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Testing the development of Species Accounts for measuring ecosystem condition in the EU

1 Introduction

The European Union (EU) has set itself ambitious targets for the preservation and better management of natural capital in the 7th Environmental Action Programme and the EU Biodiversity Strategy to 2020. To build the knowledge base for achieving these objectives, a shared project was set up at EU level to develop an integrated system for natural capital and ecosystem services accounting (KIP INCA). The key goal for KIP INCA is to test and propose a system that enables regular ecosystem accounting at EU level using the SEEA-EEA and methodological developments under the EU's 'Mapping and Assessment of Ecosystems and their Services' (MAES) initiative.

In its initial stages, Ecosystem Accounting is typically dependent on the use of readily available data. From this starting position, future improvements in design and data inputs can then be made in order to improve thematic or spatial accuracy, or in response to evolving user needs. Following this phased approach, this paper describes methods and proposals developed under KIP-INCA to calculate thematic Species Accounts using bird population data.

The objective of these Species Accounts is to support accounting for ecosystem condition of MAES ecosystem types across the EU scale. In order to achieve this, the Species Accounts are designed to deliver statistics on three key aspects of biodiversity: Species abundance, richness and population evenness for ecosystem accounting areas or assets (technically they provide a measure of species diversity within these areas, or *alpha* species diversity).

The remainder of this paper is set out as follows, Section 2 presents the MAES ecosystem typology the Species Accounts should inform on. Sections 3 and 4 set out alternative approaches to calculating Species Accounts based on different types of input data. Section 3 provides our first set of experimental Species Accounts, derived using a Top Down approach to disaggregate data on bird species reported by Member States under the EU Birds Directive. In Section 4, we introduce a bottom-up proposal to move towards a more concrete, spatially referenced Species Accounting approach using national bird survey data. We believe Section 4 provides some interesting discussion points for the London Group and hope some useful insights for us may emerge from these. Section 5 highlights the key challenges and further thoughts for achieving a fully spatial Species Accounting approach for the EU.

2 MAES Ecosystem Types

MAES (2013) establishes a typology for ecosystem mapping and assessment in the EU. This consists of 12 broad ecosystem types (9 terrestrial and 3 marine ones). Corine Land Cover (CLC) data can be used in a practical approach to delineate 9 of these ecosystems in the European landscape. CLC is a Pan-European Land Cover product provided by the European Environment Agency's Copernicus Land Services.[1] Editions are available for 1990, 2000, 2006 and 2012 (2018 is forthcoming). The specific MAES ecosystem types that CLC can directly represent comprise:

- Urban;
- Cropland;
- Grassland;
- Forest and woodland;
- Heathland and shrub;
- Sparsely vegetated land;
- Wetlands;
- Lakes and rivers; and,
- Marine Inlets and Transitional waters.

The CLC product provides land cover information for these ecosystem types at the 1 ha and 1km resolution, with 1km being the ambition for a fully-spatial approach to Ecosystem Accounting in the EU. Given its nature, CLC does not extend to cover the remaining three MAES Ecosystem types: Coastal areas; Shelf; and, Open Ocean.

3 Top Down Approach (Birds Directive Data)

Two of the key datasets for assessing the status of biodiversity in the EU are those provided by Member States under their reporting requirements for Article 12 of the Birds Directive and Article 17 of the Habitats Directive (collectively the 'Nature Directives') (MAES, 2014). An important development to the most recent reporting requirements for Article 12 of the Birds Directive (i.e., for the period 2008 to 2012) was the requirement for Member States to provide data on the estimated population size and trends of selected bird species, as well as their distribution.

