to describe habitats	Nonexhaustive list of HCI and non-HCI categories (including syntaxons) to which the habitat could belong
Andueza *et al.* 2010	Grassland rich in grasses, Grassland rich in Forbs	6430 Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
Ansquer *et al.* 2009	Grazed grasslands	6510 Lowland hay meadows (*Alopecurus pratensis, Sanguisorba officinalis*) *Agrostietea stoloniferae* Th. Müll. & Görs 1969
de Vries *et al.* 2012	Unimproved grassland, semi-improved and improved grasslands	*Plantaginetalia majoris* Tüxen ex von Rochow 1951
Gardarin *et al.* 2014	Grazed and mown permanent grasslands	
Garnier *et al.* 2004; Cortez *et al.* 2007	A successional sere following vineyard abandonment in the Mediterranean region of France	*Agropyretalia intermedii-repentis* Oberd., Th.Müll. & Görs in Th. Müll. & Görs 1969 *Artemisietea vulgaris* Lohmeyer, Preising & Tüxen ex von Rochow 1951 *Crataego monogynae-Prunetea spinosaee* Tüxen 1962 6220 * Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*
Vile *et al.* 2006 ; Garnier *et al.* 2007 ; Fortunel *et al.* 2009	Agroecosystems	6430 Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels 6510 Lowland hay meadows (*Alopecurus pratensis, Sanguisorba officinalis*) *Agrostietea stoloniferae* Th. Müll. & Görs 1969 *Plantaginetalia majoris* Tüxen ex von Rochow 1951 *Agropyretalia intermedii-repentis* Oberd., Th.Müll. & Görs in Th. Müll. & Görs 1969 *Artemisietea vulgaris* Lohmeyer, Preising & Tüxen ex von Rochow 1951 *Crataego monogynae-Prunetea spinosae* Tüxen 1962 *Polygono arenastri-Poetea annuae* Rivas Mart. 1975 corr. Rivas Mart., Báscones, T.E.Diáz, Fern.Gonz. & Loidi 1991 *Sisymbrietea officinalis* Gutte & Hilbig 1975
Quétier *et al.* 2007, Lavorel & Gargulis 2012, Lavorel *et al.* 2010	Arable rotation	*Stellarietea mediae* Tüxen, Lohmeyer & Preising ex von Rochow 1951
	Fertilized hay meadow	CORINE Biotopes 81
	Unfertilized hay meadow without *Festuca paniculata*	*Agrostietea stoloniferae* Th. Müll. & Görs 1969 6430 Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels 6170 Alpine and subalpine calcareous grasslands *Festucetum paniculatae austro-occidentale centuretosum* Lacoste 1970
	Unfertilized hay meadow with *Festuca paniculata*	6170 Alpine and subalpine calcareous grasslands *Festucetum paniculatae austro-occidentale centuretosum* Lacoste 1970
	Grazed pasture without Festuca paniculata	6170 Alpine and subalpine calcareous grasslands *Plantaginetalia majoris* Tüxen ex von Rochow 1951
	Grazed pasture with *Festuca paniculata*	6170 Alpine and subalpine calcareous grasslands *Plantaginetalia majoris* Tüxen ex von Rochow 1951 *Festucetum paniculatae austro-occidentale centuretosum* Lacoste 1970
	Never mown >2000m grasslands	6170 Alpine and subalpine calcareous grasslands 6110 * Rupicolous calcareous or basophilic grasslands of the *Alysso-Sedion albi*
	Steep grazed slopes	6170 Alpine and subalpine calcareous grasslands *Festucetum paniculatae austro-occidentale centuretosum* Lacoste 1970 *Plantaginetalia majoris* Tüxen ex von Rochow 1951

Continued

Table 1 Continued

The ontology of functional ecology		The ontology of HCI practitioners
Reference	Categories used to describe habitats	Nonexhaustive list of HCI and non-HCI categories (including syntaxons) to which the habitat could belong
Storkey *et al.* 2013	Cereals and *Brassica* cultivated plots, Annually established seed mix	*Stellarietea mediae* Tüxen, Lohmeyer & Preising ex von Rochow 1951
	Floristically enhanced grass	*Agrostietea stoloniferae* Th. Müll. & Görs 1969
	Natural regeneration of the naturally occurring arable flora	CORINE Biotopes 81 *Stellarietea mediae* Tüxen, Lohmeyer & Preising ex von Rochow 1951 *Sisymbrietea officinalis* Gutte & Hilbig 1975 *Artemisietea vulgaris* Lohmeyer, Preising, & Tüxen ex von Rochow 1951

We used the references enlisted by Garnier *et al.* (2015; see Table 6.1) to identify a representative list of publications in functional ecology dealing with the influence of plant traits on ecosystem processes (column 1). We reported the categories used in these articles to describe habitats (column 2) and identified in each case a series of HCI and non-HCI categories (including syntaxons) to which each category could correspond (column 3). This table illustrates that, on the basis of the information given in published articles, it is impossible to translate unequivocally the language used by functional ecologists to describe habitats into the one used by HCI practitioners.

To develop our evaluation, we first introduce a new normative framework inspired by recent advances in decision-aiding methodologies. Although the above-mentioned assessments exclusively focus on the impact of N2000 on conservation targets, this framework encompasses several dimensions of evaluation. Then, exploring the literature and unpublished reports and databases, we identify knowledge gaps (KG) plaguing HD's habitat policy. Gaps between research and practice have been studied on numerous conservation-related topics (Knight *et al.* 2008; Matzek *et al.* 2014), but the habitat case is poorly documented. We unveil important problems in this area, pertaining not only to how ecological advances can translate into practice, but also to capacity building and institutional design. We then use our framework to investigate the implications of these KG for the policy. Finally, we articulate concrete recommendations, and highlight the global significance of our study.

