Literature review

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"Mapping biodiversity changes across spatio-temporal scales"

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Beginning of study: October 2020

Contents

Outline

Literature review about the link between biodiversity facets trends and spatial/temporal scales.

Make a table of all these papers and `group_by(taxa) %>% order_by(spatial_scale |` `temporal_scale)`. Then see if for each taxa we can find a trend (a bit like in Chase *et al.* 2019 Oikos paper | Jarzyna *et al.* 2015 but here I am not making the analysis, just taking the analysis from papers). Best example found so far: Hill & Hamer 2004

Meeting with Petr

1) How is the trend of biodiversity metrics linked to spatial grain/spatial extent and temporal grain/temporal extent.

- Talk about papers which does compare (Jarzyna Jetz)
- The inconsistency of reporting scales (especially for models as in Jiguet et al.or Chiron et al., and for MSI metrics)

2) Data heterogeneity

- Lack of spatial replication. That's why this review is important
- The inconsistency of reporting scales (especially for models, and for MSI metrics)
- Lack in other than western countries
- Metric heterogeneity (Freixedas 2001 but they don't mention the macroecological ones as McGill, my struggle because of the time for space substitution as Hill & Hammer). Some metrics takes into account temporal dynamic but some papers don't look at the trend of these metrics (Jarzyna et al. 2015)
- Can we use space for time substitution as an actual substitution (Hill & Hammer)
- Pop trends are usually stronger (cf. all the abundance metrics)

3) Future directions

- Lack of data for other thsn western cvountries: important to harvest data in other countries

1. Introduction

Human life quality is intrinsically linked to ecosystems state that he is living in. Indeed, ecosystems services extend in a large spectrum of mechanisms including nutrient cycle, food production, or climate and water cycle regulation (Pereira, Navarro, and Martins 2012). Some of those ecosystem functions are managed by bird biodiversity such as seed dispersal, controls pests or pollinate plant. Unfortunately, anthropogenic stressors like habitat loss, over exploitation, pollution or introduction of invasive species could lead biodiversity to its sixth mass extinction (Barnosky et al. 2011).

We now know that the loss of global biodiversity is unprecedented and political decisions has been stated in order to limit it (*e.g.* Convention on Biological Diversity and Centre 2006, pp. 2010, 2002). However, current scientific literature has also shown that temporal trends in local changes of biodiversity can be opposite to trends at larger scales (*e.g.* Chase et al. 2019). Thus, current changes in biodiversity is far more complex than a simple global decrease: most of the ecosystems undergo alterations of their communities with changes in species composition (Blowes et al. 2019; Dornelas et al. 2013). Wonders persist about how the trend of these different metrics of biodiversity are link to the spatial and temporal scales used when measured.

In order to investigate this link between spatio-temporal scales and biodiversity metrics, birds is a relevant taxon. Thanks to the many ornithological monitoring and surveys, we now have a large number of long, high-quality time series on bird populations (Bejček and Stastný 2016; Sauer, Link, et al. 2013; Kamp et al. 2021). Birds are easy to observe, easy to identify and thus many volunteers are motivated to conduct standardized sampling. Given their ability to change quickly of locations, their presence is also a good indicator for ecosystem health and thus several standardized metrics have been created to assess their populations.

However, studying biodiversity can be confusing, especially because several choices must be done. Firstly, the level at which you are looking at the biodiversity must be chosen (*e.g.* taxonomic, functional, phylogenetic diversity). Secondly, one must decide which metric is the most appropriate for his study. There are many facets of biodiversity that can be measured by different metrics depending on the objective of your study. Measures of static biodiversity are commonly used such as species richness or α diversity (*i.e.* number of species, Whittaker 1960), the Shannon index (Shannon 1948) ,the Simpson index (Simpson 1949) or the Hill number (Hill 1973). The later three biodiversity indexes take into account the relative

abundances of the species and can be considered as the *quality* of the biodiversity. On an other hand, the spatial and temporal β diversity will measure the species turnover and can be measured thanks to Whittaker's (Whittaker 1972), Sørensen's (Sørensen 1948) or Jaccard's (Jaccard 1912) dissimilarity indexes (*e.g.* Keil et al. 2012). All these metrics assess the taxonomic diversity, *i.e.* they use the species as unit. However, it has also been shown that functional and phylogenetic diversity can provide supplementary information on the community structure and its dynamic (*e.g.* McGill et al. 2006; Mouquet et al. 2012; Webb et al. 2002).