3.1 Data and Methodology

In consideration of the above, the Article 12 data is a key resource for testing the calculation of Species Accounts under KIP-INCA. Article 12 data is available in spatial and tabular format for the reporting period of 2008-2012 from the EEA website. The tabular data includes breeding bird population estimates, ranges and trends at the Member State scale as part of a Microsoft Access database. Within

[1] https://land.copernicus.eu/pan-european/corine-land-cover

the database, tables are also provided of aggregated data on bird species at the EU Scale.[2]

An important associated database has been developed by the EEA (2015a) to link species and habitat types to MAES ecosystems. This database contains the MAES ecosystem preferences of all bird species considered for reporting under Article 12 of the Birds Directive, where each bird species is assigned a maximum of three ecosystem preferences. As shown in Figure 1, these preferences allow the disaggregation of the Member State and aggregated EU scale data to derive subnational and supranational Species Accounts by ecosystem type. The specifics of this approach is described in detail in UNEP-WCMC (2017), along with a number of associated accounting outputs.

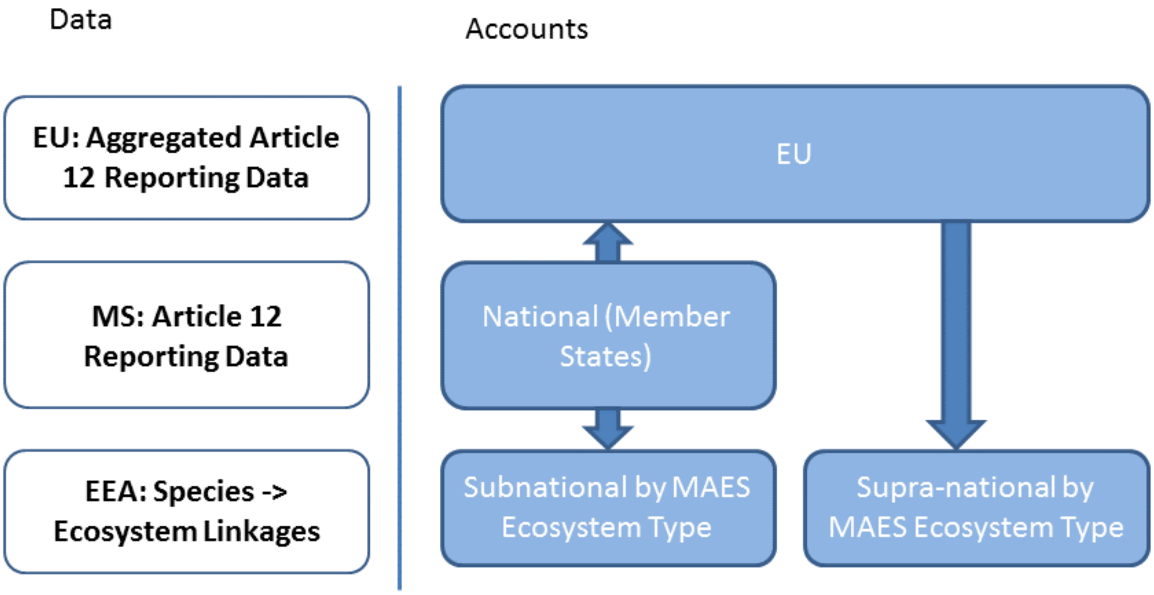


Figure 1 Disaggregation of Article 12 data using species and ecosystem linkages

3.2 Selected Results

Using the Article 12 dataset, it is possible to organise bird species into different groups that can provide different analytical insights. One such approach is to extract data on the European Bird Census Council (EBBC) group of common bird species from the Article 12 dataset. It makes sense to focus on these species as an indicator of condition as they are widespread and acknowledged to be good indicators of environmental quality (other options for organising the Article 12 data are presented in UNEP-WCMC, 2017).