Policy analytics as evaluation framework

Numerous normative frameworks have been developed to rationalize evaluations and associated decision-aiding (De Marchi *et al.* 2016). Among them, "policy analytics" states that decision-aiding should be "value-adding" (i.e. help policies reaching their objectives), science-based, operational, and legitimating (Tsoukias *et al.* 2013). We propose to use and adapt this framework because these criteria are of particular relevance to the evaluation of HD's habitat policy, for the following reasons:

— HD aims to "maintain or restore natural habitats" (SI-Table 1-B1). Assessing its contribution to habitat conservation is therefore crucial to evaluate it (criterion C1).
— It is largely admitted that scientific evidence and knowledge should contribute to assess and, in turn, to improve the effectiveness of conservation actions (Knight *et al.* 2008; Dicks *et al.* 2014; Senior *et al.* 2015). The evaluation should therefore investigate whether the policy is science-based (C2).
— Because impractical policies are pointless, the evaluation should assess whether the policy is operational (C3).
— Because N2000 sites witness highly diverse human activities (Tsiafouli *et al.* 2013), it is pivotal that N2000 initiatives be considered legitimate by local stakeholders and the general public (C4).

These criteria should not be seen as absolute requirements, because optimizing one criterion can have detrimental consequences on others. For example, a policy exceedingly reliant on cutting-edge science could become nonoperational because too demanding in technology and highly specific skills. Similarly, in some situations, non-scientific knowledge can contribute more efficiently than science to conservation (Mazzocchi 2006).

We accordingly only assume that, for each criterion C1-4, all other things held equal, the better the criterion is satisfied, the more positively the policy should be evaluated (Figure 1a). We now highlight knowledge gaps relating to HD's habitat policy, and investigate their consequences for C1-4.