An other measure of biodiversity of great interest is the abundance of the populations. As a matter of fact, as individuals react to disturbances of ecosystems by disappearing, the population trends are considered as resulting of the ecosystems health. Overall populations are impossible to assess, but determining the abundance of few indicator species can give a relevant summary on how is going the entire ecosystem (Richard D Gregory, A. v. Strien, et al. 2005). These family of metrics are called the multi-species indicators (MSI) and we have seen the emergence of several of them according to the ecosystem considered. We can cite here the farmland bird indicator, woodland bird indicator or one of the most informative, which summarizes these two previous metrics: the Wildland Bird Indicator (Richard D Gregory, Gibbons, et al. 1999; Richard D. Gregory and A. v. Strien 2010). The main idea of these metrics is to compute the geometric mean of abundance of few key species over time.

Finally a last class of indicators, not considered here, take into account both species and ecosystems feature into a summarizing index. The most known ones are the Red List Index (S. H. M. Butchart, Akçakaya, et al. 2007; S. Butchart et al. 2005; S. H. M. Butchart, Stattersfield, et al. 2004) or the Biodiversity Change Index (Normander et al. 2012).

Here, I propose to review articles assessing the temporal trends of different avian biodiversity metrics and to look at which spatial scales these studies have been done. I decided to consider the most common indicators used to assess biodiversity, such as the diversity indexes (*e.g.* species richness, functional diversity...) or the abundance indexes. Summarizing the trends of these qualitative and/or quantitative avian biodiversity indexes along with their spatial and temporal scales will help to see more clearly how the trends of biodiversity are linked to spatio-temporal scales. It is also important to demonstrate that the information about the sampling plan (*i.e.* spatial scale, time span, temporal scales etc) is not systematically indicated in the scientific literature and can bring confusion to the analysis and comparisons of their trends. I believe that this review can help to have a better overview of the current knowledge on the

trend of biodiversity metrics of bird populations.

specify that it is mainly for continental/coastal birds but no look at islandic communities and change *Stable* to *No trend*

2. Materials and Methods

For this review, articles of interest were the ones assessing temporal trends of the most common indicators (*i.e.* metrics) of avian biodiversity and specifying spatial and temporal scales. For this, I used the *"advanced search"* tool of the ISI Web of Science Core collection database with these four following queries:

1. `AB = ((biodiversity OR species richness OR diversity) AND (temporal trend* OR dynamic*) AND (bird* OR avia*))` which resulted in 1346 references.

2. `AB = ((biodiversity change index) AND (bird* OR avia*) AND trend*)` which resulted in 60 references.

3. `AB = ((species richness) AND (bird* OR avia*) AND trend*)` which resulted in 313 references.

4. `ALL=(birds AND species richness AND temporal trend)` which resulted in 88 references.

Alternatively, the articles which were often referred to in the relevant articles were also explored.

I decided to take into account only the articles for which there was spatial replicates, *i.e.* where the trend of the metric was assessed at several locations with the same spatial grain (except for the *global scale*, which can not have spatial replicate). With this replications, the trend reported is more reliable. For each query, the title and abstract of the articles were reviewed. When the temporal trend was explicitly specified (either visually or literally), the material and method part was read in order to collect the *spatial grain* of the trend (*i.e.* the area at which the trend is assessed), its *temporal grain* (*i.e.* the time span at which data have been gathered at one census session), the *spatial extent* (*i.e.* the entire area at which the study applies), the *temporal extent* and the *beginning and ending years* of the study as well as the *general trend* of the metric (Tab. 4.1).

Spatial grain sizes are discretized into four levels: $local <= 25\ Km^2$, $regional > 25\ Km^2$, *national* when an entire country is considered and *global* at the worldwide scale.

Concerning the trend assessment, different papers contain the *p-value* or directly specify the significant trend of the metric. However, a portion of papers gives only visual representations of the trend. For those, the standard error was used when displayed. For the very few only giving the trend, the rule of

thumb was applied. Information can be found in the column *Note* of the Tab. 4.2 of the supplementary material. Moreover, the final trend retained (*i.e.* either *Increase*, *Stable* or *Decrease*) doesn't reflect all the fluctuations of the metric through time but rather the difference between the starting and ending points.

