Literature review

PhD candidate: François Leroy

Programme: Environmental Earth Sciences

Department: Spatial Sciences

"Mapping biodiversity changes across spatio-temporal scales"

Advisor: doc. Ing. Petra Šímová, Ph.D.
Consultant: Mgr. Petr Keil, PhD
Beginning of study: October 2020

Contents

Outline

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

The idea is to take every paper that talk about biodiversity trends (so far using just the species richness seems already a lot of paper) and to list **1)** which biodiversity metric they use **2)** which taxon/taxa they use, **3)** the spatial scale, **4)** the temporal scale and **5)** what is the dynamic (does the biodiversity metric increase/decrease/doesn't change over time/unclear).

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

I am using the "Advanced Research" tab of Web of Science which allows me skim through the entire literature using a convenient syntax. For instance:

```
AB = ((biodiversity OR species richness OR diversity) AND
(temporal trend* OR dynamic*) AND
(bird* OR avia*))
```

And

```
AB = ((biodiversity change index)  AND (bird*  OR avia*)  AND trend*)
```

And

```
AB = ((species richness) AND (bird* OR avia*) AND trend*)
```

And

```
ALL=(birds AND species richness AND temporal trend)
```

Dashboard

Reference paper

- 05/07/2021: research wos made with the literature review filter for the first query (stopped at #13) and created the second query (stopped at #2)

- 07/07/2021: questions to Petr: **1)** can the geometric mean of relative abundance + the weighted goodness of fit be used as biodiversity trend index, **2)** can the Farmland Bird Indicator (FBI) be used as biodiversity trend (for me it is more biodiversity health, Chiron et al 2013) **3)** what about the Red List Index trend? **4)** what about Multispecies population indexes?

- 08/07/2021: stopped at the article 41 for research #2.

- 12/08/2021: stopped at article 4 for research #4

- 13/08/2021: stopped at article 8 for research #4

- 17/08/2021: stopped at article 15 for research #4

- 18/08/2021: stopped at article 30 for research #4

- 19/08/2021: stopped at article 46 for research #4

- 20/08/2021: stopped at article 64 for research #4

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 et al.). 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.).

Biodiversity erosion is now known from everyone and political decisions has been stated in order to limit it (*e.g.* The Convention on Biological Diversity, 2010, 2002). However, these objectives have been so far not reached due mainly to our confusion and misunderstanding about biodiversity dynamic and how to determine it.

As a matter of fact, 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.* species, 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, b), the Shannon index (Shannon) ,the Simpson index (Simpson) or the Hill number (Hill). 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, a), Sørensen's (Sørensen) or Jaccard's (Jaccard) dissimilarity indexes (*e.g.* Keil et al.).

However, overall biodiversity (*i.e.* taking into account species of every taxa) may not be relevant for one's case study. Thus, several multi-species indicators have also been created, taking into account the abundances of indicator species giving information on the ecosystem health. The most known ones are the Red List Index (Butchart et al., b,a,c) or the Biodiversity Change Index (Normander et al.).

Using all the metrics cited above, we now know that the loss of global biodiversity is unprecedented. 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.). 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.; Dornelas et al.). 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 spatial 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). 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. For instance, the geometric mean of relative abundances or the goodness-of-fit statistic (Studeny et al.) are some of the baseline. Other multi-species indicators have also been created specifically for birds, such as the Farmland Bird Indicator (Gregory et al., a), the Forest Bird Indicator (Gregory et al., b) or the Wild Bird Indicator (Gregory and Strien).

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. 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.

2. Materials and Methods

I used the *"advanced serach"* tool of the ISI Web of Science Core collection database. It allowed me to write these four following queries using key words:

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.