Table 1 provides this example, where data on common birds is further sub-grouped as generalists (other), farmland and forest common birds. The bird species data presented relate to total abundance and species richness of the birds within each

[2] https://bd.eionet.europa.eu/article12/

of these categories. As shown in Table 1 these statistics are broken down by MAES ecosystem type. In addition, a Shannon's Index is calculated based on the abundances of each bird species within an ecosystem type. The Shannon's Index is a classical text book metric for population evenness, it provides low values when a few species dominate and high values when no single species dominates.[3]

As the 2008 to 2012 Article 12 reporting was the first time data was collected using the new reporting format, there is no equivalent bird data for the previous reporting period (2005 to 2007). As such, Table 1 provided a prevailing trend indicator based on the trends for each species reported by Member States. This is calculated as:

- (No. Species with increasing – declining trends) / (Total No. species) * 100.

The prevailing trend indicator is an interim measure to provide a temporal aspect to the accounts whilst the 2018 Article 12 reporting data is awaited.

Table 1 provides some aggregated insights with respect to the condition of MAES ecosystem types in terms of their ability to support biodiversity. These include:

- The overall trends of common farmland birds in Cropland and Grassland, suggest the condition of these ecosystems is deteriorating with regard to hosting common bird populations.
- The overall trends of common forest birds in Forest and woodland suggest this ecosystem is improving in its condition as bird habitat.
- The overall trend of 'other' generalist common birds in Rivers and lakes and Marine inlets and transitional waters suggest these ecosystems are losing condition to support common bird species.
- The Shannon's Index indicates that species diversity (based on richness and evenness) is relatively high in river and lake; wetland and forest and woodland ecosystems. Future reporting data will allow for monitoring this over time.
- Total abundance estimates reveal Cropland and Forest and woodland are the most important ecosystems for bird species stocks.

3.3 Pros and Cons

There are major benefits that this approach has provided:

- It allows existing data (i.e., Article 12 breeding bird data) and approaches (i.e., EBCC Common Birds groupings for environmental indicators) to be rapidly brought together and presented using an ecosystem perspective.

[3] The Shannon Index varies between zero (when just one species is present in a dataset) and natural log of the number of species in the dataset (when all the species are equally common, with 1 species being a particular case) (Peet, 1975).

This can then be compared with national / EU data from other ecosystem accounts.

- It provides the key statistics on bird species abundance, richness and population evenness relevant to inform on the condition of ecosystems. These are not readily available for the Article 12 dataset at the current time.
- It is relatively easy to implement and makes use of official data on bird population estimates that will be updated on a regular 6-year cycle

The major limitations of the approach are:

- The lack of spatial referencing of the underlying bird species data results in:
    - Inaccuracy in disaggregating abundance measures across ecosystems. Area weighting could improve this but fundamental assumptions still need to be made on the relative preferences of species for different ecosystems.
    - No subnational differentiation is possible for establishing the relative importance of different areas of the same ecosystem type for bird species biodiversity and, by extension, their condition.
- Assumes bird species estimates can be compared with confidence between countries.
- Absence of time-series data for updated Article 12 reporting (but 2018 reporting will be available by early 2020).

Policy Application: The adjacent figure illustrates where these accounts best provide indicators to different stages of the policy cycle. Given the aggregated nature, they are most suitable for identifying in which ecosystem types significant problems are emerging with respect to their condition for biodiversity at national or EU scale. They also support monitoring on progress at these scales towards key policy objectives for birds and ecosystem condition.