I have found 33 references in which authors were both determining the temporal trend of a metric of interest and explicitly defining the grain size. However, only 15 of them are using spatial replicates and are thus relevant for this study (Tab. 4.1). The classes of metric are: *Species richness, Evenness, Abundance, Diversity, Temporal beta-diversity, Spatial beta-diversity, Functional diversity, Functional evenness, Functional richness*. Some of this classes contain several different indexes. This is the case for instance for the class *Diversity*, which can be defined by either the Shannon or the Simpson index, or for the class *Abundance* which contains various multi-species indicators.

3. Results

3.1 On the spatial scale

Out of 15 papers, 5 were located in North America and 10 in Europe. The median spatial extent of the data is $5.20475 \times 10^5 \ Km^2$, with the smallest area of 1800 Km^2 and the greatest representing the global emerged surface (*i.e.* $1.4894 \times 10^8 \ Km^2$). Overall, there were 9 *Decrease*, 31 *Increase* and 14 *Stable* reliable trends across the literature, without consideration of any metric or spatial scales.

Local scales are more represented than the others and the number of papers decreases with the increasing spatial scale (Figure 3.1). This is expected, as the spatial replications get more demanding in organization and resources as the grain size enlarges. The *Increase* of the metrics seems to be dominating at smaller scales. On an other hand, the proportion of *Decrease* is more important at regional scales than at local scales. At national scale, no *Decrease* is witnessed, with almost as *Increase* as *Stable* trends. At the global scale, no *Increase* were found.
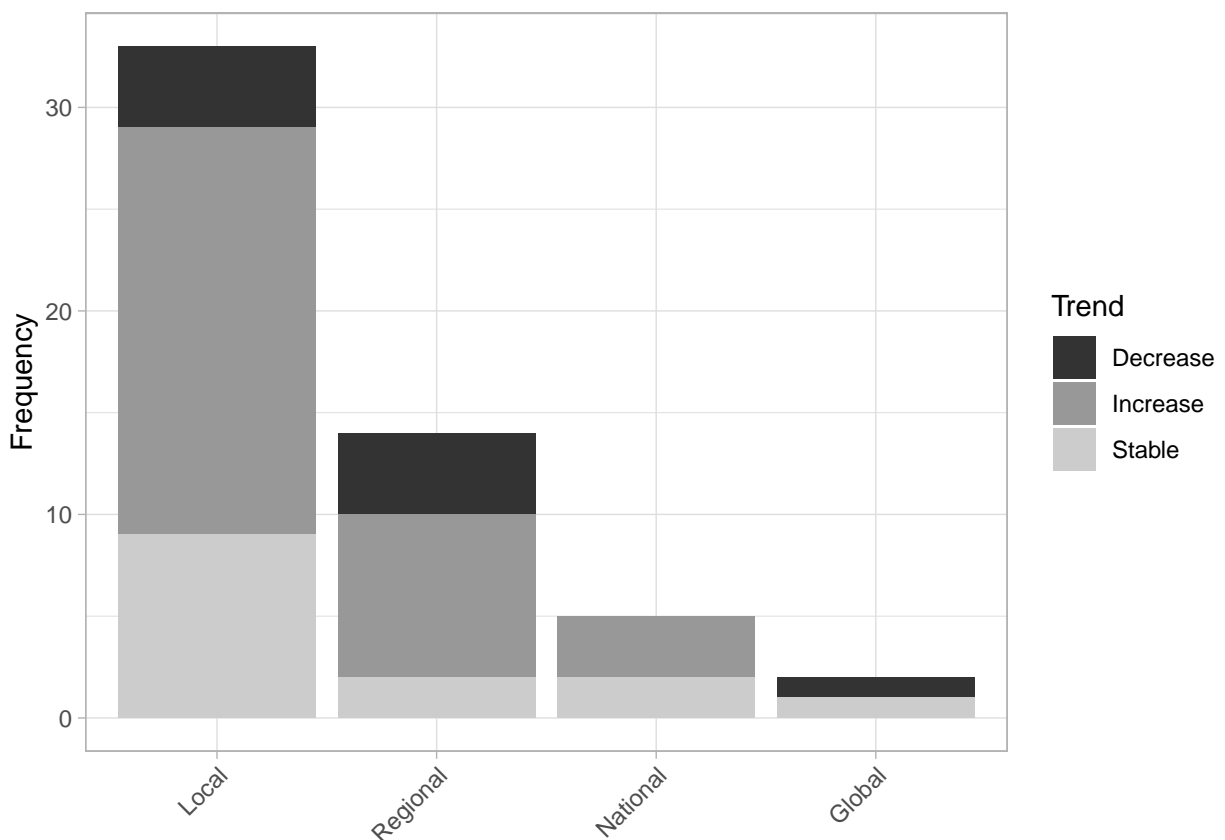

