About synchrony among birds

March 29, 2018

1 Introduction

2 Methods

2.1 Creation of a monthly snapshot of birds abundance in Teich

2.2 Synchrony: variance-ratio

We follow Loreau and Mazancourt (2008) and first use a community-wide synchrony index,

$$\phi = \frac{\mathrm{var}(C)}{\left(\sum_{i=1}^{n} \sqrt{\mathrm{var}(P_i)}\right)^2} \tag{1}$$

where $\mathrm{var}(C)$ is the variance of the whole community, made of n species, and $\mathrm{var}(P_i)$ is the variance of separated populations. This statistic varies between 0 (no synchrony, which can be viewed as compensation) and 1 (synchrony).

Another index is possible, built by Gross et al. (2013)

$$\eta = \frac{1}{n} \sum_i \mathrm{Corr}(P_i, \sum_{j \neq i} P_j) \tag{2}$$

The index described in eq. 2 varies between -1 (compensation, total biomass is constant) and 1 (synchrony), while 0 represents a case where all populations fluctuate independently. The assessment of independent dynamics is the main difference from eq. 1.

Being an aggregated value, the interpretation of these statistics can be difficult when the dynamics of the populations are not stationary, different species play separate roles in the community, or when we want to consider different frequencies. Indeed, computing this statistic over a year means computing the common responses of different species to the seasonal variability. On the other hand, computing this statistic for a fixed period of time in the year (a month, or a season), over several years, means computing the common responses to inter-annual variability which can be linked to anthropogenic changes. This does not mean that the first index, over a single year, would not contain part of this information, but it is more likely to be hidden by a more visible and stronger phenomenon such as the season. In addition to environmental variability, the birds' phenology has to be considered as some of them are just passing in the reserve while migrating to the South, some of them stop for breeding and others are there all year-round. This also changes the way we can interprete the synchrony between birds for months when breeding or migration is common.

We therefore considered several scales in our analyses: temporal scale was considered by computing synchrony at the monthly, seasonal and yearly scale; taxonomic scale was considered by computing a population-wide index, then using only the most frequent species, and finally considering only separate groups of species with a known ecology (9 species of *Anas*, 12 species of *Calidris*, and waders[1]). The taxonomic precision of the dataset was also considered by keeping separate species or grouping them by genera. Finally, anthropogenic changes were considered by separating the years before and after 2006, when a change in water management was made.

We computed these two statistics using the package 'codyn' in R (Hallett et al. 2016).

[1] We should also consider the migratory birds, but this means we have to know when and where they migrate: I assume that we both have birds coming from the North to spend the winter here and birds coming from the South in the summer... Right?

Dealing with mean values and 0's This dataset is made of presence-only data, leading to a lot of missing abundances for certain species and certain months. The codyn package replaces them with 0. When confronted to averaging over different periods (month or season), we had to choose between averaging observed values and couting a missing value as a 0. For example, a bird whose abundance has been counted only in February for a given year, with abundance X, can either have an average abundance of X (first version) or X/3 (if we consider a season with 3 months, second version). We tried both.

Season definition There are different ways of computing the season: the first one we used was based on 'official' season (winter beginning in January and ending in March, spring beginning in April and ending in June, and so on) and the second one we used separated only 'wintering season' and 'breeding season'. The first definition we had of these two seasons was based on the observation of the time series [Here, Christelle, maybe you can add how you did it?]. The wintering period was defined as the 5 months between October and February while the breeding period covered te four months between April and July. We wanted to assess the impact of this somehow arbitrary definition on the final result and varied both the number of months in each period and the beginning of the wintering period, keeping the same period of time between wintering and breeding [Fred, we need to consult ornithologists here].