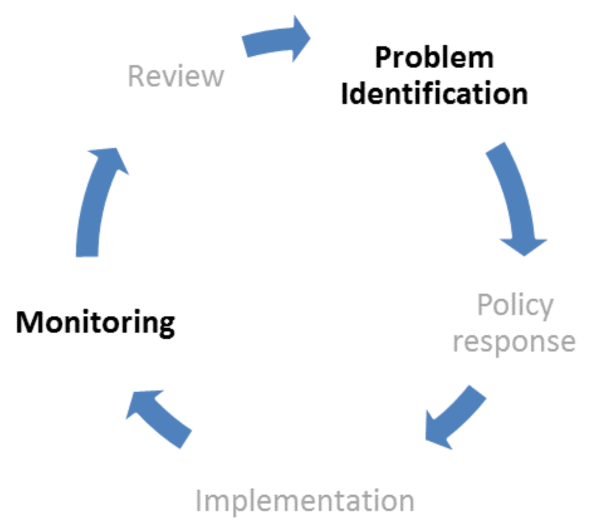


Table 1 Species Account - EBCC Common Bird Classes for EU

	Bird group classes[1]	**MAES Type**									**All Ecosystems**
		Cropland	**Grassland**	**Heathland / Shrub**	**Marine Inlets**	**Rivers / Lakes**	**Sparsely Vegetated**	**Urban**	**Wetlands**	**Woodland / Forest**	
Situation 2005-2007[2]											
Total abundance (No. individuals)	Other										
	Farmland										
	Forest										
Number of Species	Other										
	Farmland										
	Forest										
Shannon's Index	Other										
	Farmland										
	Forest										
Trends in Status 2008 - 2012											
Overall Trend[3]	Other	25.00	8.33	8.00	-23.08	-15.00	-4.35	20.83	-9.52	18.52	3.00
	Farmland	-73.33	-61.29	-52.17	-100.00	-100.00	-41.67	-55.56	-100.00	-100.00	-65.00
	Forest	50.00	-	0.00	-	100.00	100.00	-33.33	0.00	15.38	16.67
Net Change											
Total abundance (No. individuals)	Other										
	Farmland										
	Forest										
Number of Species	Other										
	Farmland										
	Forest										
Shannon's Index	Other										
	Farmland										
	Forest										
Situation 2008 - 2012											
Total abundance (No. individuals)	Other	1.42E+08	4.71E+07	4.35E+07	1.49E+06	2.16E+07	2.04E+07	2.32E+08	1.58E+07	3.26E+08	8.50E+08
	Farmland	1.13E+08	4.68E+07	3.30E+07	1.42E+04	2.25E+06	8.09E+06	6.68E+07	5.97E+06	1.95E+07	2.96E+08
	Forest	1.61E+06	0.00E+00	1.86E+07	0.00E+00	1.12E+05	1.16E+06	2.48E+06	2.40E+05	1.17E+08	1.41E+08
Number of species	Other	24	12	25	13	40	23	24	42	54	100
	Farmland	30	31	23	1	4	12	9	6	4	40
	Forest	2	0	4	0	1	1	3	2	39	36
Shannon's Index	Other	1.77	0.83	2.18	1.67	2.64	1.86	2.40	2.68	2.93	3.29
	Farmland	2.64	2.27	2.41	0.00	0.13	1.60	1.86	1.20	1.15	3.01
	Forest	0.54	-	0.78	-	0.00	0.00	0.79	0.69	2.95	2.93

4 Bottom-Up Approach (Survey Data in selected countries)

Good spatial referencing can substantially improve the potential of data to support ecosystem accounting. It is an essential prerequisite for organising data to accurately correspond with the spatial scale and location of ecosystems. It further opens up the possibilities for understanding which areas of a given ecosystem contain the most diverse species assemblages. This will increase the range of analytical and policy insights ecosystem accounts provide, in comparison to more aggregated data approaches. However, EU level biodiversity data from official reporting (including the Nature Directives) are, generally, only representative at the national and biogeographic region level.

In order to move towards a more concrete spatial accounting approach, we worked with the EBCC (an umbrella body for national bird monitoring NGOs) to identify suitable test case countries for using georeferenced data on bird species covered by the NGO-organised Pan-European Common Bird Monitoring Scheme (PECMBS). Suitable countries were determined on the basis of being known to have a time-series of georeferenced bird data that could be aligned with Corine Land Cover editions, collected on the basis of a sound methodology and likely to be readily accessible with limited processing required to be made suitable for testing a Species Accounting approach. These discussions identified the Breeding Bird Survey (BBS) coordinated by the British Trust for Ornithology (BTO) and the Breeding Bird Census Programme (Jednotný Program Sčítání Ptáků, JPSP) coordinated by the Czech Society for Ornithology (CSO) as suitable test cases. In broad terms the BBS can be considered to provide bird species counts for 1km squares (estimated from transect data). While the JPSP provides transect data derived from a series of point counts, for our analysis we assume that each of these point counts represents bird counts for a single square ha (with the point assumed to be at its centre).