Figure 3.1: Proportion of *Increase*, *Decrease* or *Stable* trends for each spatial scale

Species richness and abundance metrics are very represented in the scientific literature (Figure 3.2). Distribution of trends is rather equal for the abundance indexes but the *Increase* is clearly dominant for the species richness. Diversity indexes (*i.e.* Sørensen and Jaccard) were always found increasing and temporal β-diversity was found most of the time increasing and never decreasing. The small frequency of the other metrics doesn't allow one to discuss the trend proportions.
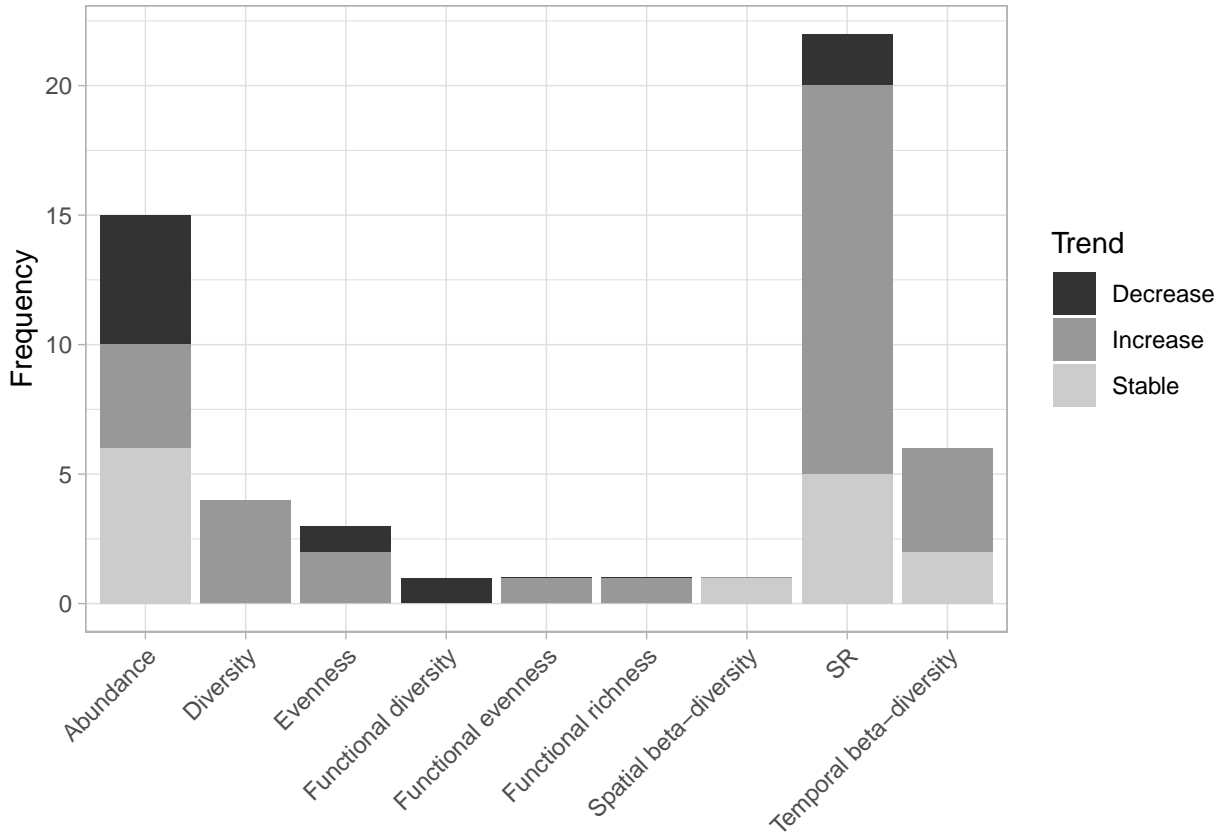