Migratory birds The migratory status of each bird was assessed based on the data from http://www.oiseaux-nature.com/liste_oiseaux_france.html. Based on this database, we can identify only 50% of all species, even for frequent species only (see Fig. 1). [2]

2.3 Synchrony: frequency-based analyses

[2]They cite the 'Comité de l'Avifaune française', but I think it's only for the categories A-D, not for the migration. We need to find a 'citable' reference, or to talk to CF about this. We also have to deal with such definition as "Nicheur sédentaire Migrateur"

3 Results

3.1 Description of the data set

During the 43 years of observations, 279 different species were recorded. Among them, 60 were recorded more than 75 times (Table 1[3]).

#	Latin	English	#	Latin	English
1	Fulica atra	Eurasian coot	31	Casmerodius albus	Great egret
2	Anas crecca	Eurasian teal	32	Limosa limosa	Black-tailed godwit
3	Anas clypeata / Spatula clypeata	Northern shoveler	33	Podiceps cristatus	Great-crested grebe
4	Anas platyrhynchos	Mallard	34	Netta rufina	Red-crested pochard
5	Ardea cinerea	Grey heron	35	Anas querquedula / Spatula querquedula	Garganey
6	Anas acuta	Northern pintail	36	Actitis hypoleucos	Common sandpiper
7	Nycticorax nycticorax	Night heron	37	Tringa nebularia	Common greenshank
8	Phalacrocorax carbo	Great cormorant	38	Calidris minuta / Erolia minuta	Little stint
9	Aythya ferina	Common pochard	39	Recurvirostra avosetta	Pied avocet
10	Egretta garzetta	Little egret	40	Circus aeruginosus	Western marsh harrier
11	Tadorna tadorna	Common shelduck	41	Tringa erythropus	Spotted redshank
12	Ciconia ciconia	White stork	42	Gallinago gallinago	Common snipe
13	Chroicocephalus ridibundus	Black-headed gull	43	Vanellus vanellus	Northern lapwing
14	Cygnus olor	Mute swan	44	Calidris canutus	Red knot
15	Anas strepera / Mareca strepera	Gadwall	45	Limosa lapponica	Bar-tailed godwit
16	Platalea leucorodia	Eurasian spoonbill	46	Charadrius dubius	Little ringed plover
17	Anser anser	Greylag goose	47	Numenius arquata	Eurasian curlew
18	Aythya fuligula	Tufted duck	48	Larus michahellis	Yellow-legged gull
19	Tachybaptus ruficollis	Little grebe	49	Tringa ochropus	Green sandpiper
20	Gallinula chloropus	Common moorhen	50	Calidris ferruginea	Curlew sandpiper
21	Rallus aquaticus	Water rail	51	Arenaria interpres	Ruddy turnstone
22	Larus marinus	Great black-backed gull	52	Falco peregrinus	Peregrine falcon
23	Bubulcus ibis	Cattle egret	53	Milvus migrans	Black kite
24	Anas penelope / Mareca penelope	Widgeon	54	Accipiter nisus	Eurasian sparrowhawk
25	Calidris alpina	Dunlin	55	Threskiornis aethiopicus	African sacred ibis
26	Larus argentatus	European herring gull	56	Himantopus himantopus	Black-winged stilt
27	Charadrius hiaticula	Ringed plover	57	Podiceps nigricollis	Black-necked grebe
28	Pluvialis squatarola	Grey plover	58	Alcedo atthis	Common kingfisher
29	Larus fuscus	Lesser black-backed gull	59	Philomachus pugnax / Calidris pugnax	Ruff
30	Tringa totanus	Redshank	60	Numenius phaeopus	Whimbrel

Table 1: Latin and common names of the most frequent species (more than 75 observations over 615 dates)

[3] I realize here that "Anas" tends to be replaced by synonymous genera, won't it be a problem when using our analysis on "Anas" only?