Both the BTO and CSO agreed to contribute their data to support these tests. As such we are very grateful to Gavin Siriwardena and David Noble (BTO), Petr Vorisek (EBCC) and the National coordinators of the JPSP (CSO) for facilitating the provision of this data and providing advice to date. Work to compile accounts using this data is ongoing but there are a number of data treatments and challenges that will be of interest to the London Group. It is also hoped the group may be able to contribute suggestions in response to some of the accounting challenges / decisions that have been encountered.

4.1 Conceptual Approach

Our conceptual approach is relatively simple and set out in Figure 2. The idea is to use georeferenced bird species data from the BBS and JPSP (black crosses in Figure 2) and associate this with the respective MAES ecosystem type at location using the Corine Land Cover product for that year, either at 1km or 1ha resolution (the squares in Figure 2). We can then aggregate the bird data by MAES ecosystem type (identified by the colour of the squares in the figure) to whatever scale is desired. We chose the national scale at this stage, as this allows a comparison of the accounts with the Member State scale Species Accounts generated using the Top-Down approach.

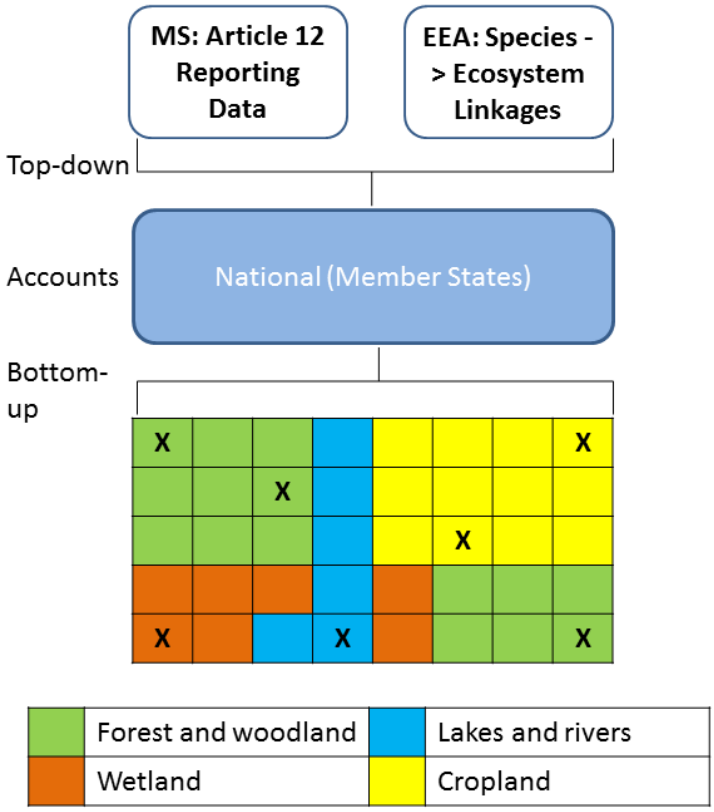


Figure 2 Bottom up approach to compile Species Accounts

4.2 Delivering a Measurement Approach

Whilst the BBS data endeavours to provide a consistent, repeated but increasing sampling of 1km squares over years, the JPSP is found to be less consistent but also greatly increasing. For the JPSP, the number of transects surveyed increased from 50 in 2000 to 121 in 2006 and to 143 in 2012. Over these three sampling points in time, only 35 transects were consistently sampled. This is a common type of data situation, with similar issues encountered when experimenting with data reported to the EU under the Habitats Directive and Water Framework Directive in an ecosystem accounting context.