Figure 3.2: Proportion of *Increase*, *Decrease* or *Stable* trends for each of the metric

At local scales, species richness experiences dominantly increases (Figure 3.3). Evenness indexes, *i.e.* taxonomic and functional evenness, are mainly found increasing. Concerning the abundance indexes, the stability dominates but the increase is also often witnessed. In contrast, **at regional scale**, abundance metrics always decrease, whilst temporal β-diversity always increase. Species richness experiments mainly increases, then stability but no decrease is reported. Concerning **national and global scales**, one have to keep in mind that spatial replicates are less frequent and that most of the trends reported here for these two spatial scales are not replicated. Exception is made by Bowler et al. (2021), who showed negative trends in abundance indexes for Denmark and Germany and positive trends for Switzerland and Czech Republic, indicating that one can not conclude about general trend at national scale (here referred as *Stable*). Global trends only come from Jarzyna and Jetz (2018).
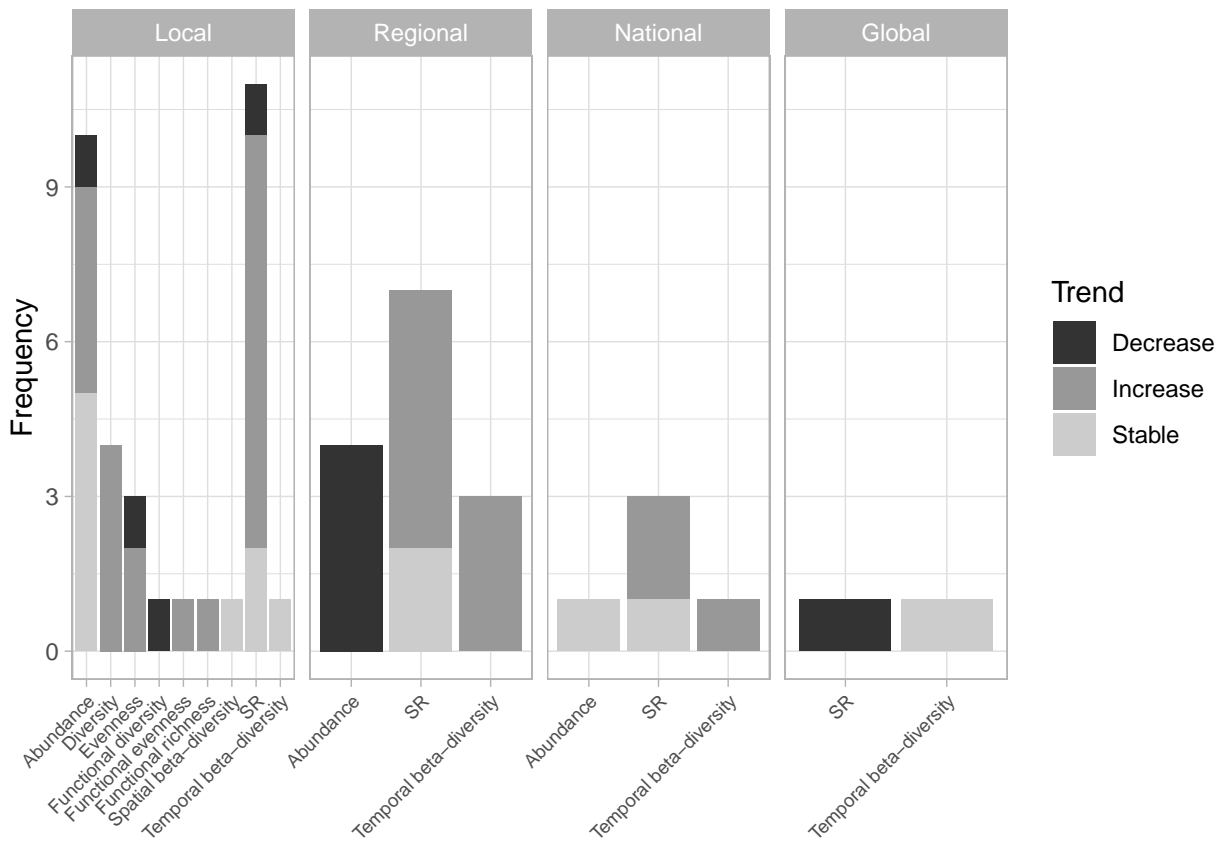
Figure 3.3: Proportion of *Increase*, *Decrease* or *Stable* trends for each metric. Each panel represent one spatial scale

3.2 On the temporal scale

The oldest study started in 1968 and the median duration is 27 years, with a minimum time span of 11 years and a maximum of 45.