Table 2.1: SR = species richness, Ab = abundance, Eve = evenness,

Reference	Metric	Spatial grain	Temporal grain	Spatial extent	Temporal extent	Years	Country	Trend
Barnagaud et al.	SR	0.5 Km^2	1 year	9,834 millions km^2	41 years	1970-2011	USA	Increase
Barnagaud et al.	Abundance	0.5 Km^2	1 year	9,834 millions km^2	41 years	1970-2011	USA	Decrease
Barnagaud et al.	Evenness	0.5 Km^2	1 year	9,834 millions km^2	41 years	1970-2011	USA	Increase
Barnagaud et al.	Functional richness	0.5 Km^2	1 year	9,834 millions km^2	41 years	1970-2011	USA	Increase
Barnagaud et al.	Functional dispersion	0.5 Km^2	1 year	9,834 millions km^2	41 years	1970-2011	USA	Stable
Barnagaud et al.	Functional evenness	0.5 Km^2	1 year	9,834 millions km^2	41 years	1970-2011	USA	Increase
Roels et al.	SR	0.04 Km^2	1 year	0.04 Km^2	5 years	NA	Panama	Increase
Roels et al.	Bird activity	0.04 Km^2	1 year	0.04 Km^2	5 years	NA	Panama	Increase
Wretenberg et al.	SR	0.03 Km^2	1 year	1800 km2	11 years	1994-2004	Sweden	Decrease
Ram et al.	SR	1.6 Km2	1 year	350 000 Km2	18 years	1998-2015	Sweden	Increase
Ram et al.	SR	1.6 Km2	1 year	350 000 Km2	18 years	1998-2015	Sweden	Stable
Ram et al.	SR	1.6 Km2	1 year	350 000 Km2	18 years	1998-2015	Sweden	Increase
Ram et al.	Multi-species indicator	1.6 Km2	1 year	350 000 Km2	18 years	1998-2015	Sweden	Increase
Ram et al.	Multi-species indicator	1.6 Km2	1 year	350 000 Km2	18 years	1998-2015	Sweden	Increase

Table 2.1: SR = species richness, Ab = abundance, Eve = evenness, *(continued)*

Reference	Metric	Spatial grain	Temporal grain	Spatial extent	Temporal extent	Years	Country	Trend
Harrison et al. (b)	Geometric mean	10 000 Km2	0.5 year	242 495 km^2	20 years	1994-2013	UK	Increase
Harrison et al. (b)	GoF (λ = -1)	10 000 Km2	0.5 year	242 495 km^2	20 years	1994-2013	UK	Stable
Harrison et al. (b)	GoF (λ = -2)	10 000 Km2	0.5 year	242 495 km^2	20 years	1994-2013	UK	Stable
Doxa et al.	FBI	4 Km^2	1 year	643 801 km^2	8 years	2001-2008	France	Increase
Doxa et al.	FBI	4 Km^2	1 year	643 801 km^2	8 years	2001-2008	France	Stable
Doxa et al.	FBI	4 Km^2	1 year	643 801 km^2	8 years	2001-2008	France	Stable
Arnold et al.	SR	0.02 Km^2	1 year	1000 km^2	100 years	NA	Trinidad	Stable
Arnold et al.	Shannon	0.02 Km^2	1 year	1000 km^2	100 years	NA	Trinidad	Stable
Arnold et al.	Simpson	0.02 Km^2	1 year	1000 km^2	100 years	NA	Trinidad	Stable
Xu et al.	SR	6.56 Km^2	1 year	6.56 Km^2	12 years	2002-2013	China	Decrease
Jiguet et al.	GBI (Generalist Bird Indicator)	643 801 km^2	1 year	643 801 km^2	22 years	1989-2009	France	Increase
Jiguet et al.	EU bird directive	643 801 km^2	1 year	643 801 km^2	22 years	1989-2009	France	Increase
Jiguet et al.	RLI (Red list Index)	643 801 km^2	1 year	643 801 km^2	22 years	1989-2009	France	Decrease
Keten	SR	1.7 Km^2	1 year	1.7 Km^2	11 years	2006-2016	Turkey	Stable
Davey et al.	Simpson	1 km^2	1 year	242 495 km^2	13 years	1994-2006	UK	Increase
Davey et al.	SR	1 km^2	1 year	242 495 km^2	13 years	1994-2006	UK	Increase