One way to achieve a consistent measurement approach would be to focus on the consistent sampling locations between periods. Figure 3 presents this diagrammatically, these consistent locations being represented by the black crosses. However, this is clearly undesirable as a lot of information is discarded and there would be no incentive to invest in improving biodiversity monitoring programmes with such a treatment. It would be expected that over time this set of consistently monitored locations would tend to zero and it is very possible that ecosystems will be converted to different land uses at some locations.

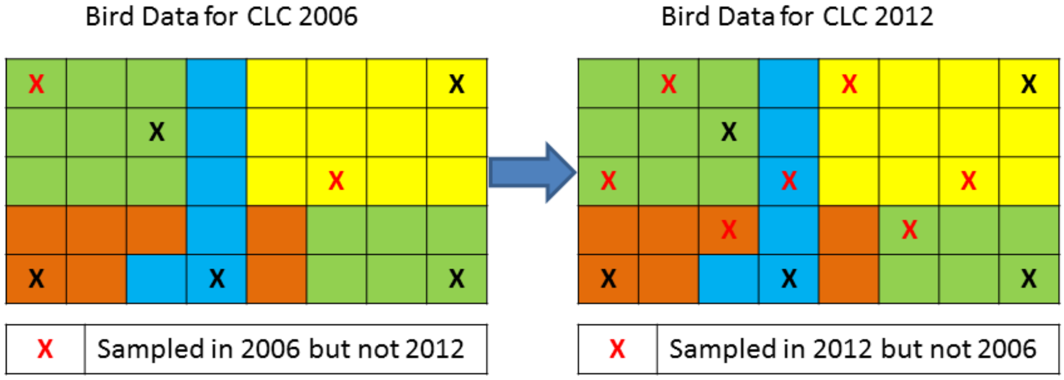


Figure 3 Issue of inconsistent and increasing sampling

Our proposed approach is based on two key assumptions on the sampling strategy for the surveys:

1. There are sufficient observations to identify all common bird species in their preferred ecosystems. This is considered reasonable, given they are common birds and the MAES ecosystem typology is broad – particularly for large scale accounting applications.
2. The counts of common bird species are representative of the real distribution of common bird populations (i.e., their abundances relative to each other in different MAES ecosystem types).

If these assumptions are accepted, species richness and the Shannon's index can be calculated using all data from different monitoring visits and compared for the same ecosystem accounting area (by ecosystem type) or asset. The benefit of investing in increased monitoring is that these metrics can be calculated at smaller spatial scales with increased confidence and accuracy will be improved at larger spatial scales.

The above is demonstrated using an example for a 1,000 km^2 ecosystem accounting area in Table 2, where surveys are completed and bird abundance counts recorded at 100 x 1km^2 survey sites (column 2) and 10 x 1km^2 survey sites (column 3). For simplicity the 1,000 km^2 ecosystem accounting area in Table 2 is assumed to be one ecosystem type. As shown in Table 2 (bottom of columns 2 and 3), the species richness and Shannon's Index are the same for the 1,000 km^2 ecosystem accounting area regardless of the number of 1km^2 surveys completed. This allows for sampling intensity to be increased over time and these survey statistics to still be compared with each other for the same ecosystem accounting area, assuming the assumptions outlined above remain true. Of course further evaluation of any identified trends is required, including the influence of improved accuracy and identifying and correcting for any sampling bias.

Table 2 Species abundance survey results and statistics for a 1,000 km^2 ecosystem accounting area

Species	Total abundance measured in 100 x 1km^2 survey sites	Total abundance measured in 10 x 1km^2 survey sites	Abundance / km^2 of Forest
Woodpecker	500	50	5
Grouse	1500	150	15
Goshawk	80	8	0.8
Great Horned Owl	50	5	0.5
Wood Thrush	600	60	6
Broad-winged Hawk	60	6	0.6
Barred Owl	20	2	0.2
Chaffinch	2000	200	20
Jay	350	35	3.5
Blckcap	700	70	7
Total Abundance	5860	586	58.6
Species Richness	10	10	10
Shannons Index	1.75	1.75	1.75

As shown in Table 2 (bottom of column 4), species richness and the Shannon's index are also consistent at the grid cell scale (e.g., 1km or 1ha). However, allocating these statistics to grid cells is somewhat misleading, as they represent the total richness and overall evenness across all the surveyed sites. In short, it should not be expected that the same set of species would be present at each 1km survey site within the ecosystem accounting area. This needs to be considered when selecting the scale for any spatial analysis and reporting.

