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Contributed Paper

Advantages of Volunteer-Based Biodiversity Monitoring in Europe

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Abstract: *Without robust and unbiased systems for monitoring, changes in natural systems will remain enigmatic for policy makers, leaving them without a clear idea of the consequences of any environmental policies they might adopt. Generally, biodiversity-monitoring activities are not integrated or evaluated across any large geographic region. The EuMon project conducted the first large-scale evaluation of monitoring practices in Europe through an on-line questionnaire and is reporting on the results of this survey. In September 2007 the EuMon project had documented 395 monitoring schemes for species, which represents a total annual cost of about €4 million, involving more than 46,000 persons devoting over 148,000 person-days/year to biodiversity-monitoring activities. Here we focused on the analysis of variations of monitoring practices across a set of taxonomic groups (birds, amphibians and reptiles, mammals, butterflies, plants, and other insects) and across 5 European countries (France, Germany, Hungary, Lithuania, and Poland). Our results suggest that the overall sampling effort of a scheme is linked with the proportion of volunteers involved in that scheme. Because precision is a function of the number of monitored sites and the number of sites is maximized by volunteer involvement, our results do not support the common belief that volunteer-based schemes are too noisy to be informative. Just the opposite, we believe volunteer-based schemes provide relatively reliable data,*

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with state-of-the-art survey designs or data-analysis methods, and consequently can yield unbiased results. Quality of data collected by volunteers is more likely determined by survey design, analytical methodology, and communication skills within the schemes rather than by volunteer involvement per se.

Keywords: biodiversity monitoring, costs, data collection, sampling effort, volunteer involvement

Ventajas del Monitoreo de Biodiversidad Basado en Voluntarios en Europa

Resumen: *Sin sistemas de monitoreo robustos y objetivos, los cambios en los sistemas naturales seguirán siendo un enigma para los políticos, ya que no tendrán una idea clara de las consecuencias de las políticas ambientales que puedan adoptar. Generalmente, las actividades de monitoreo de la biodiversidad no están integradas o evaluadas en ninguna región geográfica extensa. El proyecto EuMon llevó a cabo la primera evaluación a gran escala de las prácticas de monitoreo en Europa por medio de un cuestionario en línea y presenta los resultados de este muestreo. En septiembre 2007, el proyecto EuMon había documentado 395 esquemas de monitoreo de especies, lo que representa un costo anual total de casi €4 millones, y la participación de más de 46,000 personas que dedican más de 148,000 personas días/año en actividades de monitoreo de la biodiversidad. Aquí, nos centramos en el análisis de variaciones en las prácticas de monitoreo de un conjunto de grupos taxonómicos (aves, anfibios y reptiles, mamíferos, mariposas, plantas y otros insectos) en cinco países europeos (Francia, Alemania, Hungría, Lituania y Polonia). Nuestros resultados sugieren que el esfuerzo de muestreo total de un esquema está vinculado con la proporción de voluntarios que participan en el ese esquema. Debido a que la precisión es una función del número de sitios monitoreados y el número de sitios es maximizado por la participación de voluntarios, nuestros resultados no soportan la creencia popular de que los esquemas basados en voluntarios tienen demasiado ruido para ser informativos. Al contrario, consideramos que los esquemas basados en voluntarios proporcionan datos confiables, con diseños de muestreo o métodos de análisis de datos de vanguardia, y consecuentemente pueden proporcionar resultados objetivos. La calidad de los datos recolectados por voluntarios probablemente está determinada por el diseño del muestreo, la metodología analítica y las habilidades de comunicación de los esquemas y no por la participación de voluntarios per se.*

Palabras Clave: costos, esfuerzo de muestreo, monitoreo de biodiversidad, participación de voluntarios, recolección de datos

Introduction

International conventions, such as the Convention on Biodiversity (CBD) and the European nature directives, compel national governments to implement and identify existing biodiversity-monitoring schemes (92/43/EEC, conservation of natural habitats and of wild fauna and flora [Habitats Directive]; 79/409/EEC, conservation of wild birds [Birds Directive], see also Evans 2005). Without robust and unbiased systems for monitoring changes in natural systems, policy makers will not realize the extent of change, and they will have no clear way to evaluate the consequences of environmental policies they might adopt (Balmford et al. 2003, 2005). A good recent example of how policy can be informed by biodiversity monitoring and analysis was shown for European bird species (Donald et al. 2007).