#	Latin	English
1	Recurvirostra avosetta	Pied avocet
2	Limosa limosa	Black-tailed godwit
3	Limosa lapponica	Bar-tailed godwit
4	Calidris temminckii	Temminck's stint
5	Calidris canutus	Red knot
6	Calidris alba	Sanderling
7	Calidris alpina	Dunlin
8	Calidris minuta	Little stint
9	Calidris maritima	Purple sandpiper
10	Gallinago gallinago	Common snipe
11	Tringa flavipes	Lesser yellowlegs
12	Tringa nebularia	Common greenshank
13	Tringa erythropus	Spotted redshank
14	Tringa ochropus	Green sandpiper
15	Tringa totanus	Common redshank
16	Tringa glareola	Wood sandpiper
17	Actitis hypoleucos	Common sandpiper
18	Philomachus pugnax	Ruff
19	Numenius arquata	Eurasian curlew
20	Numenius phaeopus	Whimbrel
21	Himantopus himantopus	Black-winged stilt
22	Charadrius hiaticula	Ringed plover
23	Charadrius alexandrinus	Kentish plover
24	Haematopus ostralegus	Eurasian oystercatcher
25	Burhinus oedicnemus	Eurasian stone curlew
26	Charadrius dubius	Little ringed plover
27	Phalaropus lobatus	Red-necked phalarope
28	Pluvialis squatarola	Grey plover
29	Pluvialis apricaria	European golden plover
30	Arenaria interpres	Ruddy turnstone
31	Vanellus vanellus	Northern lapwing

Table 2: Wader list

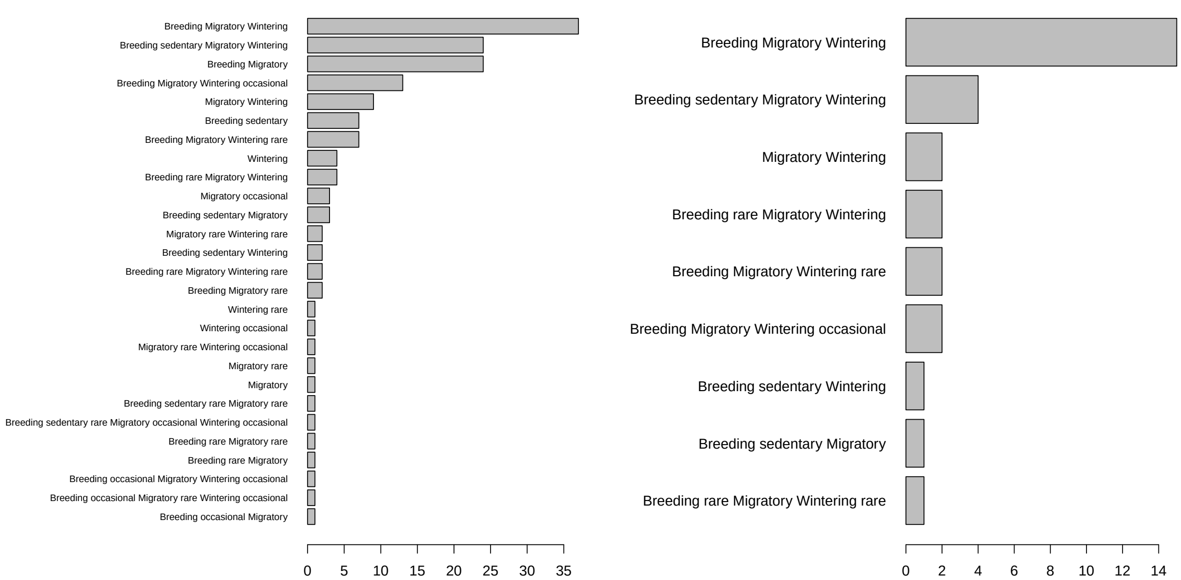


Figure 1: Number of birds in each 'migratory category': 155 (over 279) species were identified (left) and 30 (over 60) frequent birds only (right)