For abundance there is clearly a proportionate relationship to sampling effort and (as shown by the decreasing counts from column 2 to 4 in Table 2). A simple approach to account for bird species stocks is, then, to estimate the average expected abundance using the available survey results for an ecosystem accounting area expressed on a per km^2 basis. These estimates can then be scaled-up by the area of a given ecosystem type in any given ecosystem accounting area. The X' cells in Figure 4 illustrate this type of approach to allocating abundance in non-surveyed grid cells based on the surveyed counts from the X cells.[4] Again, care needs to be taken on how such results are communicated

[4] It may be possible to further confine the extent of these inferences using spatial data on distributions reported by Member States under Article 12 of the Birds Directive. However, this is unlikely to be that helpful for common birds with widespread distributions.

and employed at different scales, as spatial heterogeneity of species populations within individual ecosystem types is clearly to be expected. This especially true for the MAES ecosystem types given how broad they are.

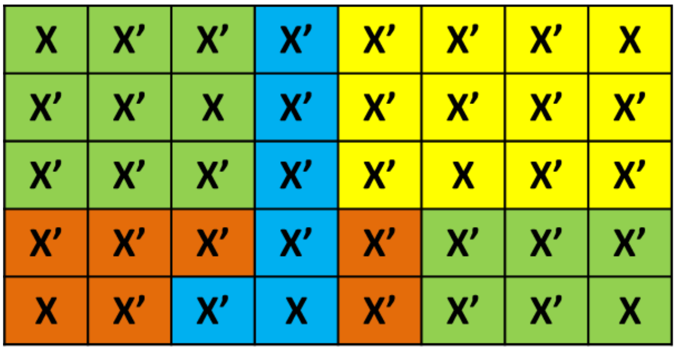


Figure 4 Allocating species abundance measures

As Figure 4 suggest, in theory, we could do this at the scale of each individual ecosystem asset if we had a sufficiently comprehensive sampling strategy. However, in most cases this is an unreasonable expectation. So whilst the spatial referencing of our input data is now OK, we return to the issue of not being able to spatially differentiate the relative importance of different pixels / ecosystem assets for bird biodiversity / condition within our ecosystem accounting area of interest. The overall Pros and Cons of this approach are further highlighted and discussed in the following section.

4.3 Pros and Cons

The major benefits that this approach provides:

- Can be aligned to the 1 km accounting grid and CLC time points for the EU.
- Very flexible, responds to changing sample size and allows accounts to be constructed at multiple spatial scales with limited processing requirements
- A reasonable approach for key condition metrics for species richness and evenness in ecosystem accounting areas.
- Based on yearly estimates, often supported by a substantial time series. As such it is the CLC time series that become the main temporal constrains for accounting.

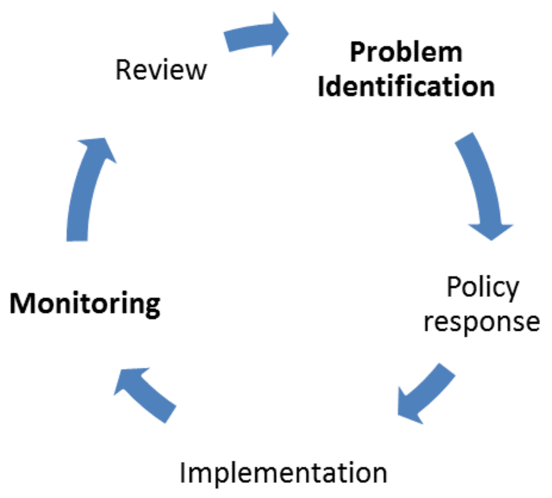
The major limitations of the approach are:

- Requires some strong assumptions that rely on decent monitoring data and sampling strategies.

