EBONE

European Biodiversity Observation Network:

Design of a plan for an integrated biodiversity observing system

in space and time

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Exploring the sampling efficiency of national, EU and global stratifications using CLC2000

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EXECUTIVE SUMMARY

Stratification, dividing the statistical population into less heterogeneous subgroups before sampling, can help improve sampling efficiency by improving representativeness and reducing sampling error. A European Stratification has been developed to support the design of the European Biodiversity Observation Network (EBONE). This report explores the added sampling efficiency that is achieved by using the European stratification for estimating the area covered by the 25 Corine Land Cover (CLC) categories occurring in the semi-natural and managed terrestrial habitats of the wider-countryside. Although the dataset is not ideally suited to assess stratification efficiency for EBONE, because the CLC land cover categories are considerably coarser than the habitats that are surveyed under the EBONE field protocol, both spatially and thematically, the results give some encouragement. The analysis indicates that the pan-European stratification improves sampling efficiency for several land cover categories and performs similar to four more detailed national stratifications, supporting their use as a basis for designing a pan-European biodiversity observation network.

1. INTRODUCTION

There is growing urgency for integration and coordination of global environmental and biodiversity data required to respond to the ‘grand challenges’ our planet is facing, including biodiversity decline (Mooney *et al.*, 2009). On-going and new programmes are gathering valuable data through a profusion of projects at regional, national and international scales, but great challenges remain for consistent monitoring of global biodiversity change and data aggregation across scales (Mooney *et al.*, 2009; Scholes *et al.*, 2008; Margules & Pressey, 2000). Progress in these fields is essential to improve future assessments and policy targets relating to the stock and change of global ecosystem resources and biodiversity (Scholes *et al.*, 2008), including the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES; Larigauderie & Mooney, 2010)), and the United Nations Convention on Biodiversity (CBD) Aichi targets (Nayar, 2010).

Consistent classification, or stratifications[1], of land into relatively homogenous strata provides a valuable spatial framework for comparison and analysis of ecological and environmental data across large heterogeneous areas. The basic idea behind statistical environmental stratification is that the relation between biodiversity and the environment can be expressed by a multiple regression model (Jongman *et al.*, 2006), i.e. the probability of occurrence of species can partly be explained by the environment. Multivariate clustering of climate data has proved successful in creating stratifications in many parts of the world (Bunce, et al., 1996ab; Leathwick et al., 2003; Tappan et al., 2004; Metzger et al., 2005) using transparent, reproducible methods that are, as far as possible, independent of personal bias. Such stratifications have been used for stratified random sampling of ecological resources, the selection of representative study sites, and summary reporting of trends and impacts bias (Jongman *et al.*, 2006).

Random sampling, also referred to as probability sampling, enables model-free, unbiased and valid estimation of target parameters and their standard error (Gruijter & ter Braak, 1990; Brus & Gruijter, 1997). Stratification, dividing the population into homogenous subgroups before sampling, can help improve sampling efficiency by improving representativeness and reducing sampling error. Stratified random sampling was first used in broad scale landscape ecological monitoring in Great Britain (GB), where it gained prominence in the Countryside Survey (Sheail & Bunce, 2003). Since the 1970s a succession of national surveys has provided robust figures for ecological change in the wider countryside in GB (Firbank *et al.*, 2003), and has inspired similar projects in other European countries (e.g. in Spain (Elena-Rossello, 2005) and Sweden (Ståhl *et al.*, 2011)). More recently, substantial preparatory effort has been placed into developing such a monitoring programme for the European

[1] When classes are not meant as descriptive units, but specifically designed to divide gradients into relatively homogeneous subpopulations we prefer to use the statistical term *stratification*.

domain (Bunce *et al.*, 2008; Brus *et al.*, 2011), where robust figures are required to evaluate EU and CBD biodiversity targets and the success of the Natura2000 network.

One of the objectives for developing the European Environmental Stratification (EnS) was to provide a basis for stratified random sampling of ecological resources in Europe (Metzger *et al.*, 2005; Jongman *et al.*, 2006; Bunce *et al.*, 2008). In this deliverable report we explore the efficiency of the EnS as a basis for stratified simple random sampling compared to simple random sampling without stratification. Furthermore, the efficiency of the EnS is compared to several national stratifications, and a newly developed global stratification. The gain in sampling efficiency is tested using the Corine Land Cover map 2000 (CLC; Bossard *et al.*, 2000), a pan-European dataset describing 44 land cover categories at a 100m spatial resolution.

2. DESCRIPTION OF THE DATA

2.1 The European Environmental Stratification (EnS)

The EnS was created using tried-and-tested statistical clustering procedures on primary physical environment variables, and covers a 'Greater European window' (11°W–32°E, 34°N–72°N), extending into northern Africa. This wider extent was needed to permit statistical clustering that could distinguish environments whose main distribution is outside the European continent. Data were analysed at 1 km^2 resolution. Twenty of the most relevant available environmental variables were selected, based on those identified by statistical screening (Bunce, Watkins, Brignall, *et al.*, 1996). These were (1) climate variables from the Climatic Research Unit (CRU) TS1.2 dataset (Mitchell *et al.*, 2004), (2) elevation data from the United States Geological Survey HYDRO1k digital terrain model, and (3) indicators for oceanicity and northing. Principal Components Analysis (PCA) was used to compress 88% of the variation of these twenty environmental characteristics into three dimensions, which were subsequently clustered using an ISODATA clustering routine. The classification procedure is described in detail by Metzger *et al.* (2005).

The EnS comprises 84 strata, aggregated into 13 Environmental Zones (EnZ; Fig. 1). The latter were constructed using arbitrary divisions of the mean first principal component score of the strata, with the exception of Mediterranean mountains, which were separated on altitude. Within each EnZ, the EnS strata have been given systematic names based on a three-letter abbreviation of the EnZ to which the stratum belongs and an ordered number based on the mean first principal component score of the PCA. For example, the EnS stratum with the highest mean principal component score within the Mediterranean South EnZ is named MDS1 (Mediterranean South one).