3.2 Synchrony: variance ratio

3.2.1 Yearly synchrony

We first wanted to test the effect of the taxonomic level on the synchrony index. We see on Fig. 2 that the indices of Loreau and Gross do not show the same patterns. Until 1981, synchrony according to Loreau seems high (over 0.4). It then drops constantly until 1986. After 1987, values remain between 0.1 and 0.4, until the last year. The pattern is the same for the species- and genus-levels. The species-level index is consistantly below the genus-level, which indicates that $\left(\sum_{i=1}^{n}\sqrt{\mathrm{var}(P_i)}\right)^2 \leqq \left(\sum_{i=1}^{n'}\sqrt{\mathrm{var}(\sum_{j=1}^{m_i}P_j)}\right)^2 = \left(\sum_{i=1}^{n'}\sqrt{\sum_{j=1}^{m_i}\mathrm{var}(P_j)+2\sum_{1\leqq j<k\leqq m_i}\mathrm{cov}\ (P_j,P_k)}\right)^2$ where m_i is the number of species in genus i and n' is the total number of genera.[4]

The index developped by Gross is more stable and its values remain between -0.1 and 0.3, except for 2016 when we can observe a sharp increase at the genus-level. Contrary to what we observe with ϕ, the taxonomic level has a different effect before and after 2006 for η. During the first period, the species level leads to higher values, but after 2005/2006, the genus level has higher values (except in 2009).

As differences remained small, we kept the species level in the following analyses. Frequent species and the whole community have a similar pattern.

We could interprete the small values observed after 1987 as populations being independent (according to Gross) or at least, asynchronous (according to Loreau). This may indicate that bird dynamics are not too sensitive to seasonal changes, or that their phenology varies according to this environmental fluctuations. The first hypothesis makes sense if we consider that most birds have a lifetime exceeding the year.

[4]Tried to simplify this to have a better idea of what was going on. Didn't find a smart way to do it. Same thing for Gross' index