- Still limited spatial differentiation of ecosystems in terms of their condition for biodiversity. This could be as significant constraint for decision making, especially given the MAES types are broad and can be expected to exhibit significant internal heterogeneity. In aggregated analyses, this will be reflected in spatial heterogeneity of species stocks within ecosystem types.

- Decisions need to be made on the spatial scale at which statistics on bird species should be generated. Ideally this would be for individual ecosystem assets, reflecting the conceptual ecosystem accounting unit. Alternatively, it would make sense to align ecosystem accounting areas with population dynamics knowledge on areas of ecosystems required for stable populations or the management areas meant to inform environmental resource management (e.g., Natura 2000 areas in the EU). A tool to generate statistics at different scales would be desirable for routine reporting.

- A variety of surveying approaches are used under different bird monitoring programmes (e.g., transects, transect point methods and survey squares). Expanding this approach to EU scale accounting will require a substantial data harmonisation exercise and engagement with all national monitoring programmes. This will be essential for many policy relevant ecosystem accounting areas (e.g., biogeographical regions that cover multiple countries).

Policy Applications: The adjacent figure illustrates where these accounts best provide indicators to different stages of the policy cycle. By improving the spatial referencing and being able to compile Species Accounts for different management or statistical accounting areas the approach opens up a full range of policy entry points. However, these possibilities are inherently limited by the sampling strategy underpinning the input data. Hence, the Review, Response and Implementation stages are not in bold.	

5 Challenges in moving to a spatial Species Accounting approach for the EU

Our experimentations with the Article 12 data reported by Member States and evaluation of data provided via NGO monitoring programmes in the UK and Czech Republic identify some key challenges and treatment questions for ecosystem accounting. Feedback from the group on how these could be addressed would be appreciated. In particular:

- Key decisions need to be made on the scale at which species statistics ae calculated. What can we use to inform these decisions? Are there any similar treatments in the SEEA CF or SNA?
- Here we only consider bird species diversity within an ecosystem type (or asset). This is aligned with the conceptual units for ecosystem accounting. But if we are interested in maintaining multifunctional landscapes we also need to understand how the diversity of species assemblages and their functional traits varies at landscape scale and between different ecosystem types (*Gamma* diversity). These will be highly scale dependent metrics. How can we build this into accounts? Is ecosystem diversity sufficient?
- Bird surveys are the best temporally and spatially resolved biodiversity data in most EU countries. Whilst they provide clear indicators for ecosystem condition for maintaining biodiversity, how do we explicitly link this to ecosystem service provision? Do we need to?
- What are the perverse / misleading signals that could emerge from relying on such a mobile species group for inferring ecosystem condition? Could birds congregate in lesser preferred ecosystems as their most preferred ones are subject to loss of condition or habitat conversion?
- One way to increase our spatial understanding of which areas of certain ecosystem types are in the best condition is to implement modelling approaches using key explanatory variables to explain heterogeneity in species stocks and diversity within individual MAES ecosystem types. This is likely to be a significant effort for the EU scale. Is it necessary to do this for the abundance of each common bird? Or should we just limit this to community metrics on richness and Shannon's index? Which approaches should we use?
- Whilst currently outside of the SEEA EEA framework, there are thresholds and irreversibility's that species-level biodiversity statistics can inform on. Does the SEEA EEA have a role to play here?

- How do we connect data on spatial bird species distribution to (and hence condition of ecosystems) to data about land use and management – to provide the environmental economic accounting that SEEA aspires to? This is important as these are crucial factors for influencing bird species presence and trends for many ecosystem types in Europe but relatively little spatial information on land use and management is available, at least at European level.

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