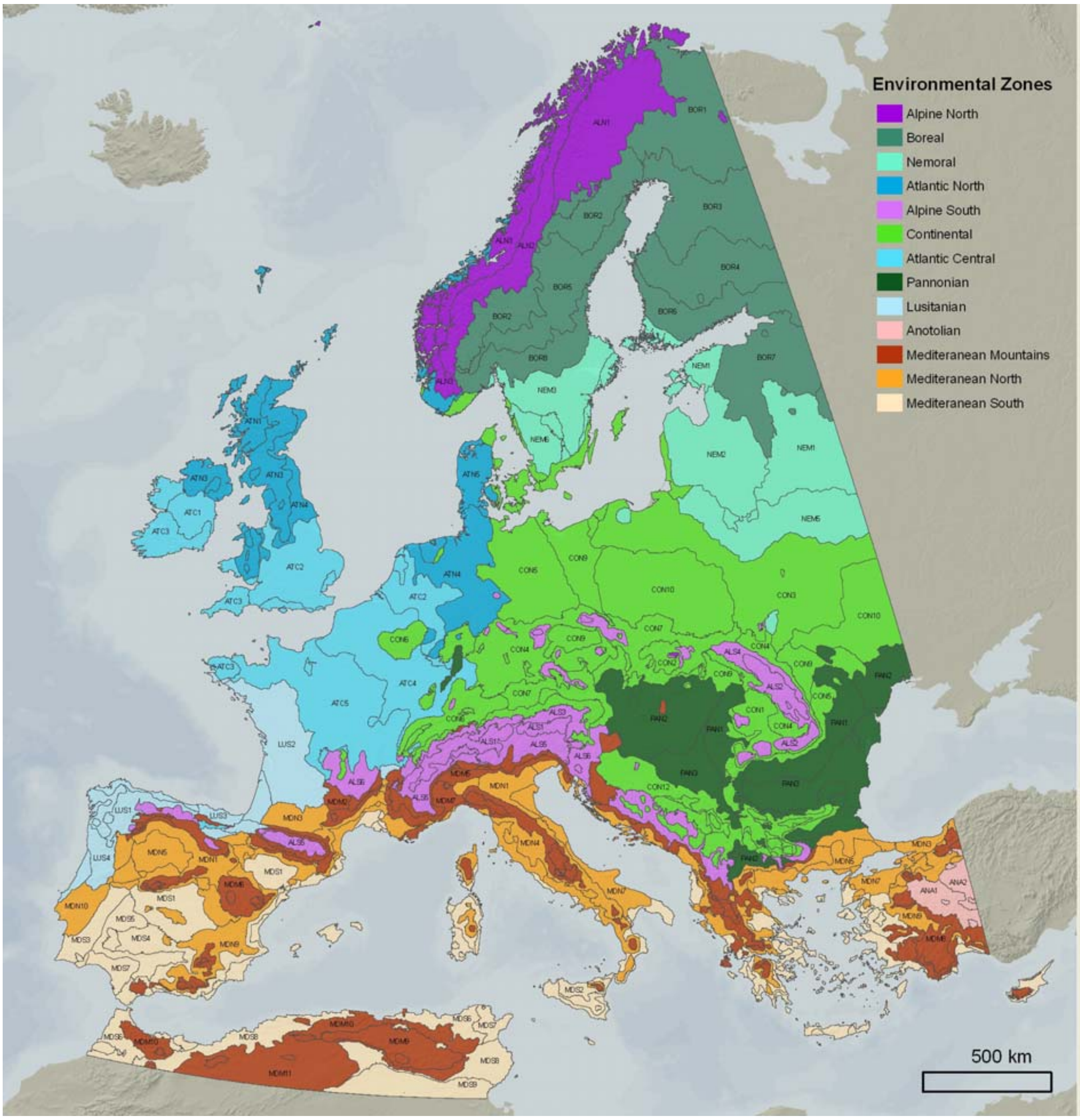

Figure 1. The Environmental Stratification of Europe (EnS) after Metzger *et al.* (2005).

2.2 The Global Environmental Stratification (GEnS)

The construction of the global environmental stratification (GEnS) followed the approach used to construct the EnS. A broad set of climate-related variables, derived from the global WorldClim database (Hijmans *et al.*, 2005), were considered for inclusion into a quantitative model, which partitions geographic space into bioclimate regions. Statistical screening produced a subset of four bioclimate variables: growing season, reflecting latitudinal and altitudinal temperature gradients; an aridity index, which forms an expression of plant available moisture; and seasonality in temperature and potential evapotranspiration, which express both seasonality and continentality. These variables were further compacted into independent dimensions using PCA. An ISODATA clustering routine was then used to classify the first three principal components into relatively homogenous environmental strata. The classification procedure is described in detail in EBONE deliverable D3.1, and by Metzger *et al.* (2012).

The GEnS distinguishes 125 strata, which were aggregated into 18 global environmental zones based on the attribute distances between strata to provide structure and support a consistent nomenclature. Aggregations of the strata were compared to nine existing global, continental and national bioclimate and ecosystem classifications using the Kappa statistic. Values range between 0.54 and 0.72, indicating good agreement in bioclimate and ecosystem patterns between existing maps and the GEnS.

2.3 National Stratifications

2.3.1 The Countryside Survey (CS) Land Classification of Great Britain

The Countryside Survey (CS) is a monitoring project that has recorded stock and change of habitats and vegetation by means of a stratified random series of 1x1 km squares in five surveys since 1978. The land classification (Bunce et al., 1996ab) was initially developed using multivariate TWINSPAN analysis (Hill, 1979) of environmental variables. Climatic, topographic, geological and anthropogenic data were recorded from 1200 out of the 240,000 1x1 km squares of the National Grid of Great Britain (GB) laid out at the intersections of a 15km square grid. Logistic regression and discriminant functions were subsequently used to assign all the remaining squares to the original classes, but also to reassign the squares from the initial grid sample. Field surveys of ecological parameters have been used to provide independent data for testing the classification, to characterise the classes and to provide national estimates of habitats and vegetation (Firbank *et al.*, 2003). Since CS2000, the policy requirement was for Scotland to be kept separate from the rest of the UK. This led to 40 classes being derived from the initial 32 classes according to their presence in the two regions.