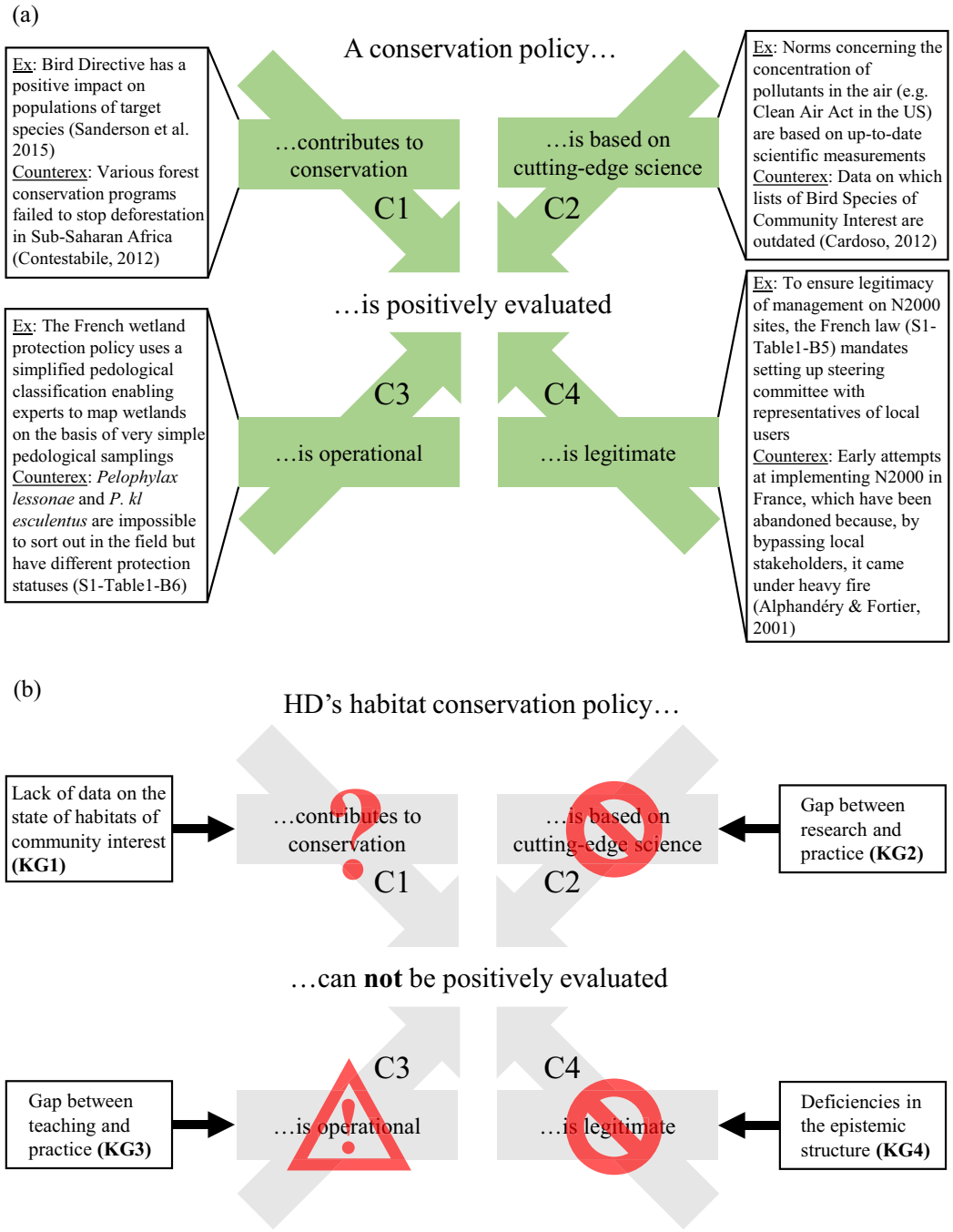

Figure 1 (a) Our evaluation framework, based on "policy analytics," explained and exemplified. C1-4 stand for the four criteria of evaluation of the policy under scrutiny. The four criteria should be understood as "all other things held equal" conditions: for any of these criteria, all other things held equal, the better the criterion is satisfied, the more positively the policy is evaluated. Notice that, in a general setting, maximizing the satisfaction of one criterion can impair the satisfaction of one or several of the others. Elaborating whether and how the various criteria can be aggregated in such cases falls beyond the scope of the present article. (b) Our framework applied to habitat conservation policy as part of the Habitat Directive. KG1-4 stand for the four knowledge gaps (see section Knowledge gaps). Because of KG1, C1 is indeterminate. Because of KG2, C2 is unsatisfied. Both notions apply to EU as a whole. Because of KG3, C3 is unsatisfied in France, where phytosociology is marginal in biology curricula. The French example should set off alarm bells for EU as a whole. KG4 testifies for a fragility of the European system as a whole, implying that C4 is not satisfied. Based on C1-4, one cannot positively evaluate HD's habitat conservation policy.

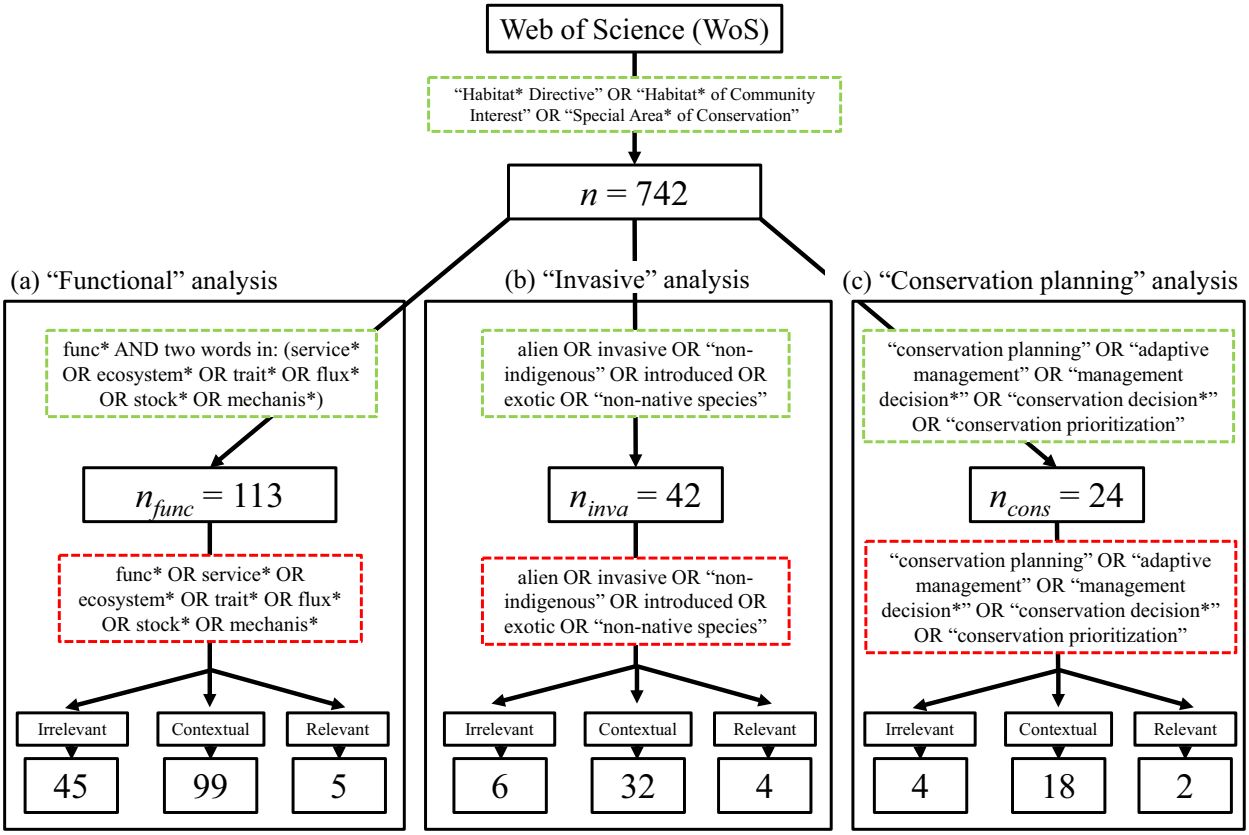

Figure 2 Flow chart explaining the bibliographical analyses performed on Web of Science Core Collection (Thomson Reuters, NY) and their results. Dashed boxes represent search on bibliographical corpus. Green dashed boxes mean that search is done on title, abstract and keywords of each publication. Red dashed boxes mean that search is done on entire text. We first identified a corpus of articles (*n*) dealing with habitats conservation in the N2000 sense, by selecting all the articles containing occurrences of "Habitat(s) Directive" or "Habitat(s) of Community Interest" or "Special Area(s) of conservation" in their abstracts, titles or keywords in the Web of Science Core Collection (timespan: 1970–2016; extensive list of articles can be found in SI-Table 5). On this first corpus, we then performed three parallel analyses to detect the available scientific knowledge on HCI pertaining to three prominent branches of ecology and conservation: functional ecology (a), invasive ecology (b), and conservation planning (c). The first step of each of the three analyses selects a branch-specific corpus by selecting articles containing occurrences of keywords of the corresponding branch in their title, abstract or keywords (corpuses n_{func}, n_{inva}, n_{cons}, respectively). In a second step, we detect occurrences of keywords of the concerned discipline in the whole text of each article in corpuses n_{func}, n_{inva}, n_{cons}. In a third step, we categorize these occurrences. Occurrences of branch-specific keywords are termed "irrelevant" when the detected words are actually homonyms of the searched words, used in another sense (e.g. searching for occurrences of "function" to detect occurrences of keywords of functional ecology, we select an article where the term "function" is used to refer to a mathematical function). Occurrences of branch-specific keywords are termed "contextual" when they are used to contextualize the study (e.g. in the introduction or the conclusion of the article) or when they appear in articles that do not mention any HCI in their main text. Occurrences are termed "relevant" when they appear in the formulation of scientific results dealing with both HCI and notions pertaining to the concerned branch. The sum of irrelevant, contextual and relevant occurrences can be greater than the size of the corresponding corpus because some words can appear multiple times in the same publication.