Biodiversity monitoring entails 3 activities: collecting monitoring data, such as occurrence or abundance indices in a target area over an appropriate timescale; analyzing the spatial and temporal patterns of biodiversity components, including diagnosing the causes of change as robustly as possible; and deriving results oriented toward policy makers, such as status and trend assessments or management evaluations. Biodiversity monitoring faces at least 2 practical difficulties: the need to maintain a sustained effort of monitoring across years to ensure the collection of relevant monitoring time series and the need to obtain precise monitoring data that allow the detection of significant changes across space and time in biodiversity. These needs come into conflict with the usually limited amount of available financial and human resources. A trade-off solution is to involve volunteers in monitoring activities. In Europe and North America many monitoring organizations rely on such volunteer programs (van Swaay et al. 1997; Link & Sauer 1998; Vandenbosch 2003; Thomas 2005; Gregory et al. 2005). The involvement of the public is imperative to reduce the cost of biodiversity monitoring and has the added benefit of enhancing citizen participation in science practices and thus environmental awareness (e.g., Bell et al. 2008). Nevertheless, volunteer-based monitoring is often perceived as simplistic, prone to higher biases than professional monitoring schemes (Engel & Voshell 2002; Genet & Sargent 2003), and as a trade-off between precision and cost (Brashares & Sam 2005).

Here we report on the results of the first large-scale evaluation of monitoring practices in Europe. We compared monitoring practices and potential benefits resulting from volunteer involvement in different species groups and across several eastern and western European countries.

Methods

The EuMon project (Schmeller et al. 2006) conducted a survey on biodiversity-monitoring practices across Europe from 2005 to 2007. We examined the data gathered up to September 2007. Information on monitoring programs and practices was and still is collected through an Internet questionnaire. The questionnaire had 8 questions on basic features of biodiversity monitoring and 33 questions specific to species-monitoring methods and design (see Supporting Information). For reaching representatives of stakeholder groups involved in monitoring activities (governmental and nongovernmental bodies), we distributed announcements of the questionnaire through emails, letters, and at conferences to over 1600 individuals and several national and international mailing lists. We asked respondents to provide data on-line, but also accepted written responses, which were inputted to the database by us. Responses were checked for completeness, and missing details were sought from the coordinators of monitoring projects. After validation data were accepted and made publicly available in a database. Complete information was not available for all schemes; hence, the sample sizes and degrees of freedom differ slightly among tests and comparisons.

Determination of Biases in Taxonomic and Geographical Coverage

Despite the fact that the EuMon survey is the first large-scale survey of its kind, it may suffer from biases in taxonomic and geographic coverage. We assessed the geographical bias by searching for country-related monitoring entries in Zoological Records. We used the following search string: biodiversity AND monitoring AND species AND country. The taxonomic bias was assessed by searching the Zoological Records for animal species only and Google Scholar for references to monitoring. The search query we used was monitoring AND species group AND europ. AND biodiversity. We computed the bias as logit(observed) – logit(expected), where the observed values were the values from our database and the expected values the records from Zoological Records or Google Scholar that met our search criteria. Nevertheless, the 2 databases may suffer from the same type of biases as our survey—differential inclinations of monitoring schemes to publish their results. Therefore, the biases in our data would not differ much from usual publication biases.

Variables and Statistical Analysis

In total we collected data on 14 variables (Table 1), which characterized monitoring practices and resource needs of biodiversity monitoring in Europe. We examined differences of monitoring schemes among species groups that were sufficiently covered by our survey (birds, $n = 149$; amphibians and reptiles, $n = 53$; mammals, $n = 90$; plants, $n = 58$; butterflies $n = 37$; other insects, $n = 31$). The bird group comprised all bird-monitoring schemes, regardless of whether they targeted passerines, water birds, or any other subgroup. In addition, the mammal group comprised species as different as bats, rodents, and large carnivores. In plants we considered only monitoring schemes of vascular plants. The other-insects group included monitoring schemes of dragonflies, beetles, and

Table 1. Variables describing biodiversity-monitoring practices in our study.

Variable	*Abbreviation*	*Description*
Annual frequency	ann. freq.	between-year frequency of monitoring; 1, every year; 2, every second year, etc.
Work effort	person-days	person-days/monitoring scheme
Work effort per species divided by the number of species monitored	person-days$_{spec}$	person-days/monitoring scheme
No. of professionals	N_{prof}	no. professionals in a scheme
No. of samples	$N_{samples}$	no. samples collected/visit
No. of sites	N_{sites}	no. sites visited
No. of species	$N_{species}$	no. species monitored simultaneously in a scheme
No. of visits	N_{visits}	no. visits per year
No. of volunteers	$N_{volunteers}$	no. volunteers in a scheme
Persons	$N_{persons}$	sum of volunteer and professionals in one scheme
Proportion of volunteers	% vol	proportion of volunteers in a scheme
Total costs	costs	sum of costs of equipment and salaries of professionals, as given by the average salary per country in 2005 (World Bank 2006)
Total costs per species	costs$_{spec}$	sum of costs of equipment and salaries of professionals, as given by the average salary per country in 2005 (World Bank 2006) divided by no. of species monitored in one scheme
Year	year	start year of monitoring scheme

grasshoppers, but not butterflies. Country-specific differences were examined for France ($n = 91$), Germany ($n = 37$), Hungary ($n = 30$), Lithuania ($n = 32$), and Poland ($n = 101$).