Table 2.1: SR = species richness, Ab = abundance, Eve = evenness, *(continued)*

Reference	Metric	Spatial grain	Temporal grain	Spatial extent	Temporal extent	Years	Country	Trend
Davey et al.	Evenness	1 km^2	1 year	242 495 km^2	13 years	1994-2006	UK	Increase
Siriwardena et al.	Diversity profile	32300 Km^2	5 years	32300 Km^2	36 years	1965-2000	UK	Stable
Christian et al.	SR	15.4 km2	NA	15.4 km2	209 ans	1898-2006	France	Increase
Dittrich et al.	SR	0.053 km^2	0.33 year	53 Km^2	3 years	2010-2012	Spain	Increase
Dittrich et al.	SR	0.053 km^2	1 year	53 Km^2	3 years	2010-2012	Spain	Increase
Dittrich et al.	SR	0.083 km^2	0.33 year	53 Km^2	3 years	2012-2014	UK	Stable
Dittrich et al.	SR	0.083 km^2	1 year	53 Km^2	3 years	2012-2014	UK	Stable
Sirami and Monadjem	SR	0.38 km^2	1 year	430 Km^2	21 years	1998-2018	Swaziland	Decrease
García-Navas et al.	spatial beta-diversity	267 Km^2	1 year	267 Km^2	20 years	1999-2018	Switzerland	Decrease
McGeoch et al.	RLI (Red list Index)	NA	1 year	148,939,063.133 km^2	11 years	1998-2008	Worldwide	Decrease
Ellis et al.	SR	0.16 Km^2	1 year	NA	21 years	1994-2014	Oregon, USA	Stable
Ellis et al.	SR	0.16 Km^2	1 year	NA	21 years	1994-2014	Oregon, USA	Stable
Ellis et al.	SR	0.16 Km^2	1 year	NA	21 years	1994-2014	Oregon, USA	Increase
Ellis et al.	SR	0.48 Km^2	1 year	NA	21 years	1994-2014	Oregon, USA	Stable
Ellis et al.	Shannon	0.16 Km^2	1 year	NA	21 years	1994-2014	Oregon, USA	Increase
Ellis et al.	Shannon	0.16 Km^2	1 year	NA	21 years	1994-2014	Oregon, USA	Decrease
Ellis et al.	Shannon	0.16 Km^2	1 year	NA	21 years	1994-2014	Oregon, USA	Increase
Ellis et al.	Shannon	0.48 Km^2	1 year	NA	21 years	1994-2014	Oregon, USA	Increase

Table 2.1: SR = species richness, Ab = abundance, Eve = evenness, *(continued)*

Reference	Metric	Spatial grain	Temporal grain	Spatial extent	Temporal extent	Years	Country	Trend
Ellis et al.	Simpson	0.16 Km^2	1 year	NA	21 years	1994-2014	Oregon, USA	Increase
Ellis et al.	Simpson	0.16 Km^2	1 year	NA	21 years	1994-2014	Oregon, USA	Decrease
Ellis et al.	Simpson	0.16 Km^2	1 year	NA	21 years	1994-2014	Oregon, USA	Increase
Ellis et al.	Simpson	0.48 Km^2	1 year	NA	21 years	1994-2014	Oregon, USA	Decrease
Sicurella et al.	Occurence (%)	17 370.3 Km^2	1 year	23 844 km^2	22 years	1992-2013	Lombardy, Italy	Stable
Sicurella et al.	Occurence (%)	1 403.9 Km^2	1 year	23 844 km^2	22 years	1992-2013	Lombardy, Italy	Stable
Sicurella et al.	Occurence (%)	6 461.9 Km^2	1 year	23 844 km^2	22 years	1992-2013	Lombardy, Italy	Increase
Nally	SR	0.49 Km^2	1 day	10 Km^2	3 years	1994-1996	Australia	Increase
Latta et al.	SR	0.000942 Km^2	2 years	NA	14 years	1994-2007	Ecuador	Decrease
Latta et al.	SR	0.000942 Km^2	2 years	NA	14 years	1994-2007	Ecuador	Decrease
Scarton	SR	0.55 Km^2	2 years	0.55 Km^2	25 years	1990-2014	Lagoon of Venice, Italy	Increase
Scarton	Shannon	0.55 Km^2	2 years	0.55 Km^2	25 years	1990-2014	Lagoon of Venice, Italy	Increase
Scarton	Temporal beta-diversity	0.55 Km^2	2 years	0.55 Km^2	25 years	1990-2014	Lagoon of Venice, Italy	Increase
Scarton	Temporal beta-diversity	0.55 Km^2	2 years	0.55 Km^2	25 years	1990-2014	Lagoon of Venice, Italy	Increase
Chiron et al.	FBI	4 Km^2	1 year	643 801 Km^2	14 years	2007-2020	France	Decrease
Chiron et al.	FBI	4 Km^2	1 year	643 801 Km^2	14 years	2007-2020	France	Decrease
Chiron et al.	FBI	4 Km^2	1 year	643 801 Km^2	14 years	2007-2020	France	Decrease
Chiron et al.	FBI	4 Km^2	1 year	643 801 Km^2	14 years	2007-2020	France	Decrease