4. Discussion

Articles using spatial replicates to compute the trend of a metric were limited, either due to a lack of data or from an analysis focusing on the global trend of the data. For instance, the Breeding Bird Surveys (*e.g.* Sauer, Link, et al. 2013; Kamp et al. 2021) follow standardized sampling plan with spatial replications (*i.e.* census plots) but not all the trend of the metrics reported are averaged or summarized at specific grain sizes. As a matter of fact, the common method encountered in the scientific literature is to learn a predictive model from the data, predict the target feature (*i.e.* the variable of interest such as abundance or species richness) and then compute the metric and its trend from the output of the model and at the dataset spatial extent, giving no spatial replicates of the trend (*e.g.* Frederic Jiguet et al. 2005; Frédéric Jiguet et al. 2012; Eglington and Pearce-Higgins 2012; Doxa et al. 2010; Sauer, Pardieck, et al. 2017).

3) Future directions

- Lack of data for other than western countries: important to harvest data in other countries. Here, out of the 15 papers, 5 were located in north america and 10 in Europe.

Table 4.1: Trends of different metrics of biodiversity at various spatial and temporal scales

Reference	Metric	Spatial grain (Km²)	Temporal grain (year)	Spatial extent (Km²)	Temporal extent (year)	Years	Country	Trend
Barnagaud et al. 2017	Evenness	Local	1.0	9834000	41	1970-2011	USA	Increase
	SR	Local	1.0	9834000	41	1970-2011	USA	Increase
Bowler et al. 2021	Abundance	National	1.0	520475	27	1990-2016	Czech Rep., Switzerland, Denmark, Germany	Stable
Chase et al. 2019	SR	Local	5.0	2800000	30	1982–2011	USA, Canada	Stable
	SR	Regional	5.0	2800000	30	1982–2011	USA, Canada	Stable
	SR	Regional	5.0	2800000	30	1982–2011	USA, Canada	Stable
	SR	Local	5.0	2800000	30	1982–2011	USA, Canada	Increase
	SR	Local	5.0	2800000	30	1982–2011	USA, Canada	Increase
Chiron et al. 2013	Abundance	Regional	1.0	643801	14	2007-2020	France	Decrease
	Abundance	Regional	1.0	643801	14	2007-2020	France	Decrease
	Abundance	Regional	1.0	643801	14	2007-2020	France	Decrease
	Abundance	Regional	1.0	643801	14	2007-2020	France	Decrease
Davey et al. 2012	Diversity	Local	1.0	242495	13	1994-2006	UK	Increase
	Evenness	Local	1.0	242495	13	1994-2006	UK	Increase
	SR	Local	1.0	242495	13	1994-2006	UK	Increase

Table 4.1: Trends of different metrics of biodiversity at various spatial and temporal scales *(continued)*

Reference	Metric	Spatial grain (Km²)	Temporal grain (year)	Spatial extent (Km²)	Temporal extent (year)	Years	Country	Trend
Harrison, Buckland, et al. 2014	Abundance	Local	1.0	200000	18	1994-2011	Great Britain, UK	Increase
	Abundance	Local	1.0	200000	18	1994-2011	Great Britain, UK	Stable
	Abundance	Local	1.0	200000	18	1994-2011	Great Britain, UK	Stable
Harrison, Yuan, et al. 2016	Abundance	Local	0.5	242495	20	1994-2013	UK	Increase
	Abundance	Local	0.5	242495	20	1994-2013	UK	Stable
	Abundance	Local	0.5	242495	20	1994-2013	UK	Stable
Jarzyna and Jetz 2018	SR	Regional	1.0	9834000	45	1969-2013	USA	Increase
	SR	Regional	1.0	9834000	45	1969-2013	USA	Increase
	SR	Regional	1.0	9834000	45	1969-2013	USA	Increase
	SR	National	1.0	9834000	45	1969-2013	USA	Increase
	SR	Global	1.0	148940000	45	1969-2013	World	Decrease
	Temporal beta-diversity	Regional	1.0	9834000	45	1969-2013	USA	Increase
	Temporal beta-diversity	Regional	1.0	9834000	45	1969-2013	USA	Increase
	Temporal beta-diversity	Regional	1.0	9834000	45	1969-2013	USA	Increase