Notice that, in analysis (a), among the n_{func} articles, none is published in what we considered to be influential journals specialized in functional ecology (*Ecosystems*, *Functional Ecology*, *Biogeochemistry*), influential journals in ecology with sections devoted to functional ecology (*New Phytologist*, *Ecology*, *Journal of Ecology*, *Oikos*, *Oekologia*, *Ecology Letters*, *Global Change Biology*, *Basic and Applied Ecology*) or important review journals (*Trends in Ecology and Evolution*, *Annual Reviews of Ecology*, *Evolution and Systematics*, *Biological Reviews*). As addendum to analysis (b), all invasive species names from DAISIE, TAXREF v9 and EPPO Lists of Invasive Alien Plants (see SI-Table 3) were also searched in the general corpus ($n = 742$) on title, abstract and keywords. Linnaean binomial Latin names were used for each species because complete names (with authors and date) are not always given in articles. All synonyms were also checked using the French Taxonomic Reference Source TAXREFv9 (SI-Table 1-C5). This supplementary analysis does not reveal any other relevant articles than those previously detected by the principal analysis with n_{inva}.

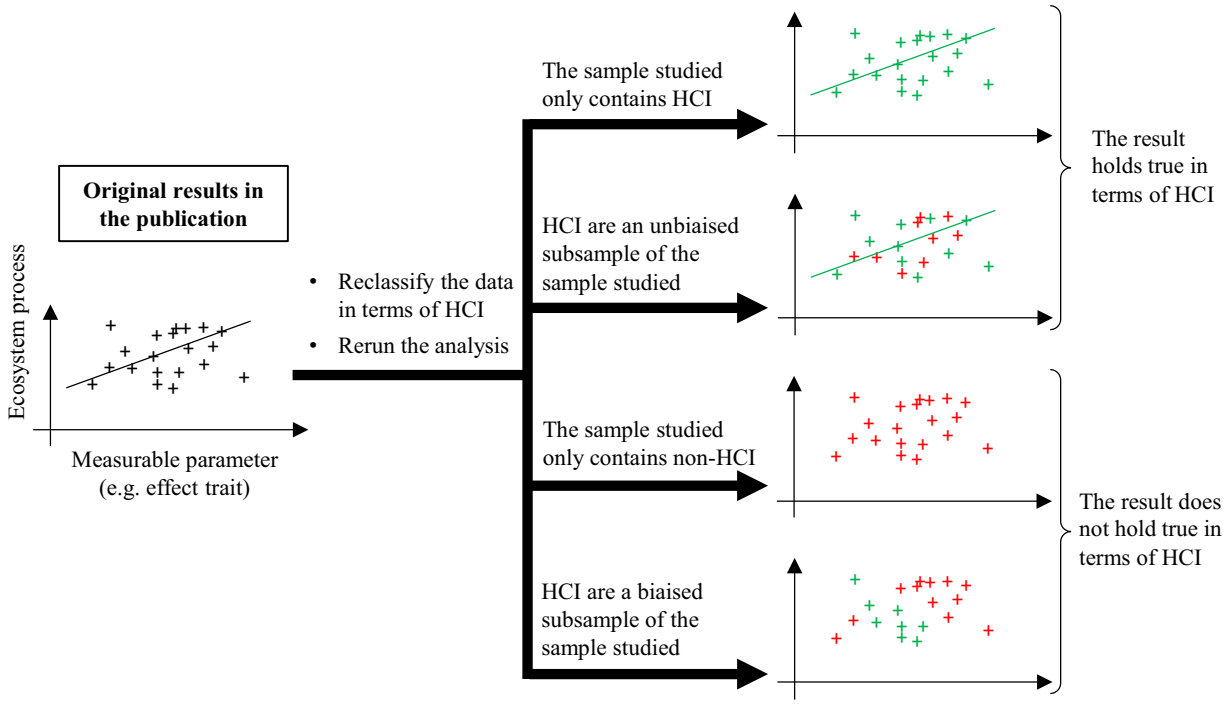

Figure 3 Schematic explanation of the analyses needed to translate typical results published in scientific journals into results usable in the field by N2000 practitioners, using results in functional ecology as a focal example. The left panel schematizes the results of a fictive scientific article, demonstrating a linear relation between a given ecosystem parameter and a given ecosystem process, for a series of habitats represented by black crosses and described in the original article using one or several of the categories exemplified in Table 1, column 2. Green and red crosses in the right panel respectively represent habitats that would be categorized as HCI and non-HCI using HD practitioners' categories, as exemplified in Table 1, column 3.

Evaluating HD's habitat policy

Knowledge gaps

Lack of data on HCI conservation status (KG1)

HD requires that Member States periodically perform conservation status assessments of HCI along three ecological parameters: range, coverage, and structure and function (article 17 evaluation: A17E). In each country, each HCI is evaluated in each biogeographical region (SI-Table 1-D2) where it occurs. The latest A17E (SI-Table 1-A3) spans over 2007–2012.