We used principal component analyses with 14 variables to describe differences in monitoring practices in different species groups and countries. For determination of the most discriminating variables among species groups and countries, we used a fully saturated discriminate analysis with stepwise exclusion of statistically insignificant variables. We checked visually that all pairwise relationships between the variables were linear (Supporting Information). For correlations, we used the nonparametric Spearman rank correlation to obtain most robust results. The statistical analyses were done with the R statistical package (R Development Core Team 2008) and the package ADE4 (Dray & Dufour 2007).

Results

The EuMon survey compiled descriptive data for 395 species-monitoring schemes led by 227 organizations in 28 European countries (data extracted September 2007). The total annual cost of these monitoring schemes was approximately €4 million, and they engaged more than 46,000 people, who devoted over 148,000 person-days per year to monitoring activities. Only 13.3% of the participants in the monitoring programs were professionals.

Biases

Despite a large sample we found some biases in our survey. Schemes from Hungary, Lithuania, Poland, and Slovenia were overrepresented, whereas schemes from Greece, the United Kingdom, Italy, and Spain were underrepresented (Supporting Information). The taxonomic bias following from Google Scholar and from Zoological Record entries was consistent in a few taxonomic groups only (Supporting Information). Whereas amphibian and reptile monitoring schemes were overrepresented in the EuMon database, schemes monitoring fungi were the most underrepresented followed, respectively, by lichens and fishes. Schemes monitoring vascular plants were slightly overrepresented according to Google Scholar. For the remaining analyzed taxonomic groups, their relative representation in the EuMon database, the Zoological Records, and Google Scholar were similar (Supporting Information).

Monitoring in Different Species Groups

The different variables not only showed some differences between the different species groups analyzed but also had some common features (Fig. 1). For plant monitoring only, the starting year was negatively related to the number of species and sites and the proportion of volunteers, whereas starting year hardly contributed to the principal components in the other species groups. For all species groups, number of sites was positively related to variables describing the work effort per scheme, with varying degrees in the different species groups. Other variables of sampling effort were related to work-effort variables, especially to the proportion of volunteers (Fig. 1). For monitoring of all species groups, except butterflies, the proportion of volunteers was positively associated with the number of sites and species. In butterfly monitoring, the proportion of volunteers was positively associated with the number of sites and visits. The proportion of volunteers correlated well with the number of sites in schemes monitoring herpetofauna ($R_{48} = 0.39$; $p = 0.006$), birds ($R_{142} = 0.28$; $p < 0.001$), butterflies ($R_{36} = 0.38$; $p = 0.024$), and mammals ($R_{85} = 0.23$; $p = 0.031$).

The variable costs contributed strongly to the principal components in all species groups, but related differently to the other variables (Fig. 1). For birds, costs were negatively associated with proportion of volunteers. For herpetofauna, monitoring costs were positively associated with number of species and the between-year frequency of sampling, and negatively related to the proportion of volunteers. For schemes monitoring mammals and the group other insects, costs were positively related to number of sites and species. For butterflies the annual frequency and number of species were positively associated with the total costs. For plants costs were positively associated with the per species variables, person-days and costs per species.

The main differences in monitoring practices in the different species groups resulted from differences in 3 variables, the starting year of a scheme, the number of sites monitored, and the proportion of volunteers per scheme (Fig. 2a). Across different species groups, the variables overlapped largely (Table 2). Nevertheless, costs by species were the highest for mammal, amphibian, and reptile species, whereas the overall costs of a monitoring scheme were highest for butterfly monitoring. Obviously, bird-monitoring schemes were among the longest running schemes, but usually only 23 sites were monitored, whereas most butterfly-monitoring schemes surveyed more than 50 sites (Table 2).