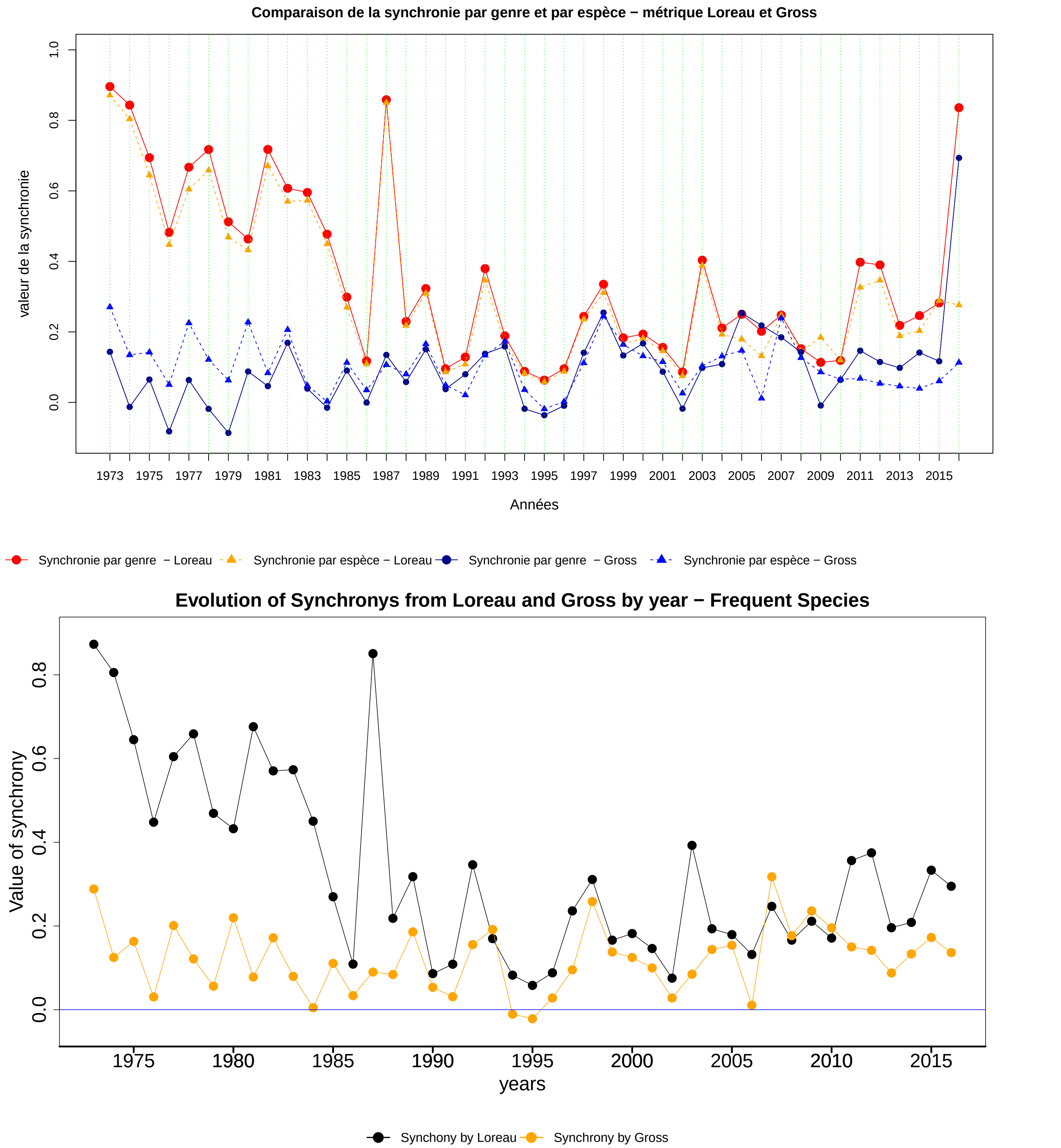


Figure 2: Evolution of the synchrony of the whole community (top) and frequent birds only (bottom) over years, according to Loreau's (red and orange) and Gross' (blue) indices and according to the taxonomic level (the species-level is indicated by triangles and the genus-level is indicated by dots).

3.2.2 Monthly synchrony

We compared the monthly synchrony indices for all species and for frequent species only (Fig. 3). Patterns are similar but more pronounced when using frequent species only. Focusing on this second analysis and on Loreau's index, we can see that the changes in 2006 made a difference in bird dynamics: for the period before 2006, birds tended to be more synchronous during the warm months whereas after 2006, they tend to desynchronize during the summer. On the contrary, Gross' index shows the same pattern for all years, with a change a synchrony from April to September.