Table 2.1: SR = species richness, Ab = abundance, Eve = evenness, *(continued)*

Reference	Metric	Spatial grain	Temporal grain	Spatial extent	Temporal extent	Years	Country	Trend
Eglington and Pearce-Higgins	FBI	1 Km^2	1 year	242 495 km^2	39 years	1970-2008	UK	Decrease
Harrison et al. (a)	Geometric mean	10 000 km^2	1 year	200 000 km^2	18 years	1994-2011	Great Britain, UK	Stable
Harrison et al. (a)	GoF (λ = -1)	10 000 km^2	1 year	200 000 km^2	18 years	1994-2011	Great Britain, UK	Decrease
Harrison et al. (a)	GoF (λ = -2)	10 000 km^2	1 year	200 000 km^2	18 years	1994-2011	Great Britain, UK	Increase
Harrison et al. (a)	Geometric mean	10 000 km^2	1 year	200 000 km^2	18 years	1994-2011	Great Britain, UK	Increase
Harrison et al. (a)	GoF (λ = -1)	10 000 km^2	1 year	200 000 km^2	18 years	1994-2011	Great Britain, UK	Decrease
Harrison et al. (a)	GoF (λ = -2)	10 000 km^2	1 year	200 000 km^2	18 years	1994-2011	Great Britain, UK	Increase
Juslén et al.	RLI (Red list Index)	338 440 km^2	1 year	338 440 km^2	10 years	2001-2010	Finland	Decrease
Normander et al.	BCI (Biodviersity Change Index)	84 266 km^2	NA	1 260 663 km^2	16 years	1990-2005	Finland, Sweden, Norway, Denmark and Iceland	Decrease

Table 2.1: SR = species richness, Ab = abundance, Eve = evenness, *(continued)*

Reference	Metric	Spatial grain	Temporal grain	Spatial extent	Temporal extent	Years	Country	Trend
Normander et al.	BCI (Biodviersity Change Index)	529,831 km^2	NA	1 260 663 km^2	16 years	1990-2005	Finland, Sweden, Norway, Denmark and Iceland	Stable
Normander et al.	BCI (Biodviersity Change Index)	163 131 km^2	NA	1 260 663 km^2	16 years	1990-2005	Finland, Sweden, Norway, Denmark and Iceland	Decrease
Schipper et al.	Geometric mean	32 Km^2	5 years	21 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Geometric mean	32 Km^2	5 years	21 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Decrease
Schipper et al.	Geometric mean	32 Km^2	5 years	21 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Geometric mean	32 Km^2	5 years	22 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Geometric mean	32 Km^2	5 years	23 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Stable
Schipper et al.	SR	32 Km^2	5 years	24 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Increase

Table 2.1: SR = species richness, Ab = abundance, Eve = evenness, *(continued)*

Reference	Metric	Spatial grain	Temporal grain	Spatial extent	Temporal extent	Years	Country	Trend
Schipper et al.	SR	32 Km²	5 years	25 792 000 km²	40 years	1971-2010	Canada, USA, Mexico	Decrease
Schipper et al.	SR	32 Km²	5 years	26 792 000 km²	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	SR	32 Km²	5 years	27 792 000 km²	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	SR	32 Km²	5 years	28 792 000 km²	40 years	1971-2010	Canada, USA, Mexico	Stable
Schipper et al.	Shannon	32 Km²	5 years	29 792 000 km²	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Shannon	32 Km²	5 years	30 792 000 km²	40 years	1971-2010	Canada, USA, Mexico	Decrease
Schipper et al.	Shannon	32 Km²	5 years	31 792 000 km²	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Shannon	32 Km²	5 years	32 792 000 km²	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Shannon	32 Km²	5 years	33 792 000 km²	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Simpson	32 Km²	5 years	34 792 000 km²	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Simpson	32 Km²	5 years	35 792 000 km²	40 years	1971-2010	Canada, USA, Mexico	Stable

Table 2.1: SR = species richness, Ab = abundance, Eve = evenness, *(continued)*

Reference	Metric	Spatial grain	Temporal grain	Spatial extent	Temporal extent	Years	Country	Trend
Schipper et al.	Simpson	32 Km^2	5 years	36 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Simpson	32 Km^2	5 years	37 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Simpson	32 Km^2	5 years	38 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Functional richness	32 Km^2	5 years	39 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Functional richness	32 Km^2	5 years	40 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Decrease
Schipper et al.	Functional richness	32 Km^2	5 years	41 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Functional richness	32 Km^2	5 years	42 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Functional richness	32 Km^2	5 years	43 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Decrease
Schipper et al.	Functional evenness	32 Km^2	5 years	44 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Functional evenness	32 Km^2	5 years	45 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Functional evenness	32 Km^2	5 years	46 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Decrease