Monitoring in Different Countries

The principal component analysis revealed some differences in monitoring practices in France, Germany, Hungary, Poland, and Lithuania (Fig. 3). In France variables of the sampling effort, except of number of sites, contributed weakly to any principal component. In German monitoring schemes, proportion of volunteers was positively associated with several variables of sampling effort

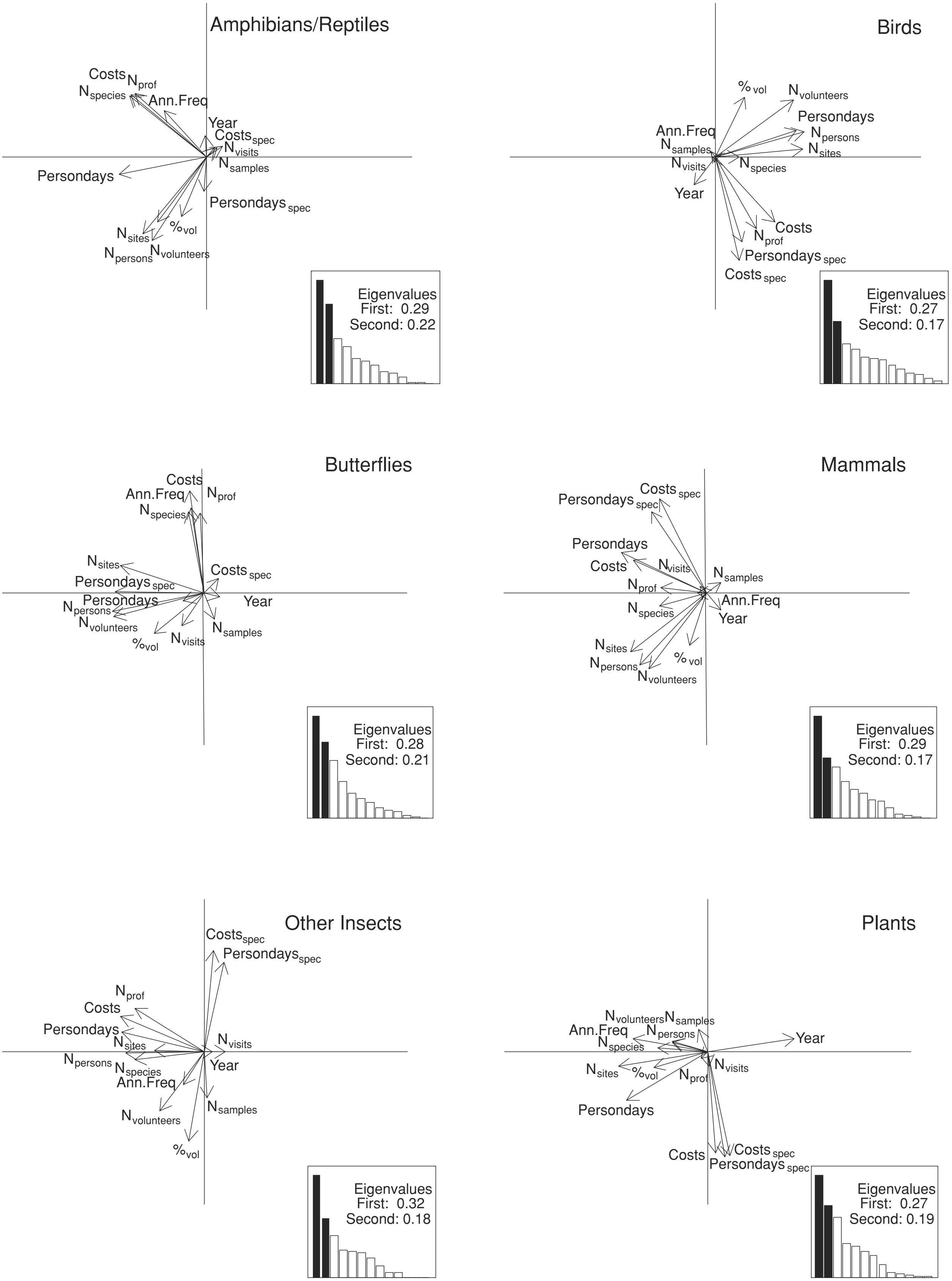

Figure 1. Results of the principal component analysis of monitoring practices in different species groups. Abbreviations are defined in Table 1 (x-axis = axis 1; y-axis = axis 2).