The methods and results of A17E are gathered by the European Topic Center on Biological Diversity (ETC-BD: SI-Table 1-D3) in a European-wide database (SI-Table 1-C1). France produced an additional, more detailed, database (SI-Table 1-C2). According to these databases, in France, evaluations based on a "complete survey or a statistically robust estimate" (in the official terminology: SI-Table 1-A4) are marginal (6.3%). 52.5% of evaluations are admitted to be based on data that are "partial" and 38% are "based on expert opinion." The lack of data is especially patent for structure and function: 85% of evaluations are expert opinions (SI-Table 1-C2). This can be compared with evaluations of population size and population trends of Bird SCI in France in the BD reporting (SI-Table 1-C3), among which 44% are complete surveys and 7% are expert opinions. At European level, complete or statistically robust surveys are more important but in minority (16.6%), experts opinion are less dominating but still important (22.7%), and significantly more so (χ^2-test: $P < 0.001$) for structure and function (43.4%).

For each biogeographical zone/country/HCI combination, A17E provides an aggregate conservation status for all sites inside and outside N2000. A handful of countries (France, UK, Belgium, Germany, and Austria: SI-Table 1-A4) also produce evaluations at site level. However, these initiatives lack coordination (Maciejewski *et al.* 2016). The site-level French database (SI-Table 1-C4) contains information encoded in categories different from the ones used in A17E, with admitted ambiguities of translations between the two (SI-Table 1-A5). Besides, standardized evaluation methods are available only for a minority of HCI (in France: 52 HCI out of 132).

To sum-up, the data on the conservation status of HCI are of two sorts, too heterogeneous to be aggregated:

- A17E, which lumps together all sites at biogeographic/country level and is weakly based on complete or statistically robust estimates.
- Evaluations at site level, which are scarce and non-standardized.

Gap between research and practice (KG2)

Following the CORINE (SI-Table 1-A6) and Palearctic habitat classifications (Devilliers & Devilliers-Terschuren 1993), the denomination and descriptions of HCI (detailed in regional manuals such as the French "Habitat Books": SI-Table 1-A7) are largely based on phytosociological categories ("syntaxons"; Evans 2010).

To establish whether conservation actions based on HCI or phytosociological categories can take advantage of ecological advances, we explored the peer-reviewed literature in three disciplines that we take, for complementary reasons, to be the ones that should be the most useful for HD practitioners:

(a) *Functional ecology* because European texts emphasize the importance of preserving ecological functioning, and the A17E structure and function evaluation patently lacks data (3.1.1). We identified 113 articles in the literature about ecological functioning on N2000 habitats (Figure 2a). However, key terms of functional ecology are used there mainly to describe the context; only five articles refer both to HCI and functional ecology in their results. This illustrates that functional ecology and N2000 do not have a shared ontology: functional ecologists do not use HCI categories to elaborate and design their projects and never articulate results in this language. To be able to use these results, practitioners would have to reanalyze raw data to reclassify them in HCI terms, and redo analyses to see whether published results persist when translated (Figure 3).

(b) *Invasive ecology* because other European policies target invasive species (Beninde *et al.* 2015) and A17E takes them as an important threat to habitats (SI-Table 1-A4). Definitions of habitats in practitioner's manuals (SI-Table 1-A7) are however based on lists of "index species" often including invasive species. Depending on the invasive database used, 8–28% of the HCI present in France have, among their "index species," at least one species considered invasive in France (SI-Table 3). Robust knowledge on the impact of invasive species on HCI is therefore greatly needed, especially for HCI with index invasive species. However, to date, only four articles display results on the impact of invasive species on HCI (Figure 2b).

(c) *Conservation planning* because Popescu *et al.* (2014) identified it as the dominant discipline in the N2000 literature. We identified only 24 articles pertaining to this discipline on habitats (suggesting that the literature identified by Popescu *et al.* (2014) mainly dealt with the species aspects of N2000), and only two referred both to HCI and conservation planning in their results (Figure 2c).

The three corpuses, therefore, illustrate the same problem: despite their potential usefulness for HD practitioners, published results are not usable because they are not expressed in the categories that practitioners use, and translating them would be a scientific task on its own. As a consequence, it is not surprising that, among the 3117 evaluations performed as part of A17E, only 312 (10%) refer to articles published in journals listed in the *Journal of Citation Reports* (SI-Table 2).

Gap between teaching and practice (KG3)

Associated with the fact that academics rarely use phytosociological categories, phytosociology tends to disappear from ecology curricula. In France, all biology universities have marginalized phytosociology teaching (Bouzillé 2007); only four 1-week-long continuing formations are dispensed in phytosociology per year (SI-Table 1-D4). Phytosociology teaching remains more developed for example in Italy, Spain, or Eastern countries (e.g. SI-Table 1-D5). But the durability of this situation is uncertain if phytosociological categories vanish from the scientific literature.

Deficiencies in the structure of the epistemic community (KG4)

One of the strengths of N2000 is that numerous international experts were involved in its construction through seminars and experts groups (Evans 2012; Popescu *et al.* 2014). However, the French A17E database reveals problems in the structure of these panels. Although A17E involved more than 800 contributors, writing was largely confined to expertise institutions (81%), whereas research and teaching institutions played a marginal role (<5%). Among the 319 evaluations by expert institutions, all but one were performed by "Conservatoires Botaniques," institutions representing botanists and phytosociologists. The relevance of these actors for A17E is indisputable but others, including researchers and managers, also have insights to contribute, and the panel is biased against them (Figure 4). Social and economic scientists or experts could also contribute by improving the identification of threats impacting habitats and policies contradicting N2000 actions. Going beyond