2.3.2 The National Inventory of Landscapes in Sweden (NILS) stratification

The NILS program analyses environmental conditions and ecological processes at the landscape scale (Ståhl *et al.*, 2011), providing national statistics of land cover, land use, and landscape structure. NILS was launched in the summer of 2003, and by the end of 2007 inventories for all plots in the five-year sample were completed. The environmental stratification was based on a 5km grid that was divided into ten strata based on natural and sociological/cultural factors. In southern and middle Sweden the distribution is based on agricultural yield areas, defined by the Swedish Board of Agriculture. In northern Sweden, the alpine areas and the alpine forests are assigned to a special stratum according to a nature conservation boundary defined by the Swedish Society for Nature Conservation and agricultural land is separated by assigning a specific stratum based to coastal areas.

2.3.3 The Spatial Indices for Land Use Sustainability (SINUS) stratification

SINUS is a project designed to develop reliable, operational, and spatially explicit indicators of practical use in long-term monitoring and assessment of ecological sustainability of Austrian cultural landscapes (Peterseil, 2004). In 1997, land use and hemerobiotic character were recorded in 182 1x1 km squares with a stratified sampling using a design based on Austrian Landscape Classification (Wrbka, 1999). The SINUS classification provides a framework for the description of the natural preconditions of agricultural land use in Austria. The classification was based on geo-morphological features, historical land-use patterns and preliminary coarse landscape types. The methodology used was intersection of three thematic maps (altitudinal zones, geological land units and land use type) and classification with an isoclustering algorithm. About 16,000 individual landscapes were delineated for the whole Austrian territory and then classified into 12 first-order landscape-type series and 42 second-order landscape-type groups.

2.3.4 The Spanish Rural Landscape Monitoring System (SISPARES) Land Classification

SISPARES is an on-going project designed to assess the ecological value and dynamics of rural landscapes in Spain, based on aerial photographic interpretation of stratified random samples. Historic imagery for 1956, 1984 have been compared with more recent data from 1998 and 2007 (Peterseil, 2004). The sampling design was based on a biogeoclimatic land classification of Spain called CLATERES (Wrbka, 1999) constructed using a divisive multivariate classification approach adapted from the CS land classification (Elena-Rossello, 2005), and applied to climatic, physiographic and geological data. The construction was structured into two phases. First, the whole Spanish Peninsula and Balearic Islands were classified into 13 classes at 5x5km resolution and then into 215 land classes with a greater resolution of 2x2km. Soil type, vegetation class, and land-use data were used for testing the ecological value of the classes.

2.4 CORINE Land Cover (CLC)

There is a growing need for spatial analysis in integrated environmental assessment to support EU policy-making. CORINE Land Cover (CLC) aims to provide comparable and consistent land cover data across Europe. CLC is a digital map of the European land cover, based on the interpretation of satellite images, providing data for each country in EU27, and several other countries. The construction of CLC is coordinated by the European Environment Agency (EEA), but implemented by member countries following a common protocol.

Land cover information is derived from high-resolution satellite data by computer assisted visual interpretation, in combination with ancillary information. The final CORINE land cover database describes vegetation and land cover in 44 classes, grouped into a three level nomenclature (Table 1) in order to cover the entire land cover spectrum of Europe (Bossard *et al.*, 2000). The minimum mapping element (MME) is 25 hectares, and for line elements the minimum width is 100 meters. The vector database has a spatial scale of 1 : 100.000, and has been gridded to a 100m raster. CLC was first constructed in 1990, with subsequent releases for 2000, and 2008. The present analysis was carried out using the 2000 version. Full details of its construction can be found in the Corine land cover technical guide (Bossard *et al.*, 2000).

Although widely used, there are major limitations to CLC for ecological studies (Gimona *et al.*, 2008). The 25ha MME is coarse for many habitats of interest (Rickebusch *et al.*, 2010) and 625 times larger than the 400 m^2 MME suggested by Bunce *et al.* (2008) and in the EBONE field protocol (EBONE Deliverable D4.3). Equally important is the limited thematic detail. Only roughly half of the 44 categories (Table 1) are related to (semi-natural) terrestrial habitats, and these categories are by necessity broadly defined. For example: *Pastures* (2.3.1) includes both intensive *Lolium perenne* monocultures in The Netherlands and the extensively managed Machair on the Western Isles of Scotland; *Moors and heathland* (3.2.2) includes both Atlantic heaths and Mediterranean *Pinus mugo* forest; and Scandinavian and Mediterranean coniferous forests are in the same category despite major differences in species composition and vegetation structure. Finally, there are also issues with the interpretation of some classes between national CLC teams. For example, clear national distinctions can be seen in the interpretation of *Sclerophylous vegetation* (3.2.3) between Spain and Portugal, and in *Moors and heathland* (3.2.2) between the UK and Ireland. Given these limitations, considerable care must be taken in the interpretation of the results of this study.

Table 1. Nomenclature of the CORINE land cover database.

Level 1	level 2	Level 3
1. Artificial surfaces	1.1 Urban fabric	1.1.1 continuous urban fabric
		1.1.2 discontinuous urban fabric
	1.2 Industrial, commercial and Transport units	1.2.1 industrial and commercial units
		1.2.2 road and rail networks and associated land
		1.2.3 port areas
		1.2.4 airports
	1.3 Mine, dump and Construction sites	1.3.1 mineral extraction sites
		1.3.2 dump sites
		1.3.3 construction sites
	1.4 Artificial non-agricultural Vegetated areas	1.4.1 green urban areas
		1.4.2 port and leisure facilities
2. Agricultural areas	2.1 Arable land	2.1.1 non-irrigated arable land
		2.1.2 permanently irrigated land
		2.1.3 rice fields
	2.2 Permanent crops	2.2.1 vineyards
		2.2.2 fruit trees and berry plantation
		2.2.3 olive groves
	2.3 Pastures	2.3.1 pastures
	2.4 Heterogeneous agricultural areas Agricultural areas	2.4.1 annual cops associated with permanent crops
		2.4.2 complex cultivation patterns
		2.4.3 land principally occupied by agriculture with significant natural vegetation
		2.4.4 agro-forestry areas
3. Forests and semi-natural Areas	3.1 Forest	3.1.1 broad-leaved forest
		3.1.2 coniferous forest
		3.1.3 mixed forest
	3.2 shrub and/or herbaceous vegetation associations	3.2.1 natural grasslands
		3.2.2 moors and heath lands
		3.2.3 sclerophyllous vegetation
		3.2.4 transitional woodland-scrub
	3.3 open spaces with little or no Vegetation	3.3.1 beaches, sand, dunes
		3.3.2 bare rocks
		3.3.3 sparsely vegetated areas
		3.3.4 burnt areas
		3.3.5 glaciers and perpetual snow
4. Wetlands	4.1 inland wetlands	4.1.1 inland marshes
		4.1.2 peat bogs
	4.2 coastal wetlands	4.2.1 salt marshes
		4.2.2 salines
		4.2.3 intertidal flats
5. Water bodies	5.1 inland waters	5.1.1 water courses
		5.1.2 water bodies
	5.2 marine waters	5.2.1 coastal lagoons
		5.2.2 estuaries
		5.2.3 sea and ocean