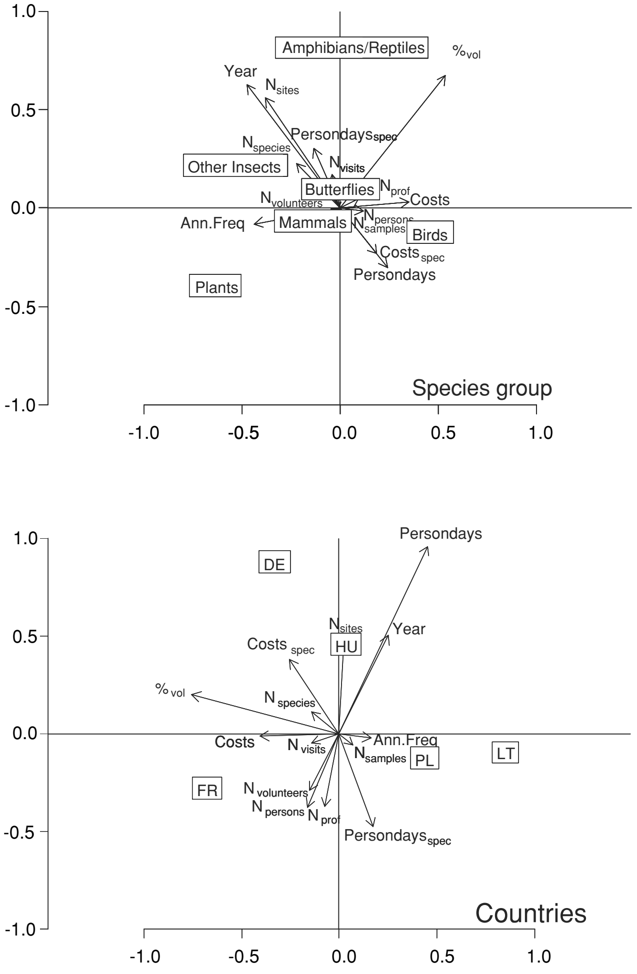

Figure 2. Canonical analysis results of the discriminant analysis, indicating the contributions of the different variables to monitoring schemes in the (a) different species groups and for (b) different countries. The labels of the species groups and countries are located at the group's mean. Abbreviations are defined in Table 1 (x-axis is axis 1; y-axis is axis 2).

(number of sites, number of samples, and number of species). In Hungary, Germany, and Lithuania, the variable year was negatively associated with proportion of volunteers in a scheme.

Generally, costs increased with increasing work force of a scheme, regardless of the country. In Hungary, costs increased with increasing sampling effort and proportion of volunteers. In Germany and Lithuania costs increased with number of sites and person-days, whereas in France costs were positively related to number of professionals in a scheme. Across all schemes number of sites ($R_{376} = 0.48$; $p < 0.001$), number of visits ($R_{376} = 0.15$; $p = 0.004$), and number of samples ($R_{366} = 0.28$; $p < 0.001$) were all significantly related to the sampling effort of a monitoring scheme (number of people).

The variables person-days, proportion of volunteers, starting year, and number of sites explained most of the differences in monitoring practices in the different countries (Fig. 2b). Although in France monitoring was started in 1993 for 50% of the schemes, the majority of monitoring schemes in Lithuania started after 2005 (Table 2). Furthermore, most of the schemes in Poland and Lithuania were expert schemes, with no involvement of volunteers. Germany had the highest number of person-days of all 5 countries. Poland had the lowest number of sites per scheme (Table 2).

Three variables—total costs, number of samples, and proportion of volunteers—contributed most to discrimination of monitoring practices in the different countries (Fig. 2b). In addition, number of professional schemes differed geographically. In Poland 63.7% ($n = 101$) of monitoring schemes were run by professionals only, whereas this proportion was 33.3% ($n = 30$) in Hungary, 28.3% ($n = 93$) in France, and 23.7% ($n = 38$) in Germany.

Discussion

Our results show various differences among monitoring practices in different species groups and different countries. Generally, our results support an increased sampling effort with increasing involvement of volunteers in biodiversity monitoring. Hence, our results do not support the common belief that volunteer-based schemes yield noisy, imprecise results.

Geographic Bias

Despite large efforts in seeking addresses and sending out requests to fill out our on-line questionnaire, the response rate was low and varied greatly among countries, which led to a geographic bias in our survey. That led to underrepresentation of Nordic countries in particular. Our survey, therefore, may be representative of only 15% of the landmass of Europe (9,938,000 km^2). Combined, France, Germany, Hungary, Poland, and Lithuania are 1,502,773 km^2. These countries contain 6 of the 11 European biogeographic regions (55%). The Mediterranean, however, was underrepresented, and a large proportion of these 5 countries lie within the Atlantic and Continental biogeographic region only. Despite these biases, our survey covered wide geographic area, with at least one scheme from each country in Europe, and it sufficiently covered postcommunistic (Poland, Hungary, Lithuania) and western EU countries (Germany, France) and thus different monitoring histories (H. Kobierska et al., unpublished data).