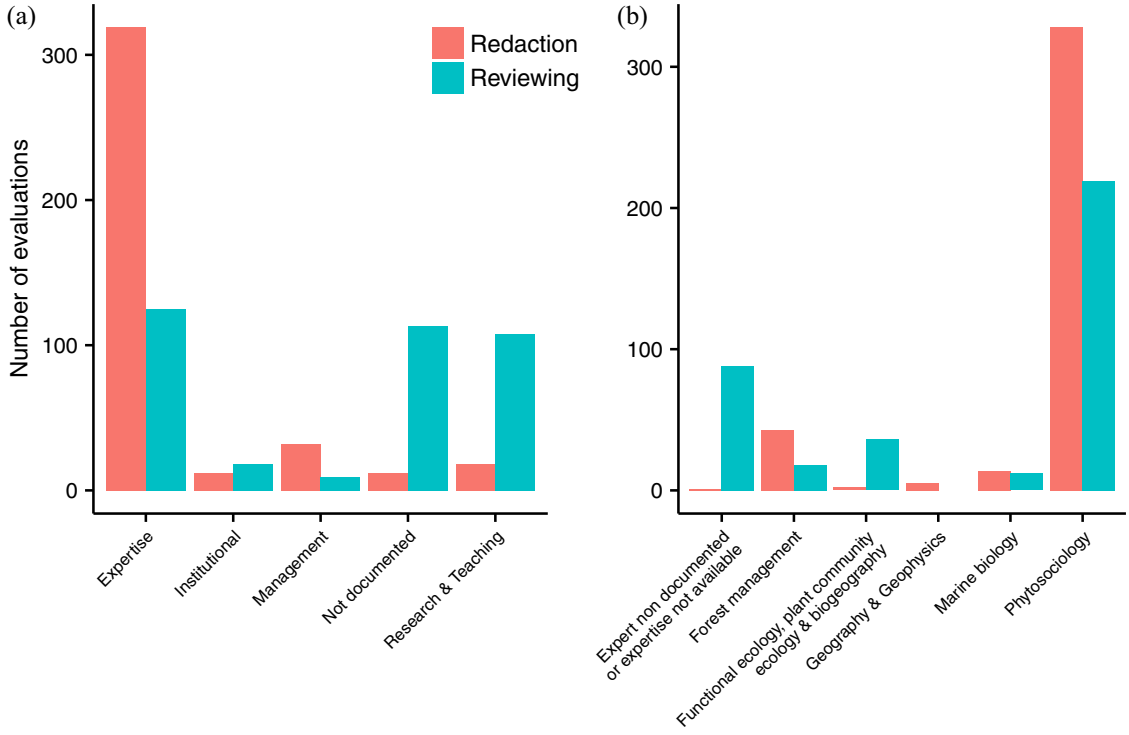

Figure 4 Institutional and disciplinary balance in the composition of the panel involved in the latest A17E in France. These information are from the French A17E database (SI-Table 1-C2). The database provides names and institutional affiliations for most of the experts involved in the evaluation. Part (a) of the graph reproduces the data from this database. To construct part (b), we used the disciplinary affiliation presented by the various experts on the websites of their institutions. "Conservatoires Botaniques" are the only exception, because most of the experts from these institutions do not have a personal page presenting them in the website of the "Conservatoire Botaniques" to which they belong. Since "Conservatoires Botaniques" are institutions devoted to botany and phytosociology, we classified experts from Conservatoires Botaniques in the disciplinary category "phytosociology."

European guidelines, the French database, therefore, unveils problematic biases invisible at European level.

Moreover, as far as reports indicate (SI-Table 1-A8), it has not been verified that the various A17E evaluators agreed in their understanding of "conservation status". The European guidelines (SI-Table 1-A4) do not require any such verification. Similarly, the construction of site scale methods (SI-Table 1-A9-A19) admits that "conservation status" is unproblematic for the panel of experts involved. Recent discussions (Epstein *et al.* (2016) on species, Boitani *et al.* (2015) on ecosystems, Maciejewski *et al.* (2016) on habitats), however, prove that the notion of conservation status is still open to largely divergent interpretations—despite purported clarifications in an internal European note (SI-Table 1-A20).

How knowledge gaps undermine HD's habitat policy (Figure 1)

Assessing HD's contribution to habitats conservation requires sorting out its proper effect from confounding factors such as historical trends or unrelated policies (Ferraro & Pattanayak 2006). This requires data on conservation status in sites inside and outside the network. But data on conservation status at site level are scarce and A17E lumps together statuses inside and outside the network (KG1). The contribution of N2000 to conserving habitats is therefore unproven due to a lack of data (C1 indeterminate).

KG2 shows that N2000 practice cannot take advantage of an important part of published scientific results. Although knowledge relevant to conservation is not confined to the academic world (Burgman *et al.* 2011), and A17E and HD practices are based on an extensive unpublished literature, they accordingly appear insulated from a large part of cutting-edge science (C2 unsatisfied).

In terms of operationality (C3), countries like France are additionally plagued by a lack in capacity building in phytosociology (KG3), and one can consequently hardly expect to find enough phytosociological competences in the field to produce robust management practices. In countries where phytosociology teaching remains

important, the situation is less problematic, but due to the links between research and teaching, its durability is fragile.

KG also have implications for legitimacy (C4). Indeed, the procedural organization of collective scientific expertise, and in particular a balance between various knowledge-holders (in terms of institutions, discipline or background), is increasingly considered pivotal to achieve the pluralist knowledge liable to inform policies while bestowing legitimacy on them (Montana & Borie 2016). KG4 is therefore detrimental to the legitimacy of HD.

To sum up, C1 is indeterminate (due to KG1) and C2 unsatisfied (due to KG2) for Europe as a whole. Concerning C3, due to KG3 in France it is unsatisfied, and in countries where phytosociology is more developed the situation remains problematic. Concerning C4, KG4 testifies for a fragility of the European system as a whole. Based on C1-4, one therefore cannot positively evaluate this policy.