3. METHOD OF ANALYSIS

The CLC land cover categories (Table 1) were used in this experiment as the population for which the efficiency of the stratifications will be tested. Artificial surfaces, Coastal Wetlands and Water bodies were excluded from the analysis, because they do not form target areas within EBONE. The remaining 25 categories comprise the semi-natural and managed terrestrial habitats of the wider-countryside, which can be related to the General Habitat Categories the areas and composition of which form the target parameters in the EBONE field protocol (Bunce *et al.*, 2008; Deliverable 4.3). Note that we treat CLC as an errorless dataset, assuming that the spatial variance of the areas of the CLC categories as depicted on the map within the 1 km^2 samples is equal to the spatial variance of the true areas of the CLC units within the km-squares.

Because the full population is known, i.e. we treat CLC as reality, the gain in precision of estimates derived by using a stratification (compared to simple random sampling) can be calculated, as described below.

With stratified simple random sampling an unbiased estimator for the total area of a land cover type *u* is:

$$\hat{T}_u = \sum_{h=1}^{L} \hat{T}_{hu} = \sum_{h=1}^{L} \frac{N_h}{n_h} \sum_{i=1}^{n_h} t_{hui}, \quad (1)$$

with N_h the total number of sampling units (km-squares) in stratum *h*, n_h the selected number of sampling units in stratum *h*, and t_{hui} the area of land cover type *u in* the *i*th selected sampling unit (km square) in stratum *h*.

The sampling variance of this estimated total area equals

$$v_{STSI}(\hat{T}_u) = \sum_{h=1}^{L} v(\hat{T}_{hu}) = \sum_{h=1}^{L} N_h^2 \left(\frac{N_h - n_h}{N_h} \right) \frac{v_h(t_u)}{n_h}, \quad (2)$$

with $v_h(t_u)$ the spatial variance inside stratum *h* of the area of land cover *u* in km-squares. Note that this variance can be calculated without error from CLC as the area of land cover *u* within all km-squares is known (CLC is considered to be the reality). The quantity between brackets in Eq. (2) is the finite population correction (fpc), and was neglected as for all strata the total number of km-squares,

N_h , is very large so that the fpc is approximately equal to 1. Note further that in strata where land cover type *u* is absent, the areas t_{hui} are 0 for all km-squares in this stratum, so the variance for this stratum then will be 0. Finally, from the above it follows that when the number of selected km-squares per stratum is known, then the true sampling variance of the estimated total area can be computed without error. A sampling experiment is not needed.

The gain in precision is partly determined by the distribution of the observations (surveyed km-squares) over the strata. This is referred to as the allocation of the sampling units to the strata. A commonly applied allocation-type is proportional allocation: large strata receive more sampling units than small strata. In proportional allocation the number of km-squares equals

$$n_h = \frac{N_h}{N} \cdot n \tag{3}$$

For proportional allocation the sampling variance, Eq. 2, reduces to

$$v_{STSI,prop}(\hat{T}_u) = \frac{N}{n} \sum_{h=1}^{L} N_h v_h(t_u) \tag{4}$$

To quantify the gain in precision (reduction of the sampling variance of the estimated total area) we compare the sampling variance with that of simple random sampling (SI), i.e. no stratification, with equal number of selected sampling units $n = \sum_{h=1}^{L} n_h$. This sampling variance for simple random sampling equals

$$v_{SI}(\hat{T}_u) = N^2 \frac{v(t_u)}{n}, \tag{5}$$

with $v(t_u)$ the spatial variance inside the study area of the area of land use *u* in km- squares. It is usual to use the ratio of the sampling variance for SI to that for STSI $v_{SI}(\hat{T}_u)/v_{STSI}(\hat{T}_u)$ as a measure of the gain in precision due to stratification.

Dividing the sampling variance for SI (Eq. 5) by the variance for STSI with proportional allocation (Eq. 4) gives the very simple formula for the gain in precision:

$$\frac{v_{SI}(\hat{T}_u)}{v_{STSI,prop}(\hat{T}_u)} = \frac{v(t_u)}{\sum \frac{N_h}{N} v_h(t_u)} \tag{6}$$

All computations have been done in R, using a dBase file as input. The dBase files were combined in an Excel spread sheet and all cases where the stratification reduces sample variance by more than 10% are classified as cases where stratification clearly results in more precise estimates.

The foremost objective is to assess the sampling efficiency of the EnS. Although this can be expressed as a single number for each CLC category for the EU27, we also explored potential differences between countries and between the 12 EnZ, indicated in Figure 1. Furthermore, the sampling efficiency of the EnS is compared to the GEnS (for the EU27 countries and the EnZs), and with national stratifications for the UK, Sweden, Austria and Spain.

4. RESULTS

The tables on the following pages provide the outcomes of the calculations, comparing the stratification efficiency of the two pan-European and the four national stratifications. Stratification efficiencies greater than 1.10 (i.e. a greater than 10% gain in efficiency by using the stratification), have been highlighted in green. There are clear differences in the efficiency between land use categories and between countries (Table 2) and EnZs (Table 3). Nevertheless, Table 4 shows that the pan-European stratifications have a similar performance to the national stratifications. The results are discussed further in the following section.