Table 2.1: SR = species richness, Ab = abundance, Eve = evenness, *(continued)*

Reference	Metric	Spatial grain	Temporal grain	Spatial extent	Temporal extent	Years	Country	Trend
Schipper et al.	Functional evenness	32 Km^2	5 years	47 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Functional evenness	32 Km^2	5 years	48 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Functional divergence	32 Km^2	5 years	49 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Decrease
Schipper et al.	Functional divergence	32 Km^2	5 years	50 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Functional divergence	32 Km^2	5 years	51 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Decrease
Schipper et al.	Functional divergence	32 Km^2	5 years	52 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Decrease
Schipper et al.	Functional divergence	32 Km^2	5 years	53 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Decrease
Schipper et al.	Functional dispersion	32 Km^2	5 years	54 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Functional dispersion	32 Km^2	5 years	55 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Functional dispersion	32 Km^2	5 years	56 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Increase
Schipper et al.	Functional dispersion	32 Km^2	5 years	57 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Increase

Table 2.1: SR = species richness, Ab = abundance, Eve = evenness, *(continued)*

Reference	Metric	Spatial grain	Temporal grain	Spatial extent	Temporal extent	Years	Country	Trend
Schipper et al.	Functional dispersion	32 Km^2	5 years	58 792 000 km^2	40 years	1971-2010	Canada, USA, Mexico	Decrease
Pilotto et al.	SR	1402 Km^2	0.08 year	1402 Km^2	27 years	1991-2017	Belgium	Decrease
Pilotto et al.	Simpson	1402 Km^2	0.08 year	1402 Km^2	27 years	1991-2017	Belgium	Increase
Pilotto et al.	Abundance	1402 Km^2	0.08 year	1402 Km^2	27 years	1991-2017	Belgium	Decrease
Pilotto et al.	Temporal beta-diversity	1402 Km^2	0.08 year	1402 Km^2	27 years	1991-2017	Belgium	Stable
Pilotto et al.	SR	509 Km^2	1 year	509 Km^2	43 years	1976-2017	Bulgaria	Increase
Pilotto et al.	Simpson	509 Km^2	1 year	509 Km^2	43 years	1976-2017	Bulgaria	Stable
Pilotto et al.	Abundance	509 Km^2	1 year	509 Km^2	43 years	1976-2017	Bulgaria	Increase
Pilotto et al.	Temporal beta-diversity	509 Km^2	1 year	509 Km^2	43 years	1976-2017	Bulgaria	Decrease
Pilotto et al.	SR	10 Km^2	1 year	10 Km^2	43 years	1976-2017	Bulgaria	Increase
Pilotto et al.	Simpson	10 Km^2	1 year	10 Km^2	43 years	1976-2017	Bulgaria	Stable
Pilotto et al.	Abundance	10 Km^2	1 year	10 Km^2	43 years	1976-2017	Bulgaria	Stable
Pilotto et al.	Temporal beta-diversity	10 Km^2	1 year	10 Km^2	43 years	1976-2017	Bulgaria	No trend

References

Arnold, H., Deacon, A. E., Hulme, M. F., Sansom, A., Jaggernauth, D., and Magurran, A. E. Contrasting trends in biodiversity of birds and trees during succession following cacao agroforest abandonment. 58(6):1248–1260. _eprint: https://besjournals.onlinelibrary.wiley.com/doi/pdf/10.1111/1365-2664.13869.

Barnagaud, J.-Y., Gaüzère, P., Zuckerberg, B., Princé, K., and Svenning, J.-C. Temporal changes in bird functional diversity across the united states. 185(4):737–748.

Barnosky, A. D., Matzke, N., Tomiya, S., Wogan, G. O. U., Swartz, B., Quental, T. B., Marshall, C., McGuire, J. L., Lindsey, E. L., Maguire, K. C., Mersey, B., and Ferrer, E. A. Has the earth's sixth mass extinction already arrived? 471(7336):51–57. Number: 7336 Publisher: Nature Publishing Group.

Bejček, V. and Stastný. Velké ptačí mapování.