Taxonomic Bias

We focused on species groups for which we could obtain a significant number of descriptions of monitoring

Table 2. Median and quartiles* (in parentheses) of variables of monitoring practices by species group and country examined in our study.

Variable	*Amphibians and reptiles*	*Birds*	*Butterflies*	*Other insects*	*Plants*	*Mammals*
Year	2000 (1993–2002)	1992 (1984–2001)	1999 (1992–2003)	2001 (1995–2003)	2000 (1995–2003)	2000 (1990–2003)
$N_{species}$	7 (1–21)	12 (1–70)	45.5 (2–148)	75.5 (32–400)	6 (1–71)	3 (1–12)
$N_{volunteers}$	10 (0–100)	11 (0–80)	1.5 (0–91)	2.5 (0–15)	0 (0–2)	1 (0–10)
N_{prof}	2 (1–5)	4 (2–10)	3 (2–9)	5 (2–9)	3 (2–4)	3 (1–10)
$N_{persons}$	16 (3–103)	23 (6–104)	15.5 (3–150)	9.5 (3–40)	3.5 (2–23)	10 (3–21)
% vol	80.1 (50–98)	71.4 (0–95)	50 (0–93.5)	50 (0–71.8)	0 (0–36.7)	33.3 (0–76.9)
N_{visits}	3 (1–5)	2 (1–5)	3 (1–20)	2 (1–6)	1 (1–2)	1 (1–2)
Ann. freq.	1 (1)	1 (1)	1 (1)	1 (1–2)	1 (1–2)	1 (1)
N_{sites}	10 (2–120)	23 (3–200)	50 (5–500)	38 (7–100)	10.5 (3–150)	10 (2–55)
$N_{samples}$	1 (1–5)	1 (1–3)	1 (1–5)	1 (1–10)	1 (1–2)	1 (1–4)
Person-days	109 (16–456.6)	150 (31–640)	122.3 (45–550)	100 (35–251)	45 (8–100)	55 (15–150)
Costs	2056.6 (401.3–10401)	2572.2 (811.2–14181.1)	4665.8 (926.6–8162.2)	2791.8 (989.3–6550.8)	1886.9 (433.7–7620.4)	1215.9 (364.3–7886)
Person-days$_{spec}$	14.6 (3.1–94.3)	17.4 (2.7–72)	10.7 (2.3–45)	1.3 (0.4–3.5)	3.1 (0.7–11.1)	12 (4.5–38)
Costs$_{spec}$	374.2 (39–1757.4)	331.9 (42.7–2027.2)	223.0 (39.2–867.6)	25.5 (9.8–108.7)	107.1 (21.6–449.8)	374.7 (72.8–1517.3)

	France	*Germany*	*Poland*	*Lithuania*	*Hungary*
Year	1993 (1985–2002)	2000 (1993–2003)	2000 (1993–2003)	2005 (1994–2006)	2001 (1999–2003)
$N_{species}$	6.5 (1–35)	9 (1–70)	4 (1–20)	5 (1–15)	5 (1–35)
$N_{volunteers}$	5 (0–32)	10 (0–30)	0 (0–3)	0 (0)	10 (0–15)
N_{prof}	2 (1–5)	2 (1–3)	3 (1–8)	3.5 (1–6)	8.5 (4–12)
$N_{persons}$	12 (3–66)	12 (3–31)	5 (2–20)	4.5 (1.5–6)	20 (10–60)
% vol	66.7 (0–93.7)	83.3 (0–96.5)	0 (0–50)	0 (0)	56.3 (0–75)
N_{visits}	3 (1–10)	1 (1–5)	1 (1–2)	1.5 (1–3)	3 (2–6)
Ann. freq.	1 (1)	1 (1)	1 (1)	1.5 (1–3)	1 (1)
N_{sites}	22 (3–100)	19 (4–235)	5 (1–50)	15.5 (4–27)	18.5 (8–96)
$N_{samples}$	1 (1–5)	1 (1)	1 (1)	1 (1–12)	3.5 (1–15)
Person-days	68 (19–287)	214 (60–412)	40 (14.7–150)	16 (10–80)	165 (108–313)
Costs	2200.8 (735–9402)	9494 (1912–20420)	769.4 (246–2889)	381.8 (193–2028)	6178.7 (2000–14618)
Person-days$_{spec}$	13 (1.3–89)	46.3 (5–100)	7.5 (2–24)	7 (2–20)	25 (3.5–115)
Costs$_{spec}$	373.6 (46.7–2012)	412.1 (56.9–9524)	139.6 (31–447)	135.2 (43–510)	815.3 (180–2873)