Improving European habitat conservation policies

Updating scientific basis

To ensure that HD's habitat policy becomes more science-based, a two-steps European-wide initiative is needed:

(1) First, the identifiability of HCI without referring to syntaxons should be assessed, and new characterizations clarified in up-to-date guidelines. The point is not to discard phytosociology, because valorizing phytosociological knowledge about species assemblages and repartition (Ewald 2003; Biondi 2011) is undoubtedly a cogent strategy for HD. A pervasive usage of phytosociological vocabulary, however, insulates HD from ecological advances. For some HCI, such as the easily identifiable "Dunes with *Hippophae rhamnoides*" (2160), a clarification of EUR28 will suffice. For others, deeper reshufflings are necessary. In France, an ongoing work coordinated by the "Muséum National d'Histoire Naturelle" considers that 92 HCI (out of 130 analyzed) need clarifications (V. Gaudillat, personal communication), because their definitions raise unsettled questions.

(2) Second, uncertainties concerning the rarity status of HCI should be assessed. The outdatedness of the knowledge justifying lists of HCI is currently tackled in a piecemeal, informal way. For example, *Heleochloion schoenoidis* communities in Corsica are part of HCI 3170*, but they are now known to be common, and are informally excluded in cartographies of HCI (SI-Table 1-A21). A systematic review and resolution of similar problems are needed. The workload will vary from one country to another. In the UK, the national vegetation classification (SI-Table 1-A22) involved a country-wide sampling, providing reliable data on relative rarity. By contrast, in France, the vegetation prodrome (SI-Table 1-A23) does not display completeness assessments, and only 10% of the territory is covered by vegetation maps (SI-Table 1-A24), which makes current rarity assessments pointless. In the Mediterranean area, arguably the most biodiverse in France (Blondel 2010), there is no vegetation catalog available, and small-scale studies suggest that phytosociological knowledge is vastly lacunar. A complete bibliographical synthesis in the Préalpes d'Azur (SI-Table 1-A25) hence shows that, for 16 of the 24 HCI inventoried, no post-1980 source was available, for three, no sources at all and only one was concerned by a post-2000 source. Up-to-date phytosociological knowledge appears practically nonexistent in this region.

In this process, scientific journals will have a prominent responsibility. Publishing and valorizing catalogues of plant communities could help increase scientific quality control and ensure a wider diffusion. This would also incite researchers to develop collaborations with local knowledge-holders, which would strengthen the link between researchers and practitioners.

Ecology journals could also require that authors integrate in their manuscripts a discussion of the translatability of their results in terms of HCI. If this translation is possible, articulating it will be helpful for practitioners. If it is impossible, making it clear prevents misinterpretations.

Building capacity

Strengthening scientific bases is, however, only one aspect of the improvements needed. By adopting HD, Member States committed to equip themselves with the capacity to implement it. In France, reference institutions for habitats are "Conservatoires Botaniques." Their botanical competence is indisputable but they have neither the obligation nor the financial and human means to perform teaching (SI-Table 1-B4) and have more limited access to scientific bibliographical databases than research institutions. This condemns France to competence scarcity. To perform the two tasks above, the EU and Member States should learn from this counterexample. They should provide financial and organizational support to retrieve the competence to learn, critically assess and renew phytosociological knowledge.

Reforming A17E

Our analysis also highlights A17E reforms that should be moved to the top of the ETC-BD agenda:

(1) The structuration of epistemic communities involved should be rationalized, e.g. through the work of a dedicated committee involving ecologists, social scientists, philosophers and practitioners;
(2) Evaluations at site level should become mandatory, inside and outside the network;
(3) Requirements should be specified in terms of quantitative data content and publication for sources used.

Our recommendations are all costly initiatives. But numerous N2000 funding instruments (SI-Table 1-A26) could contribute by integrating them in their guidelines. In particular, they represent opportunities for Life-Nature, the main EU conservation financial instrument, to fix its inability to address conservation priorities (Hermoso *et al.* 2016).

Conclusions

The weaknesses of HD's habitat policy that we highlight should not overshadow the undeniable strengths of N2000: its coherence with international environmental agreements (Beresford *et al.* 2016), its contribution to conserving species (Sanderson *et al.* 2015), or the breadth of the network. Our point is not to vilify the policy, but to identify how to improve it. In this respect, our analysis highlights knowledge gaps that have a more general bearing than N2000. In particular, problems encountered if categories used by practitioners and researchers differ carry lessons for conservation initiatives focused on habitats whatever their geographical and political context. The same goes for associated problems of capacity building and biased epistemic communities. Accordingly, our concrete recommendations can be transposed in other contexts, such as e.g. the emergent IUCN red list ecosystem initiative (SI-Table 1-A27).

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web site:

SI-Table 1. Unpublished sources cited in the article.

SI-Table 2. List of evaluations in A17E referring to peer-reviewed sources in scientific journals.

SI-Table 3. List of habitats of community interest present in France, for the identification of which the presence of alien invasive species plays a key role because they are considered "index species" in the Habitat Books (SI-Table 1-A7).

SI-Table 4. Complete list of HCI, with codes and official denomination; and list of the HCI present in France, in the different biogeographic region.

SI-Table 5. Extensive list of articles analyzed in Figure 2.

References

Alphandéry, P. & Fortier, A. (2001). Can a territorial policy be based on science alone? The system for creating the Natura 2000 network in France. *Sociol. Ruralis*, **41**, 311-328.

Beninde, J., Fischer, M.L., Hochkirch, A. & Zink, A. (2015). Ambitious advances of the European Union in the legislation of invasive alien species. *Conserv. Lett.*, **8**, 199-205.

Beresford, A.E., Buchanan, G.M., Sanderson, F.J., Jefferson, R. & Donald, P.F. (2016). The contributions of the EU nature directives to the CBD and other multilateral environmental agreements. *Conserv. Lett.* doi:10.1111/conl.12259.

Biondi, E. (2011). Phytosociology today: methodological and conceptual evolution. *Plant Biosyst. - Int. J. Deal. Asp. Plant Biol.*, **145**, 19-29.

Blondel, J. (2010). *The Mediterranean region: biological diversity through time and space*. Oxford University Press, Oxford.