Blowes, S. A., Supp, S. R., Antão, L. H., Bates, A., Bruelheide, H., Chase, J. M., Moyes, F., Magurran, A., McGill, B., Myers-Smith, I. H., Winter, M., Bjorkman, A. D., Bowler, D. E., Byrnes, J. E. K., Gonzalez, A., Hines, J., Isbell, F., Jones, H. P., Navarro, L. M., Thompson, P. L., Vellend, M., Waldock, C., and Dornelas, M. The geography of biodiversity change in marine and terrestrial assemblages. 366(6463):339–345. Publisher: American Association for the Advancement of Science Section: Research Article.

Butchart, S., Stattersfield, A., Baillie, J., Bennun, L., Stuart, S., Akçakaya, H., Hilton-Taylor, C., and Mace, G. Using red list indices to measure progress towards the 2010 target and beyond. 360(1454):255–268. Publisher: Royal Society.

Butchart, S. H. M., Akçakaya, H. R., Chanson, J., Baillie, J. E. M., Collen, B., Quader, S., Turner, W. R., Amin, R., Stuart, S. N., and Hilton-Taylor, C. Improvements to the red list index. 2(1):e140. Publisher: Public Library of Science.

Butchart, S. H. M., Stattersfield, A. J., Bennun, L. A., Shutes, S. M., Akçakaya, H. R., Baillie, J. E. M., Stuart, S. N., Hilton-Taylor, C., and Mace, G. M. Measuring global trends in the status of biodiversity: Red list indices for birds. 2(12):e383.

Chase, J. M., McGill, B. J., Thompson, P. L., Antão, L. H., Bates, A. E., Blowes, S. A., Dornelas, M., Gonzalez, A., Magurran, A. E., Supp, S. R., Winter, M., Bjorkman, A. D., Bruelheide, H., Byrnes, J. E. K., Cabral, J. S., Elahi, R., Gomez, C., Guzman, H. M., Isbell, F., Myers-Smith, I. H., Jones, H. P., Hines, J., Vellend, M., Waldock, C., and O'Connor, M. Species richness change across spatial scales. 128(8):1079–1091.

Chiron, F., Princé, K., Paracchini, M. L., Bulgheroni, C., and Jiguet, F. Forecasting the potential impacts of CAP-associated land use changes on farmland birds at the national level. 176:17–23.

Christian, K., Isabelle, L. V., Frédéric, J., and Vincent, D. More species, fewer specialists: 100 years of changes in community composition in an island biogeographical study. 15(4):641–648. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1472-4642.2009.00569.x.

Davey, C. M., Chamberlain, D. E., Newson, S. E., Noble, D. G., and Johnston, A. Rise of the generalists: evidence for climate driven homogenization in avian communities. 21(5):568–578. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1466-8238.2011.00693.x.

Dittrich, R., Giessing, B., Benito, M. M., Russ, A., Wolf, C., Foudoulakis, M., and Norman, S. Multiyear monitoring of bird communities in chlorpyrifos-treated orchards in spain and the united kingdom: Spatial and temporal trends in species composition, abundance, and site fidelity. 38(3):616–629. _eprint: https://setac.onlinelibrary.wiley.com/doi/pdf/10.1002/etc.4317.

Dornelas, M., Magurran, A. E., Buckland, S. T., Chao, A., Chazdon, R. L., Colwell, R. K., Curtis, T., Gaston, K. J., Gotelli, N. J., Kosnik, M. A., McGill, B., McCune, J. L., Morlon, H., Mumby, P. J., Øvreås, L., Studeny, A., and Vellend, M. Quantifying temporal change in biodiversity: challenges and opportunities. 280(1750):20121931.

Doxa, A., Bas, Y., Paracchini, M. L., Pointereau, P., Terres, J.-M., and Jiguet, F. Low-intensity agriculture increases farmland bird abundances in france. 47(6):1348–1356. _eprint: https://besjournals.onlinelibrary.wiley.com/doi/pdf/10.1111/j.1365-2664.2010.01869.x.

Eglington, S. M. and Pearce-Higgins, J. W. Disentangling the relative importance of changes in climate and land-use intensity in driving recent bird population trends. 7(3):e30407.

Ellis, M. S., Kennedy, P. L., Edge, W. D., and Sanders, T. A. Twenty-year changes in riparian bird communities of east-central oregon. 131(1):43–61. Publisher: The Wilson Ornithological Society.

García-Navas, V., Sattler, T., Schmid, H., and Ozgul, A. Temporal homogenization of functional and beta diversity in bird communities of the swiss alps. 26(8):900–911. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/ddi.13076.

Gregory, R. D. and Strien, A. v. Wild bird indicators: using composite population trends of birds as measures of environmental health. 9(1):3–22.