Table 4.1: Trends of different metrics of biodiversity at various spatial and temporal scales *(continued)*

Reference	Metric	Spatial grain (Km²)	Temporal grain (year)	Spatial extent (Km²)	Temporal extent (year)	Years	Country	Trend
	Temporal beta-diversity	National	1.0	9834000	45	1969-2013	USA	Increase
	Temporal beta-diversity	Global	1.0	148940000	45	1969-2013	World	Stable
Pilotto et al. 2020	Abundance	Local	NA	10180000	NA	NA	Europe	Stable
	Diversity	Local	NA	10180000	NA	NA	Europe	Increase
	SR	Local	NA	10180000	NA	NA	Europe	Increase
	Temporal beta-diversity	Local	NA	10180000	NA	NA	Europe	Stable
Ram et al. 2017	Abundance	Local	1.0	350000	18	1998-2015	Sweden	Increase
	SR	Regional	1.0	350000	18	1998-2015	Sweden	Increase
Reif et al. 2013	Spatial beta-diversity	Local	1.0	79000	23	1982-2004	Czech Rep.	Stable
	SR	Local	1.0	79000	23	1982-2004	Czech Rep.	Stable
	SR	National	1.0	79000	23	1982-2004	Czech Rep.	Stable
Schipper et al. 2016	Abundance	Local	5.0	24710000	40	1971-2010	Canada, USA, Mexico	Increase
	Diversity	Local	5.0	24710000	40	1971-2010	Canada, USA, Mexico	Increase
	Diversity	Local	5.0	24710000	40	1971-2010	Canada, USA, Mexico	Increase

Table 4.1: Trends of different metrics of biodiversity at various spatial and temporal scales *(continued)*

Reference	Metric	Spatial grain (Km²)	Temporal grain (year)	Spatial extent (Km²)	Temporal extent (year)	Years	Country	Trend
	Functional diversity	Local	5.0	24710000	40	1971-2010	Canada, USA, Mexico	Decrease
	Functional evenness	Local	5.0	24710000	40	1971-2010	Canada, USA, Mexico	Increase
	Functional richness	Local	5.0	24710000	40	1971-2010	Canada, USA, Mexico	Increase
	SR	Local	5.0	24710000	40	1971-2010	Canada, USA, Mexico	Increase
Sorte and Boecklen 2005	Abundance	Local	1.0	9834000	36	1968-2003	USA	Decrease
	Evenness	Local	1.0	9834000	36	-	USA	Decrease
	SR	Local	1.0	9834000	36	1968-2003	USA	Increase
Van Turnhout et al. 2007	SR	Regional	4.0	41543	28	1973-2000	Netherlands	Increase
	SR	Local	4.0	41543	28	1973-2000	Netherlands	Increase
	SR	National	4.0	41543	28	1973-2000	Netherlands	Increase
Wretenberg, Pärt, and Berg 2010	SR	Local	1.0	1800	11	1994-2004	Sweden	Decrease

Supplementary materials

Table 4.2: Supplementary informations about each article

Reference	Spatial grain (Km²)	Trend	Note
Barnagaud et al. 2017	Local	Increase	Not sure that it is at the road scale: "Taxonomic evenness showed a marginal, yet significant, non-linear increase from close to 0.54 in the first decade to 0.56 in the last decade (Table 1), suggesting a light trend towards a more even distribution of species' abundances among species within local assemblages "
	Local	Increase	Mean change of SR at the road scales Area of the road = (40/0.8)*(pi*4002) with a road of 40 Km with point counts spaced by 0.8 Km and a census radius of 400m
Bowler et al. 2021	National	Stable	Metric = MSI, as many and as intense increase (i.e. Czech Rep. and Switzerland) than decrease (i.e. Germany and Denmarl)
Chase et al. 2019	Local	Stable	NA
	Regional	Stable	NA
	Regional	Stable	NA
	Local	Increase	NA
	Local	Increase	NA
Chiron et al. 2013	Regional	Decrease	Concerning the spatial scale, predictions are made using the spatial unit of 4 Km² and the FBI is computed for each region of France, then meanned. Prediction with baseline scenario
	Regional	Decrease	FBI prediction with CAP greening cenario
	Regional	Decrease	FBI prediction with No Pillar I scenario
	Regional	Decrease	FBI prediction with biofuel scenario
Davey et al. 2012	Local	Increase	Metric = Simpson.They predict the metric using a GAM with spatial resolution of 1 Km². Then they show the trend for the mean value of the metric per year
	Local	Increase	NA
	Local	Increase	NA