Table 2. Stratification efficiency of the EnS (A) and the GEnS (B) or the EU27 and each country separately

A (EnS)

CLC category	CLC code	EU27	AT	BE	BG	CY	CZ	DE	DK	EE	ES	FI	FR	GR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK	UK
non-irrigated arable land	211	1.38	1.62	1.19	1.48	1.18	1.28	1.11	1.01	1.01	1.19	1.14	1.26	1.21	1.04	1.02	1.37	1.01	1.00	1.02	1.00	1.14	1.04	1.19	1.51	1.36	1.30	1.60	1.65
permanently irrigated land	212	1.09			1.00	1.01					1.05		1.00	1.11			1.00				1.00			1.01	1.00		1.00		
rice fields	213	1.02			1.00						1.02		1.11	1.01	1.00		1.04							1.02	1.00				1.00
vineyards	221	1.04	1.08		1.02	1.03	1.06	1.04			1.03		1.31	1.02	1.00		1.08		1.01		1.00			1.02	1.02		1.06	1.01	
fruit trees and berry plantation	222	1.03	1.00	1.01	1.00	1.00	1.01	1.01	1.00	1.00	1.04		1.03	1.01	1.01		1.04	1.00	1.00	1.00		1.00	1.00	1.01	1.03	1.00	1.00	1.00	1.00
olive groves	223	1.12				1.00					1.09		1.01	1.12			1.09							1.03					
annual cops associated with permanent crops	231	1.32	1.08	1.09	1.01	1.00	1.14	1.07	1.01	1.00	1.11	1.00	1.10	1.01	1.01	1.12	1.02	1.00	1.01	1.01	1.00	1.08	1.01	1.01	1.06	1.06	1.04	1.09	1.15
complex cultivation patterns	241	1.05	1.00			1.00					1.09			1.00			1.03	1.00	1.00					1.05			1.00		
land principally occupied by agriculture with significant natural vegetation	242	1.08	1.20	1.01	1.02	1.00	1.02	1.07	1.03	1.01	1.05	1.00	1.12	1.05	1.00	1.00	1.07	1.00	1.01	1.00	1.00	1.04	1.03	1.02	1.02	1.01	1.13	1.01	1.03
agro-forestry areas	243	1.04	1.02	1.01	1.02	1.00	1.03	1.00	1.01	1.01	1.03	1.08	1.02	1.03	1.00	1.04	1.05	1.00	1.00	1.04	1.00	1.01	1.02	1.06	1.04	1.06	1.01	1.03	1.01
pastures	244	1.10									1.09		1.00				1.06							1.13	1.00				
broadleaf forests	311	1.14	1.13	1.08	1.10	1.00	1.06	1.02	1.03	1.03	1.09	1.11	1.05	1.24	1.07	1.00	1.26	1.00	1.01	1.00		1.00	1.01	1.13	1.14	1.11	1.08	1.20	1.03
coniferous forest	312	1.44	1.18	1.10	1.55	1.37	1.19	1.09	1.02	1.00	1.09	1.05	1.20	1.14	1.00	1.01	1.34	1.00	1.05	1.00	1.00	1.01	1.03	1.11	1.56	1.26	1.19	1.42	1.05
mixed forest	313	1.21	1.12	1.25	1.18	1.00	1.02	1.04	1.01	1.00	1.11	1.03	1.07	1.04	1.01	1.00	1.08	1.01	1.00	1.01	1.00	1.00	1.02	1.08	1.27	1.01	1.06	1.11	1.00
natural grassland	321	1.11	1.23	1.00	1.06	1.01	1.01	1.02	1.01	1.00	1.04	1.00	1.25	1.03	1.00	1.01	1.08	1.00	1.00	1.00		1.00	1.02	1.05	1.06	1.05	1.01	1.09	1.12
moors and heath lands	322	1.35	1.08	1.00	1.10		1.04	1.04	1.01	1.03	1.26	1.17	1.07	1.04		1.04	1.02	1.01				1.01	1.29	1.08	1.04	1.38	1.08	1.23	1.36
sclerophyllous vegetation	323	1.19			1.00	1.00					1.06		1.22	1.07			1.19				1.00			1.12			1.01		
transitional woodland-scrub	324	1.15	1.00	1.01	1.07	1.01	1.09	1.01	1.01	1.01	1.02	1.12	1.06	1.08	1.00	1.00	1.03	1.00	1.00	1.00	1.00	1.00	1.04	1.07	1.04	1.14	1.11	1.04	1.01
beaches, sand, dunes	331	1.00		1.00	1.00	1.00		1.01	1.01	1.01	1.00	1.00	1.01	1.00	1.00	1.00	1.00	1.03		1.00		1.00	1.00	1.00	1.00	1.00	1.01	1.00	1.00
bare rocks	332	1.17	1.14		1.02	1.00	1.00	1.28			1.12	1.00	1.40	1.01		1.00	1.29						1.17	1.03	1.00	1.05	1.05	1.24	1.02
sparsely vegetated areas	333	1.10	1.20		1.03	1.00		1.04		1.00	1.18	1.04	1.25	1.03	1.00	1.00	1.13	1.00		1.00	1.00		1.00	1.03	1.00	1.08	1.05	1.19	1.07
burnt areas	334	1.00			1.00	1.00					1.00		1.01	1.00		1.00	1.00						1.00	1.02	1.00	1.00			
glaciers and perpetual snow	335	1.08	1.05					1.00			1.00		1.19				1.10									1.00	1.00		
inland marshes	411	1.02	1.01	1.00	1.00		1.01	1.01	1.00	1.00	1.02	1.00	1.00	1.03	1.00	1.00	1.00	1.00		1.01		1.00	1.00	1.00	1.06	1.00	1.00	1.01	1.00
peat bogs	412	1.17	1.00	1.01	1.02		1.00	1.01	1.00	1.01	1.00	1.10	1.00		1.00	1.07	1.00	1.00		1.00		1.00	1.00		1.00	1.11		1.00	1.04
Mean efficiency		1.14	1.12	1.05	1.08	1.03	1.06	1.05	1.01	1.01	1.07	1.06	1.11	1.06	1.01	1.02	1.10	1.00	1.01	1.01	1.00	1.02	1.04	1.06	1.09	1.09	1.06	1.13	1.09

B (GEnS)