Gregory, R. D., van Strien, A., Vorisek, P., Gmelig Meyling, A. W., Noble, D. G., Foppen, R. P., and Gibbons, D. W. Developing indicators for european birds. 360(1454):269–288. Publisher: Royal Society.

Gregory, R. D., Vorisek, P., Strien, A. V., Meyling, A. W. G., Jiguet, F., Fornasari, L., Reif, J., Chylarecki, P., and Burfield, I. J. Population trends of widespread woodland birds in europe. 149:78–97. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1474-919X.2007.00698.x.

Harrison, P. J., Buckland, S. T., Yuan, Y., Elston, D. A., Brewer, M. J., Johnston, A., and Pearce-Higgins, J. W. Assessing trends in biodiversity over space and time using the example of british breeding birds. 51(6):1650–1660. _eprint: https://besjournals.onlinelibrary.wiley.com/doi/pdf/10.1111/1365-2664.12316.

Harrison, P. J., Yuan, Y., Buckland, S. T., Oedekoven, C. S., Elston, D. A., Brewer, M. J., Johnston, A., and Pearce-Higgins, J. W. Quantifying turnover in biodiversity of british breeding birds. 53(2):469–478. _eprint: https://besjournals.onlinelibrary.wiley.com/doi/pdf/10.1111/1365-2664.12539.

Hill, M. O. Diversity and evenness: A unifying notation and its consequences. 54(2):427–432. _eprint: https://esajournals.onlinelibrary.wiley.com/doi/pdf/10.2307/1934352.

Jaccard, P. The distribution of the flora in the alpine zone.1. 11(2):37–50. _eprint: https://nph.onlinelibrary.wiley.com/doi/pdf/10.1111/j.1469-8137.1912.tb05611.x.

Jiguet, F., Devictor, V., Julliard, R., and Couvet, D. French citizens monitoring ordinary birds provide tools for conservation and ecological sciences. 44:58–66.

Juslén, A., Hyvärinen, E., and Virtanen, L. K. Application of the red-list index at a national level for multiple species groups. 27(2):398–406. _eprint: https://conbio.onlinelibrary.wiley.com/doi/pdf/10.1111/cobi.12016.

Keil, P., Schweiger, O., Kühn, I., Kunin, W. E., Kuussaari, M., Settele, J., Henle, K., Brotons, L., Pe'er, G., Lengyel, S., Moustakas, A., Steinicke, H., and Storch, D. Patterns of beta diversity in europe: the role of climate, land cover and distance across scales. 39(8):1473–1486. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1365-2699.2012.02701.x.

Keten. Temporal patterns of wetland-associated bird assemblages in altered wetlands in turkey.

Latta, S. C., Tinoco, B. A., Astudillo, P. X., and Graham, C. H. Patterns and magnitude of temporal change in avian communities in the ecuadorian andes. 113(1):24–40.

McGeoch, M. A., Butchart, S. H. M., Spear, D., Marais, E., Kleynhans, E. J., Symes, A., Chanson, J., and Hoffmann, M. Global indicators of biological invasion: species numbers, biodiversity impact and policy responses. 16(1):95–108. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1472-4642.2009.00633.x.

Nally, R. M. Monitoring forest bird communities for impact assessment: The influence of sampling intensity and spatial scale. 82(3):355–367.

Normander, B., Levin, G., Auvinen, A.-P., Bratli, H., Stabbetorp, O., Hedblom, M., Glimskär, A., and Gudmundsson, G. A. Indicator framework for measuring quantity and quality of biodiversity—exemplified in the nordic countries. 13(1):104–116.

Pereira, H. M., Navarro, L. M., and Martins, I. S. Global biodiversity change: The bad, the good, and the unknown. 37(1):25–50.