Boitani, L., Mace, G.M. & Rondinini, C. (2015). Challenging the scientific foundations for an IUCN red list of ecosystems. *Conserv. Lett.*, **8**, 125-131.

Bouzillé, J.-B. (2007). *Gestion des habitats naturels et biodiversité*. Lavoisier, Paris, France.

Burgman, M., Carr, A., Godden, L., Gregory, R., McBride, M., Flander, L. & Maguire, L. (2011). Redefining expertise and improving ecological judgment. *Conserv. Lett.*, **4**, 81-87.

Cardoso, P. (2012). Habitats directive species lists: urgent need of revision. *Insect Conserv. Divers.*, **5**, 169-174.

Contestabile, M. (2012). Forest conservation: failed protection regimes. *Nat. Clim. Chang.*, **2**, 839-839.

De Marchi, G., Lucertini, G. & Tsoukiàs, A. (2016). From evidence-based policy making to policy analytics. *Ann. Oper. Res.*, **236**, 15-38.

Devilliers, P. & Devilliers-Terschuren, J. (1993). *A classification of palaearctic habitats*. Council of Europe, Strasbourg.

Dicks, L.V., Hodge, I., Randall, N.P., *et al.* (2014). A Transparent process for "evidence-informed" policy making. *Conserv. Lett.*, **7**, 119-125.

Epstein, Y., López-Bao, J.V. & Chapron, G. (2016). A Legal-ecological understanding of favorable conservation status for species in Europe. *Conserv. Lett.*, **9**, 81-88.

Evans, D. (2010). Interpreting the habitats of Annex I: past, present and future. *Acta Bot. Gallica*, **157**, 677-686.

Evans, D. (2012). Building the European Union's Natura 2000 network. *Nat. Conserv.*, **1**, 11-26.

Ewald, J. (2003). A critique for phytosociology. *J. Veg. Sci.*, **14**, 291-296.

Ferraro, P.J. & Pattanayak, S.K. (2006). Money for nothing? A call for empirical evaluation of biodiversity conservation investments. *PLOS Biol*, **4**, e105.

Hermoso, V., Clavero, M., Villero, D. & Brotons, L. (2016). EU's conservation efforts need more strategic investment to meet continental conservation needs. *Conserv. Lett.*

Keith, D.A., Rodríguez, J.P., Rodríguez-Clark, K.M., *et al.* (2013). Scientific foundations for an IUCN red list of ecosystems. *PLoS ONE*, **8**, e62111.

Knight, A.T., Cowling, R.M., Rouget, M., Balmford, A., Lombard, A.T. & Campbell, B.M. (2008). Knowing but not doing: selecting priority conservation areas and the research—implementation gap. *Conser. Biol.*, **22**, 610-617.

Lisón, F., Palazón, J.A. & Calvo, J.F. (2013). Effectiveness of the Natura 2000 Network for the conservation of cave-dwelling bats in a Mediterranean region: cave-dwelling bats and the Natura 2000 Network. *Anim. Conserv.*, **16**, 528-537.

Maciejewski, L., Lepareur, F., Viry, D., Bensettiti, F., Puissauve, R. & Touroult, J. (2016). État de conservation des habitats: propositions de définitions et de concepts pour l'évaluation à l'échelle d'un site Natura 2000. *Rev. D'Ecologie Terre Vie*, **71**, 3-20.

Maiorano, L., Amori, G., Montemaggiori, A., *et al.* (2015). On how much biodiversity is covered in Europe by national protected areas and by the Natura 2000 network: insights from terrestrial vertebrates: Biodiversity Conservation in Europe. *Conserv. Biol.*, **29**, 986-995.

Matzek, V., Covino, J., Funk, J.L. & Saunders, M. (2014). Closing the Knowing–Doing gap in invasive plant management: accessibility and interdisciplinarity of scientific research. *Conserv. Lett.*, **7**, 208-215.

Mazzocchi, F. (2006). Western science and traditional knowledge: despite their variations, different forms of knowledge can learn from each other. *EMBO Rep.*, **7**, 463-466.

Montana, J. & Borie, M. (2016). IPBES and biodiversity expertise: regional, gender, and disciplinary balance in the composition of the interim and 2015 multidisciplinary expert panel: IPBES and biodiversity expertise. *Conserv. Lett.*, **9**, 138-142.

Pellissier, V., Touroult, J., Julliard, R., Siblet, J.P. & Jiguet, F. (2013). Assessing the Natura 2000 network with a common breeding birds survey. *Anim. Conserv.*, **16**, 566–574.

Popescu, V.D., Rozylowicz, L., Niculae, I.M., Cucu, A.L. & Hartel, T. (2014). Species, habitats, society: an evaluation of research supporting EU's Natura 2000 Network. *PLoS ONE*, **9**, e113648.

Sanderson, F.J., Pople, R.G., Ieronymidou, C., *et al.* (2015). Assessing the performance of EU nature legislation in protecting target bird species in an era of climate change: impacts of EU nature legislation. *Conserv. Lett.*, **9**, 172-180.

Senior, M.J.M., Brown, E., Villalpando, P. & Hill, J.K. (2015). Increasing the scientific evidence base in the "high conservation value" (HCV) approach for biodiversity conservation in managed tropical landscapes. *Conserv. Lett.*, **8**, 361-367.

Tsiafouli, M.A., Apostolopoulou, E., Mazaris, A.D., Kallimanis, A.S., Drakou, E.G. & Pantis, J.D. (2013). Human activities in Natura 2000 sites: a highly diversified conservation network. *Environ. Manage.*, **51**, 1025-1033.

Tsoukias, A., Montibeller, G., Lucertini, G. & Belton, V. (2013). Policy analytics: an agenda for research and practice. *EURO J. Decis. Process.*, **1**, 115-134.