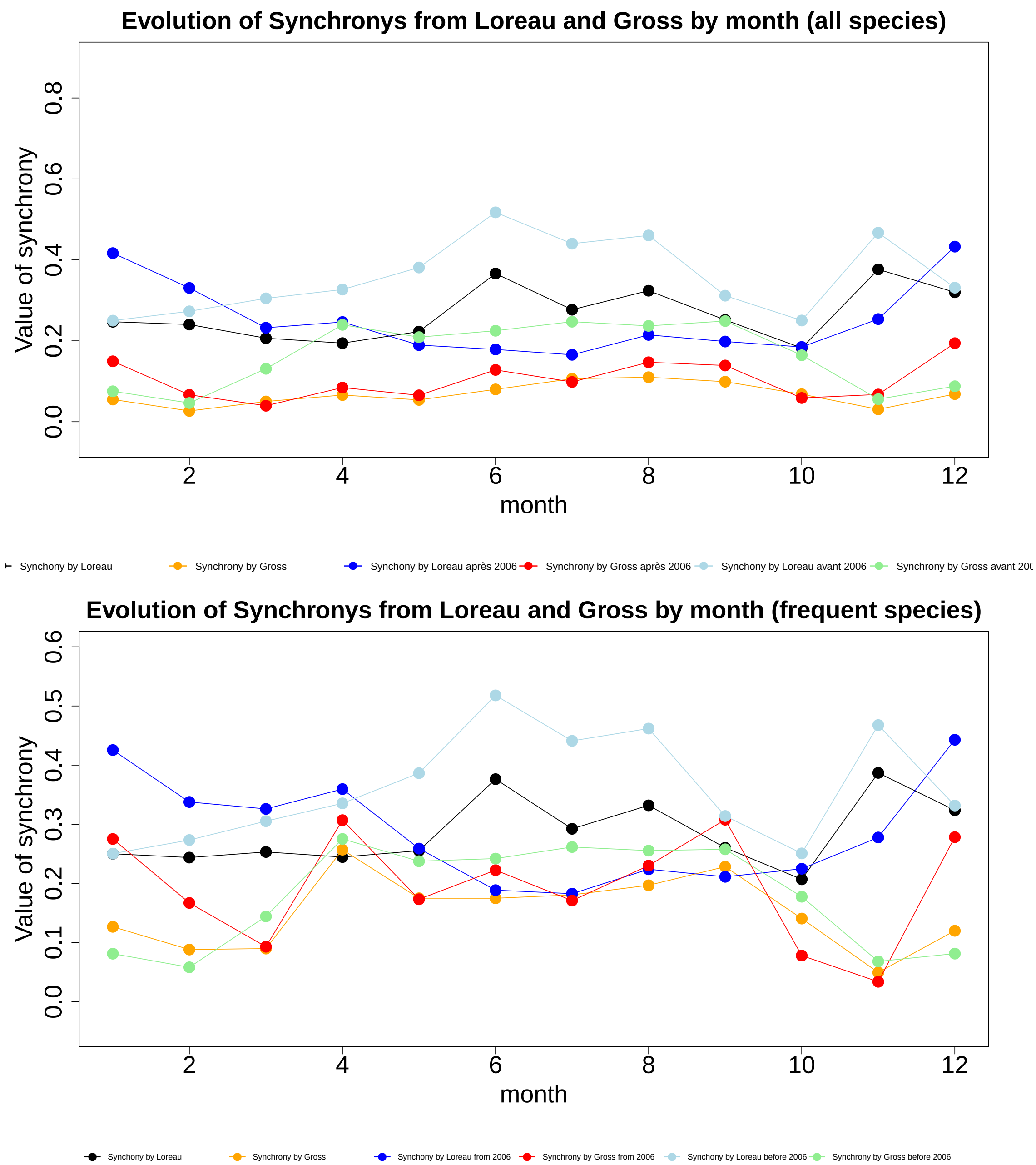
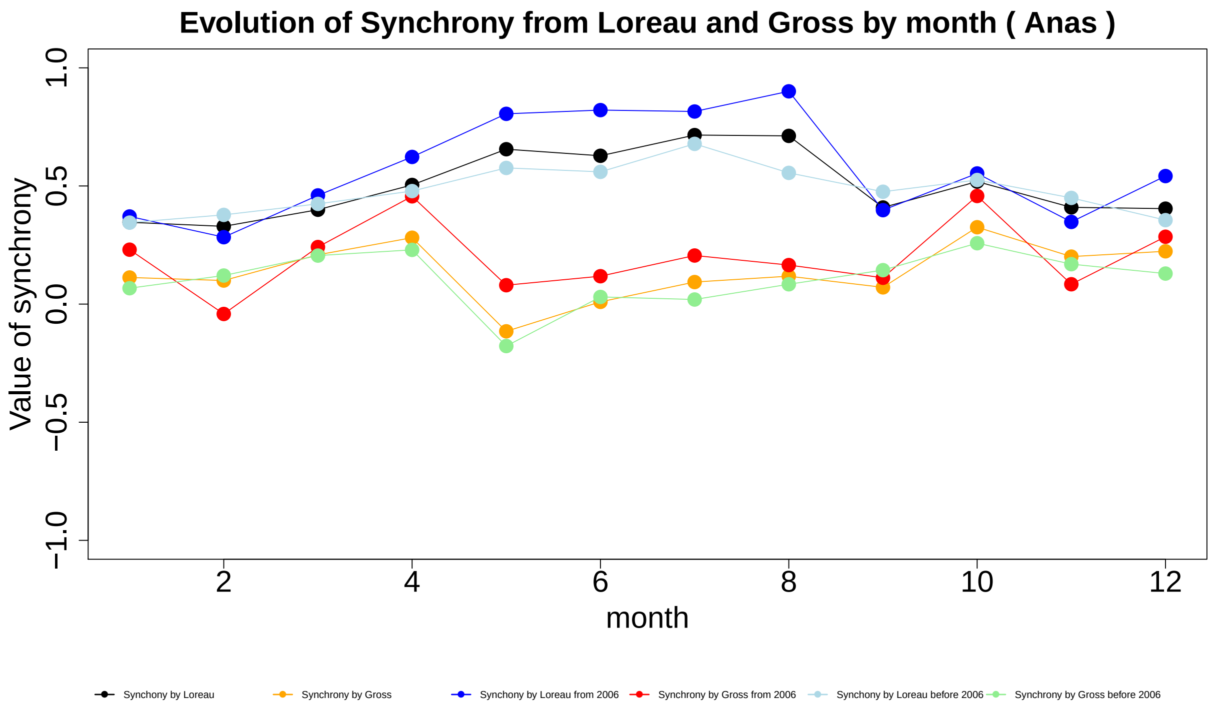