**When the upper and lower quartile were the same, only one number is indicated. Variable abbreviations are defined in Table 1.*

programs. Hence, the practices we could examine that were included in the EuMon database may not be representative of monitoring in other species groups, given that we discovered significant differences among taxonomic groups in several characteristics of monitoring schemes. Monitoring of fishes, lichens, and fungi was strongly underrepresented, whereas, for example, birds and mammals showed small biases (relative to the number of publications listed in the Zoological Record). Extrapolation of our conclusions to underrepresented groups may not be warranted. Generally, however, the databases on publication records may also be biased because in different countries different traditions of publishing exist (e.g., Gogolin et al. 2003). Overall, the EuMon database seemed biased toward more well-liked species groups—or a large percentage of them are not represented by publications accessible through Google Scholar, as suggested by our database search. The bias within each species group analyzed here might be considered low and the representativeness of our results for these species groups high.

Monitoring Costs, Volunteer Involvement, and Sampling Effort

The 395 documented monitoring schemes in the EuMon database represent a total cost of about €4 million/year. The 148,690 person-days spent per year to monitor Europe's biodiversity adds up to roughly €13 million (average salary by country in 2005; The World Bank 2006). Thus, if no volunteers were involved, the costs would be increased 3-fold. Generally, costs in France and Germany were much higher compared with Poland and Lithuania because of considerably higher salary-related costs of professionals and higher equipment costs in Western compared with Eastern Europe. Hungary, despite a