Table 4.2: Supplementary informations about each article *(continued)*

Reference	Spatial grain (Km²)	Trend	Note
Harrison, Buckland, et al. 2014	Local	Increase	To assess the metric, they use a GAM to predict the abundance over the entire area of interest (spatial resolution = 1 Km²) and then compute the geometric mean of species abundance = Multi Species Index (as in Studeny et al. 2013) from the prediction. Data used to learn the GAM are sampled from plots of 1 Km². Farmland communities
	Local	Stable	Farmland communities, GoF (λ = -1) = weighted towards the rare species
	Local	Stable	Farmland communities, GoF (λ = -2) weighted towards the common species
Harrison, Yuan, et al. 2016	Local	Increase	Geomteric mean of species abundance, they predict the abundance with resolution of 1 Km² and then computed the metric for each 10000 Km² cell across Great Britain, Visited twice a year
	Local	Stable	GoF (λ = -1) = toward rare species" The goodness-of-fit-based measure of biodiversity suggests that both rare and common species made gains through much of Britain in the first half of the time period, and losses in the second half.", Visited twice a year / Increase first half and second second halfGoF (λ = -1)
	Local	Stable	GoF (λ = -2) = toward common species " The goodness-of-fit-based measure of biodiversity suggests that both rare and common species made gains through much of Britain in the first half of the time period, and losses in the second half.", Visited twice a year / Increase first half and second second half
Jarzyna and Jetz 2018	Regional	Increase	NA
	Regional	Increase	NA
	Regional	Increase	NA
	National	Increase	NA
	Global	Decrease	NA
	Regional	Increase	NA
	Regional	Increase	NA

Table 4.2: Supplementary informations about each article *(continued)*

Reference	Spatial grain (Km²)	Trend	Note
	Regional	Increase	NA
	National	Increase	NA
	Global	Stable	NA
Pilotto et al. 2020	Local	Stable	"Analyses of the trends in local biodiversity over large spatial scales"
	Local	Increase	Metric = Simpson, "Analyses of the trends in local biodiversity over large spatial scales"
	Local	Increase	"Analyses of the trends in local biodiversity over large spatial scales"
	Local	Stable	"Analyses of the trends in local biodiversity over large spatial scales"
Ram et al. 2017	Local	Increase	MSI for forest species, road of 8 Km with no limitations so assumed 200m
	Regional	Increase	SR for forest species meaned over roads, spatial grain = 8* .4 with road of 8 Km and census radius no limitations so assumed 200m
Reif et al. 2013	Local	Stable	Jaccard index, pairwise comparisions between transects
	Local	Stable	JPSP data, transect scale
	National	Stable	JPSP data, national scale
Schipper et al. 2016	Local	Increase	The metric (i.e. geometric mean) is meaned over each road. Area of the road = 50*(pi*4002) with 50 census point per road and a census radius of 400m
	Local	Increase	Metric = Shannon
	Local	Increase	Metric = Simpson
	Local	Decrease	NA
	Local	Increase	NA
	Local	Increase	NA
	Local	Increase	NA

Table 4.2: Supplementary informations about each article *(continued)*

Reference	Spatial grain (Km²)	Trend	Note
Sorte and Boecklen 2005	Local	Decrease	NA
	Local	Decrease	Metric = evenness
	Local	Increase	The metric is meaned over each road. Area of the road = 50*(pi*4002) with 50 census point per road and a census radius of 400m
Van Turnhout et al. 2007	Regional	Increase	For each region, the trend is computed
	Local	Increase	Mainly increase of SR but the proportion of negative trend were higher than for the regional scale
	National	Increase	National scale
Wretenberg, Pärt, and Berg 2010	Local	Decrease	looking at the trend through different environmental policies, " local species richness (i.e. at the scale of sites = 3 hectares) decreased significantly probably as a result of an overall reduced abundance of several species. "