Figure 3: Evolution of monthly synchrony for all species (top) and frequent species only (bottom)

Focusing on Loreau's index, synchrony among genera or within the wader's functional group is generally higher than among the whole community, regardless of the number of species included (Fig 4 and Fig. 5). *Calidris* spp are especially synchronized throughout the year. On the contrary, waders tend to desynchronize during the warmer months.

Contrary to Loreau's index, Gross's index remains in the same, low range for frequent birds and for smaller groups. It seems more sensitive to the change made in 2006 for waders in the summer.



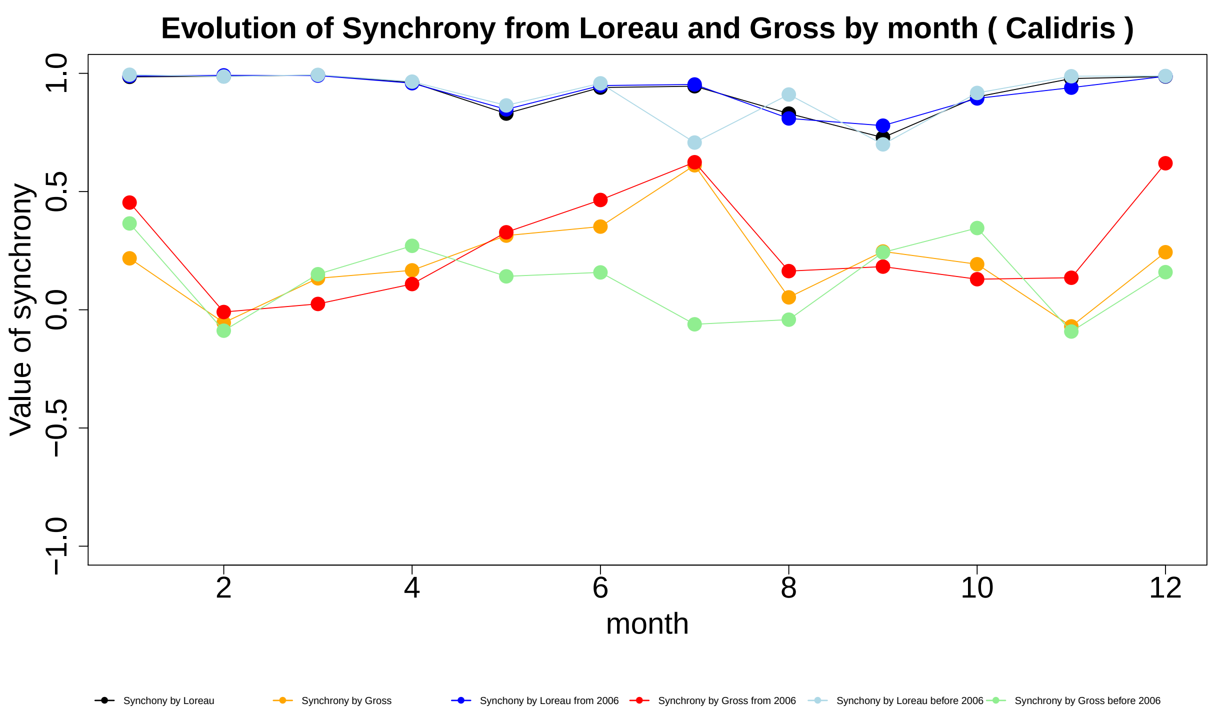


Figure 4: Evolutionf of monthly synchrony for two common genera (Anas and Calidris)