CLC category	CLC code	EU27	AT	BE	BG	CY	CZ	DE	DK	EE	ES	FI	FR	GR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK	UK
non-irrigated arable land	211	1.24	1.71	1.11	1.37	1.31	1.26	1.09	1.01	1.00	1.15	1.11	1.15	1.22	1.13	1.12	1.33	1.00	1.00	1.00	1.00	1.04	1.03	1.11	1.55	1.25	1.55	1.80	1.64
permanently irrigated land	212	1.08			1.00	1.02					1.06		1.00	1.11			1.00				1.00			1.02	1.00		1.00		
rice fields	213	1.03			1.00						1.03		1.02	1.02	1.00		1.04							1.01	1.00				1.00
vineyards	221	1.04	1.07		1.03	1.05	1.03	1.03			1.03		1.17	1.02	1.00		1.05		1.10		1.00			1.04	1.03		1.06	1.02	NA
fruit trees and berry plantation	222	1.04	1.00	1.00	1.01	1.00	1.00	1.01	1.00	1.00	1.07		1.01	1.02	1.01		1.08	1.00	1.00	1.00		1.00	1.00	1.01	1.02	1.00	1.01	1.00	1.01
olive groves	223	1.14				1.02					1.12		1.00	1.17			1.11							1.02					
annual cops associated with permanent crops	231	1.22	1.18	1.04	1.02	1.00	1.08	1.05	1.00	1.00	1.07	1.04	1.06	1.01	1.00	1.15	1.04	1.00	1.03	1.00	1.00	1.03	1.00	1.01	1.05	1.04	1.05	1.10	1.27
complex cultivation patterns	241	1.05	1.00			1.02					1.03			1.01			1.04	1.00	1.00					1.12			1.00		
land principally occupied by agriculture with significant natural vegetatio	242	1.06	1.15	1.04	1.00	1.01	1.02	1.03	1.00	1.00	1.05	1.00	1.10	1.09	1.00	1.01	1.06	1.00	1.01	1.00	1.01	1.00	1.00	1.04	1.02	1.01	1.25	1.01	1.04
agro-forestry areas	243	1.02	1.02	1.00	1.02	1.02	1.02	1.00	1.00	1.00	1.03	1.08	1.01	1.06	1.00	1.03	1.06	1.00	1.00	1.03	1.08	1.00	1.01	1.03	1.04	1.06	1.06	1.06	1.01
pastures	244	1.13									1.13		1.00				1.02							1.14	1.00				
broadleaf forests	311	1.05	1.08	1.04	1.15	1.00	1.01	1.01	1.00	1.00	1.08	1.07	1.05	1.22	1.34	1.00	1.41	1.01	1.00	1.00		1.00	1.02	1.10	1.18	1.14	1.07	1.16	1.02
coniferous forest	312	1.32	1.48	1.24	1.42	1.46	1.25	1.10	1.00	1.00	1.06	1.02	1.15	1.14	1.01	1.05	1.53	1.00	1.08	1.01	1.00	1.00	1.00	1.09	1.96	1.33	1.21	1.59	1.07
mixed forest	313	1.12	1.14	1.23	1.12	1.00	1.01	1.02	1.00	1.00	1.15	1.03	1.04	1.04	1.03	1.00	1.11	1.01	1.00	1.00	1.00	1.00	1.03	1.08	1.31	1.01	1.15	1.16	1.00
natural grassland	321	1.09	1.55	1.00	1.10	1.01	1.03	1.03	1.01	1.00	1.07	1.04	1.26	1.03	1.01	1.04	1.14	1.00	1.00	1.00		1.00	1.02	1.07	1.29	1.11	1.03	1.43	1.16
moors and heath lands	322	1.36	1.24	1.01	1.54		1.31	1.07	1.01	1.00	1.13	1.48	1.03	1.10		1.05	1.05	1.00				1.00	1.84	1.14	1.51	1.72	1.41	1.92	1.51
sclerophyllous vegetation	323	1.10			1.00	1.06					1.04		1.11	1.07			1.06				1.04			1.03			1.00		
transitional woodland-scrub	324	1.11	1.00	1.04	1.02	1.02	1.20	1.01	1.00	1.00	1.02	1.12	1.02	1.09	1.00	1.03	1.06	1.00	1.00	1.01	1.00	1.00	1.02	1.07	1.04	1.15	1.05	1.07	1.01
beaches, sand, dunes	331	1.00		1.00	1.01	1.00		1.01	1.03	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.00		1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
bare rocks	332	1.60	1.98		1.17	1.00	1.01	1.92			1.48	1.00	2.26	1.02		1.00	1.98						2.52	1.19	1.07	1.32	1.83	2.45	1.18
sparsely vegetated areas	333	1.21	1.55		1.21	1.01		1.05		1.00	1.06	1.33	1.33	1.13	1.00	1.02	1.34	1.00		1.00	1.00		1.00	1.17	1.10	1.54	1.20	1.56	1.38
burnt areas	334	1.00			1.00	1.03					1.00		1.00	1.00		1.00	1.00						1.00	1.02	1.00	1.00			
glaciers and perpetual snow	335	1.76	2.28								1.10		2.03				1.95									1.07	1.03		
inland marshes	411	1.01	1.04	1.00	1.01		1.00	1.00	1.00	1.00	1.02	1.00	1.00	1.01	1.00	1.00	1.00	1.00		1.01		1.00	1.00	1.00	1.03	1.00	1.01	1.01	1.00
peat bogs	412	1.18	1.00	1.15	1.02		1.01	1.01	1.00	1.00	1.00	1.09	1.00		1.00	1.25	1.00	1.00		1.00		1.00	1.00	NA	1.00	1.16		1.00	1.06
Mean efficiency		1.16	1.30	1.07	1.11	1.05	1.08	1.08	1.01	1.00	1.08	1.09	1.16	1.07	1.03	1.05	1.18	1.00	1.02	1.00	1.01	1.01	1.15	1.07	1.15	1.16	1.15	1.31	1.14

Table 3. Stratification efficiency of the EnS, GEnS for the twelve Environmental Zones (Fig. 1)