Pilotto, F., Kühn, I., Adrian, R., Alber, R., Alignier, A., Andrews, C., Bäck, J., Barbaro, L., Beaumont, D., Beenaerts, N., Benham, S., Boukal, D. S., Bretagnolle, V., Camatti, E., Canullo, R., Cardoso, P. G., Ens, B. J., Everaert, G., Evtimova, V., Feuchtmayr, H., García-González, R., Gómez García, D., Grandin, U., Gutowski, J. M., Hadar, L., Halada, L., Halassy, M., Hummel, H., Huttunen, K.-L., Jaroszewicz, B., Jensen, T. C., Kalivoda, H., Schmidt, I. K., Kröncke, I., Leinonen, R., Martinho, F., Meesenburg, H., Meyer, J., Minerbi, S., Monteith, D., Nikolov, B. P., Oro, D., Ozoliņš, D., Padedda, B. M., Pallett, D., Pansera, M., Pardal, M. n., Petriccione, B., Pipan, T., Pöyry, J., Schäfer, S. M., Schaub, M., Schneider, S. C., Skuja, A., Soetaert, K., Spriņģe, G., Stanchev, R., Stockan, J. A., Stoll, S., Sundqvist, L., Thimonier, A., Van Hoey, G., Van Ryckegem, G., Visser, M. E., Vorhauser, S., and Haase, P. Meta-analysis of multidecadal biodiversity trends in europe. 11(1):3486. Bandiera_abtest: a Cc_license_type: cc_by Cg_type: Nature Research Journals Number: 1 Primary_atype: Research Publisher: Nature Publishing Group Subject_term: Biodiversity;Climate-change ecology;Macroecology Subject_term_id: biodiversity;climate-change-ecology;macroecology.

Ram, D., Axelsson, A.-L., Green, M., Smith, H. G., and Lindström, k. What drives current population trends in forest birds – forest quantity, quality or climate? a large-scale analysis from northern europe. 385:177–188.

Roels, S., Hannay, M., and Lindell, C. Recovery of bird activity and species richness in an early-stage tropical forest restoration. 14(1). Publisher: The Resilience Alliance.

Scarton, F. Long-term trend of the waterbird community breeding in a heavily man-modified coastal lagoon: the case of the important bird area “lagoon of venice”. 21(1):35–45.

Schipper, A. M., Belmaker, J., Miranda, M. D. d., Navarro, L. M., Böhning-Gaese, K., Costello, M. J., Dornelas, M., Foppen, R., Hortal, J., Huijbregts, M. A. J., Martín-López, B., Pettorelli, N., Queiroz, C., Rossberg, A. G., Santini, L., Schiffers, K., Steinmann, Z. J. N., Visconti, P., Rondinini, C., and Pereira, H. M. Contrasting changes in the abundance and diversity of north american bird assemblages from 1971 to 2010. 22(12):3948–3959. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/gcb.13292.

Shannon, C. E. A mathematical theory of communication. 27(3):379–423. Conference Name: The Bell System Technical Journal.

Sicurella, B., Orioli, V., Pinoli, G., Ambrosini, R., and Bani, L. Effectiveness of the system of protected areas of lombardy (northern italy) in preserving breeding birds. 28(3):475–492. Publisher: Cambridge University Press.

Simpson, E. H. Measurement of diversity. 163(4148):688–688. Bandiera_abtest: a Cg_type: Nature Research Journals Number: 4148 Primary_atype: Research Publisher: Nature Publishing Group.

Sirami, C. and Monadjem, A. Changes in bird communities in swaziland savannas between 1998 and 2008 owing to shrub encroachment. 18(4):390–400. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1472-4642.2011.00810.x.

Siriwardena, G. M., Henderson, I. G., Noble, D. G., and Fuller, R. J. How can assemblage structure indices improve monitoring of change in bird communities using ongoing survey data? 104:669–685.

Sørensen, T. J. *A method of establishing groups of equal amplitude in plant sociology based on similarity of species content and its application to analyses of the vegetation on Danish commons.* I kommission hos E. Munksgaard. OCLC: 4713331.

Studeny, A. C., Buckland, S. T., Illian, J. B., Johnston, A., and Magurran, A. E. Goodness of fit measures of evenness: a new tool for exploring changes in community structure. 2(2):art15. _eprint: https://esajournals.onlinelibrary.wiley.com/doi/pdf/10.1890/ES10-00074.1.

The Convention on Biological Diversity, B. The convention on biological diversity. Publisher: Secretariat of the Convention on Biological Diversity.

Whittaker, R. H. Evolution and measurement of species diversity. 21(2):213–251. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.2307/1218190.

Whittaker, R. H. Vegetation of the siskiyou mountains, oregon and california. 30(3):279–338. _eprint: https://esajournals.onlinelibrary.wiley.com/doi/pdf/10.2307/1943563.

Wretenberg, J., Pärt, T., and Berg, k. Changes in local species richness of farmland birds in relation to land-use changes and landscape structure. 143(2):375–381.

Xu, X., Xie, Y., Qi, K., Luo, Z., and Wang, X. Detecting the response of bird communities and biodiversity to habitat loss and fragmentation due to urbanization. 624:1561–1576.