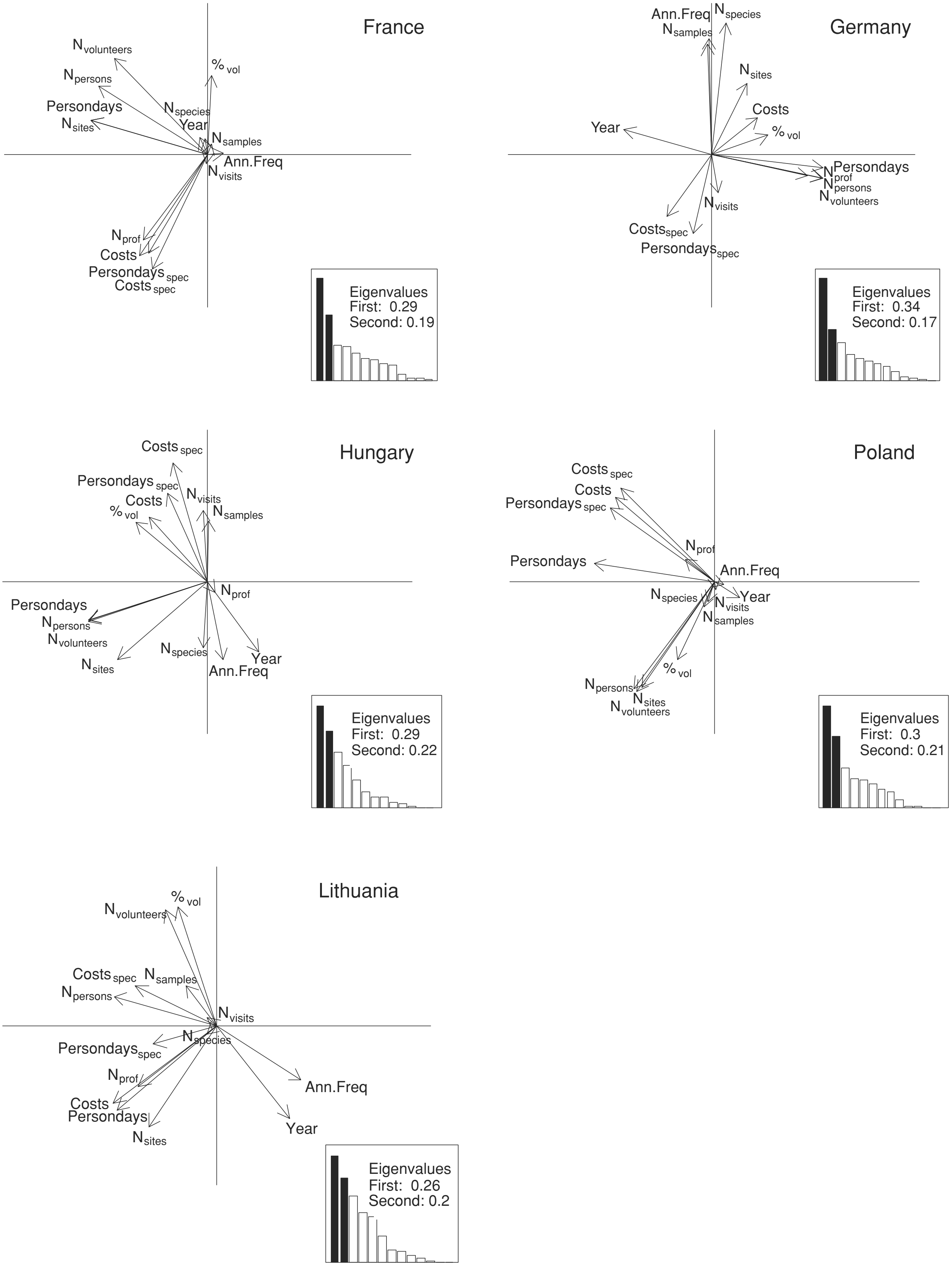

Figure 3. Results of the principal component analysis of species monitoring practices in different countries. Abbreviations are defined in Table 1 (x-axis is axis 1; y-axis is axis 2).

large proportion of volunteers, also had a large number of professionals per scheme, which explains the considerably higher costs in comparison with the other eastern European countries Poland and Lithuania. One reason could be the high biodiversity in the Pannonian region, which would explain the large average number of species monitored (the highest for the 5 countries assessed). Hence, sampling effort per monitoring scheme in Hungary seemed to be especially high, whereas the variable person-days per species was comparable to France and Germany. The case of Hungary may also give a good indication of costs and resource needs in other biodiversity-rich regions, such as the Mediterranean biogeographic region, which is so far insufficiently covered in the EuMon database.

Volunteer recruitment and the value of volunteers also had a geographic component. For example, in Lithuania and Poland, a majority of monitoring schemes were professional, whereas this proportion was much smaller in Hungary, France, and Germany. Our findings suggest that it may be more difficult to attract volunteers, that volunteers are not sought to participate in biodiversity monitoring, or that the lack of volunteer participation may be linked to unclear political and economic conditions in some countries (H. Kobierska et al., unpublished data). Furthermore, our findings may also suggest that in countries with high salary costs (i.e., France and Germany in our survey) biodiversity-monitoring obligations can only be implemented if volunteer involvement is maintained or increased for some taxonomic groups through targeted recruitment campaigns or if funds are provided for the coordination of volunteer-based monitoring programs. Nongovernmental organizations with successful volunteer involvement could serve as partners for such campaigns. For EU countries, the higher costs of biodiversity monitoring are related to a high number of endemic species, as indicated in our analysis for Hungary, and this should be accounted for in the development of instruments for fiscal transfers, as they exist, for example, in Brazil (Young 2005; Ring 2008).

Data Quality

By definition the standard error of a species' status estimate is negatively related to the total number of sampling units monitored per year (i.e., sites, species) and hence the overall sampling effort (e.g., Hochachka et al. 2000). We found a strong positive relationship between number of observers and number of sites monitored (an index for the sampling effort), number of visits per site (an index for measurement precision), and number of species monitored (a measure of the biological coverage). Hence, number of people (to a large, but varying degree volunteers) involved in a monitoring scheme directly affected sampling effort of a scheme. Large volunteer sampling efforts should counterbalance hypothesized higher measurement errors in data collected by volunteers (Hochachka et al. 2000). Therefore, all else being equal, a higher sampling effort should yield a more precise estimate of a species' status and improve the chances of detecting a statistically verifiable status change (e.g., a change in species abundance). Hence, we believe that with state-of-the-art survey designs or analysis methods, volunteer-based schemes can provide relatively reliable data and thus yield unbiased results. Quality of volunteering data is more likely determined by survey design, analytical methodology, and communication skills within the schemes rather than by volunteer involvement per se.

Conclusion

Our results show that volunteer involvement is a good trade-off solution and extremely important and valuable for biodiversity monitoring because data from participatory monitoring networks are not less informative, and may be more informative, than those collected in professional schemes. For effective biodiversity monitoring, however, it is imperative to guarantee intra- as well as inter nation comparability, data coherence, and harmonization across large geographic regions, such as Europe (e.g., Henry et al. 2008; Lengyel et al. 2008). Hence, researchers should analyze the extent of inaccuracy of data provided by volunteers compared with professionals and should develop methods and protocols that help detect and account for inaccuracies.

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Supporting Information

The on line questionnaire of the EuMon survey of biodiversity monitoring (Appendix S1), pairwise relationships between all variables describing monitoring practices (Appendix S2), and relative geographic and taxonomic bias of species monitoring schemes (Appendix S3) are available as part of the on line article. The author is responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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