A (EnS)													
CLC category	CLC code	ALN	BOR	NEM	ATN	ALS	CON	ATC	PAN	LUS	MDM	MDN	MDS
non-irrigated arable land	211	1.00	1.12	1.03	1.50	1.15	1.19	1.11	1.02	1.27	1.05	1.13	1.04
permanently irrigated land	212					1.00		1.00	1.00	1.01	1.01	1.05	1.04
rice fields	213							1.00	1.00	1.01	1.03	1.01	1.00
vineyards	221				1.00	1.00	1.01	1.00	1.00	1.01	1.01	1.03	1.02
fruit trees and berry plantation	222		1.00	1.00	1.00	1.00	1.01	1.00	1.00	1.00	1.01	1.00	1.01
olive groves	223									1.00	1.02	1.04	1.03
annual cops associated with permanent crops	231	1.02	1.30	1.07	1.11	1.06	1.04	1.20	1.01	1.06	1.04	1.04	1.01
complex cultivation patterns	241			1.00		1.00	1.00	1.00		1.07	1.00	1.02	1.03
land principally occupied by agriculture with significant natural vegetation	242	1.02	1.17	1.12	1.02	1.08	1.05	1.01	1.01	1.02	1.02	1.02	1.01
agro-forestry areas	243	1.00	1.12	1.02	1.02	1.04	1.02	1.01	1.01	1.04	1.01	1.01	1.01
pastures	244					1.00	1.00		1.00	1.00	1.01	1.03	1.02
broadleaf forests	311	1.00	1.06	1.03	1.05	1.09	1.15	1.08	1.01	1.03	1.08	1.09	1.03
coniferous forest	312	1.03	1.26	1.37	1.01	1.06	1.05	1.00	1.01	1.06	1.04	1.04	1.01
mixed forest	313	1.00	1.23	1.08	1.05	1.03	1.06	1.01	1.01	1.07	1.01	1.01	1.01
natural grasslands	321	1.02	1.01	1.01	1.14	1.10	1.03	1.01	1.01	1.05	1.03	1.01	1.01
moors and heath lands	322	1.07	1.04	1.00	1.36	1.03	1.01	1.00	1.00	1.14	1.03	1.02	1.01
sclerophyllous vegetation	323					1.00		1.00	1.00	1.01	1.10	1.07	1.02
transitional woodland-scrub	324	1.02	1.09	1.04	1.01	1.02	1.04	1.04	1.00	1.10	1.02	1.02	1.01
beaches, sand, dunes	331	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
bare rocks	332	1.00	1.00	1.00	1.02	1.16	1.01	1.00	1.00	1.01	1.01	1.01	1.00
sparsely vegetated areas	333	1.00	1.00	1.00	1.07	1.14	1.00	1.00	1.00	1.01	1.09	1.01	1.06
burnt areas	334		1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
glaciers and perpetual snow	335	1.00				1.08							
inland marshes	411	1.00	1.01	1.00	1.01	1.00	1.00	1.00	1.01	1.00	1.00	1.00	1.01
peat bogs	412	1.02	1.08	1.01	1.05	1.00	1.00	1.16	1.00	1.00	1.00		
Mean efficiency		1.01	1.09	1.04	1.08	1.05	1.03	1.03	1.00	1.04	1.03	1.03	1.02

B (GEnS)													
CLC category	CLC code	ALN	BOR	NEM	ATN	ALS	CON	ATC	PAN	LUS	MDM	MDN	MDS
non-irrigated arable land	211	1.02	1.10	1.03	1.38	1.08	1.08	1.13	1.06	1.11	1.15	1.11	1.04
permanently irrigated land	212					1.00		1.00	1.00	1.02	1.01	1.04	1.03
rice fields	213							1.00	1.00	1.02	1.05	1.03	1.01
vineyards	221				1.00	1.02	1.02	1.00	1.01	1.02	1.02	1.03	1.02
fruit trees and berry plantation	222		1.00	1.00	1.00	1.02	1.01	1.00	1.00	1.01	1.02	1.01	1.04
olive groves	223									1.02	1.05	1.06	1.06
annual cops associated with permanent crops	231	1.06	1.16	1.01	1.18	1.12	1.02	1.11	1.00	1.06	1.02	1.03	1.00
complex cultivation patterns	241			1.00		1.00	1.00	1.00		1.13	1.02	1.02	1.02
land principally occupied by agriculture with significant natural vegetation	242	1.02	1.10	1.01	1.03	1.13	1.02	1.02	1.01	1.02	1.04	1.03	1.02
agro-forestry areas	243	1.01	1.07	1.00	1.02	1.07	1.01	1.01	1.01	1.01	1.05	1.01	1.02
pastures	244					1.00	1.00		1.00	1.00	1.03	1.04	1.08
broadleaf forests	311	1.04	1.06	1.00	1.04	1.14	1.01	1.03	1.13	1.04	1.11	1.10	1.03
coniferous forest	312	1.24	1.04	1.06	1.03	1.27	1.06	1.04	1.01	1.03	1.06	1.02	1.01
mixed forest	313	1.06	1.01	1.01	1.05	1.08	1.04	1.06	1.03	1.14	1.02	1.02	1.01
natural grasslands	321	1.09	1.01	1.00	1.16	1.29	1.10	1.03	1.00	1.13	1.10	1.03	1.02
moors and heath lands	322	1.35	1.47	1.00	1.46	1.06	1.22	1.01	1.00	1.07	1.03	1.01	1.01
sclerophyllous vegetation	323					1.00		1.00	1.22	1.03	1.10	1.03	1.03
transitional woodland-scrub	324	1.09	1.09	1.01	1.01	1.02	1.02	1.05	1.00	1.04	1.03	1.02	1.01
beaches, sand, dunes	331	1.00	1.00	1.00	1.00	1.01	1.00	1.00	1.00	1.00	1.01	1.01	1.01
bare rocks	332	1.31	1.02	1.00	1.18	1.90	1.09	1.00	1.00	1.11	1.07	1.01	1.06
sparsely vegetated areas	333	1.42	1.02	1.00	1.38	1.36	1.06	1.03	1.00	1.09	1.12	1.01	1.05
burnt areas	334		1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
glaciers and perpetual snow	335	1.06				1.98							
inland marshes	411	1.00	1.01	1.00	1.00	1.00	1.00	1.00	1.01	1.00	1.00	1.00	1.01
peat bogs	412	1.13	1.08	1.00	1.05	1.00	1.00	1.40	1.00	1.00	1.00		
Mean efficiency		1.12	1.07	1.01	1.12	1.16	1.04	1.04	1.02	1.05	1.05	1.03	1.03

Table 4. Stratification efficiency of the EnS, GEnS and four national stratifications

		United Kingdom			Sweden			Austria			Spain		
CLC category	**CLC code**	**CS**	**EnS**	**GEnS**	**NILS**	**EnS**	**GEnS**	**SINUS**	**EnS**	**GEnS**	**CLATERES**	**EnS**	**GEnS**
non-irrigated arable land	211	1.72	1.65	1.64	1.52	1.36	1.25	2.96	1.62	1.71	1.42	1.19	1.15
permanently irrigated land	212										1.16	1.05	1.06
rice fields	213	1.00	1.00	1.00							1.10	1.02	1.03
vineyards	221							2.00	1.08	1.07	1.12	1.03	1.03
fruit trees and berry plantation	222	1.01	1.00	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.25	1.04	1.07
olive groves	223										1.46	1.09	1.12
annual cops associated with permanent crops	231	1.26	1.15	1.27	1.06	1.06	1.04	1.53	1.08	1.18	1.34	1.11	1.07
complex cultivation patterns	241							1.00	1.00	1.00	1.34	1.09	1.03
land principally occupied by agriculture with significant natural vegetation	242	1.05	1.03	1.04	1.01	1.01	1.01	1.49	1.20	1.15	1.14	1.05	1.05
agro-forestry areas	243	1.02	1.01	1.01	1.06	1.06	1.06	1.04	1.02	1.02	1.08	1.03	1.03
pastures	244										1.39	1.09	1.13
broadleaf forests	311	1.04	1.03	1.02	1.16	1.11	1.14	1.21	1.13	1.08	1.16	1.09	1.08
coniferous forest	312	1.11	1.05	1.07	1.35	1.26	1.33	1.46	1.18	1.48	1.16	1.09	1.06
mixed forest	313	1.00	1.00	1.00	1.06	1.01	1.01	1.18	1.12	1.14	1.21	1.11	1.15
natural grasslands	321	1.31	1.12	1.16	1.04	1.05	1.11	1.73	1.23	1.55	1.14	1.04	1.07
moors and heath lands	322	1.61	1.36	1.51	1.52	1.38	1.72	1.10	1.08	1.24	1.31	1.26	1.13
sclerophyllous vegetation	323										1.13	1.06	1.04
transitional woodland-scrub	324	1.02	1.01	1.01	1.21	1.14	1.15	1.00	1.00	1.00	1.07	1.02	1.02
beaches, sand, dunes	331	1.01	1.00	1.00	1.01	1.00	1.00				1.02	1.00	1.00
bare rocks	332	1.03	1.02	1.18	1.05	1.05	1.32	2.08	1.14	1.98	1.25	1.12	1.48
sparsely vegetated areas	333	1.53	1.07	1.38	1.10	1.08	1.54	1.44	1.20	1.55	1.32	1.18	1.06
burnt areas	334				1.00	1.00	1.00				1.01	1.00	1.00
glaciers and perpetual snow	335				1.00	1.00	1.07	1.15	1.05	2.28	1.01	1.00	1.10
inland marshes	411	1.01	1.00	1.00	1.01	1.00	1.00	1.36	1.01	1.04	1.05	1.02	1.02
peat bogs	412	1.10	1.04	1.06	1.12	1.11	1.16	1.01	1.00	1.00	1.00	1.00	1.00
Mean efficiency		1.17	1.09	1.14	1.13	1.09	1.16	1.43	1.12	1.30	1.19	1.07	1.08

5. DISCUSSION AND CONCLUSION

As discussed in the description of CLC (section 2.4), the dataset is not ideally suited to assess stratification efficiency for EBONE because the CLC land cover categories are considerably coarser than the habitats that are surveyed under the EBONE field protocol, both spatially and thematically. We also make the implicit assumption that ratio of the spatial variance over EU27 and the pooled variance within the strata is identical for the CLC categories and the General Habitat Categories the areas of which form the target parameters in the EBONE field protocol (Bunce et al., 2008; Deliverable 4.3). This is contentious, because spatial variance decreases rapidly with coarser resolutions (Schmit *et al.*, 2006), and the MME of the GHCs is 625 coarser than the MME in CLC. Nevertheless, the results give some encouragement as well as material for further reflection.

Results show that the EnS improves efficiency in many cases. However, there are great differences between categories and between countries. The stratification efficiency is generally good (i.e. above 1.10) for the forest and semi-natural vegetation categories (3.x.x). This is encouraging, because these contain the majority of habitats with significant biodiversity value. Conversely, the stratification efficiency is limited for specific agricultural land covers (rice fields, vineyards, fruit trees, agro-forestry areas) as well as mixed categories (complex cultivation patters, land principally occupied by agriculture with significant natural vegetation).

Stratification efficiency is intrinsically low for countries with relatively little topographic or climatic variability: in these situations the stratification, which are based on climate, do not provide divisions. For example, Luxemburg and Malta are not subdivided by the EnS, and Denmark, the Netherlands and the Baltic states have only arbitrary divisions is gradual gradients that span countries. Here too the stratification efficiency is bound to be low. By contrast, one would expect considerable stratification efficiency in countries with diverse environments, but this is not always the case. For example, stratification effect of both the GEnS and the EnS is limited in the Mediterranean countries and EnZs.

Although there is little difference between the EnS and the GEnS in the average gain in efficiency for the EU27, the GEnS performs considerably better for categories associated with mountaintops (bare rock, snow and ice). This can be explained because the GEnS has more altitudinal differentiation. This limitation of the EnS has been observed previously and should be taken into consideration in the design of the final network design.

It is encouraging that the stratification effect of the EnS and GEnS is generally similar to the four national stratifications. They perform well for the same land cover categories, which support the use of a pan-European stratification for monitoring European habitats. In general, the EnS is comparable to national stratification (Schmit *et al.*, 2006), but that some regionally important gradients are not discerned, explaining the superior performance of national stratifications.

In conclusion, the present study indicates that the pan-European stratifications improve sampling efficiency for several land cover categories and perform similar to national stratification, supporting their use as a basis for designing a pan-European biodiversity observation network. Greater efficiency of the GEnS compared to the EnS in mountainous regions suggests that altitudinal divisions may be required. The comparatively poor performance in Mediterranean Europe may require further testing.

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