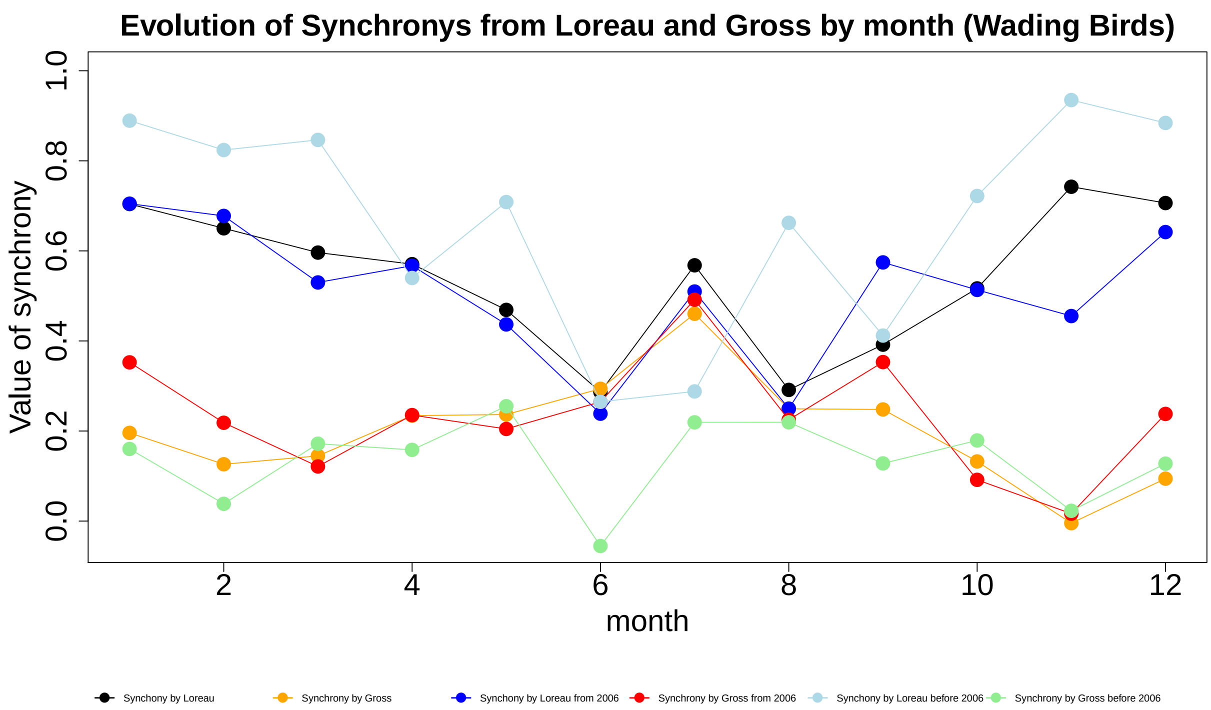


Figure 5: Evolutionf of monthly synchrony within the waders' functional group

3.2.3 Seasonal synchrony

Comparing methods In Fig. 6, we compare the values of the different synchrony indices for different groups of birds. As before, Loreau's statistic is higher for smaller groups than for all frequent birds. Calidris spp. form the most stable and most synchronous groups whereas the Anas genus is not necessarily more synchronous than all waders (which could be expected for phylogeny reasons [?]). The index values do not vary much from one season to another, or from one classification to another.

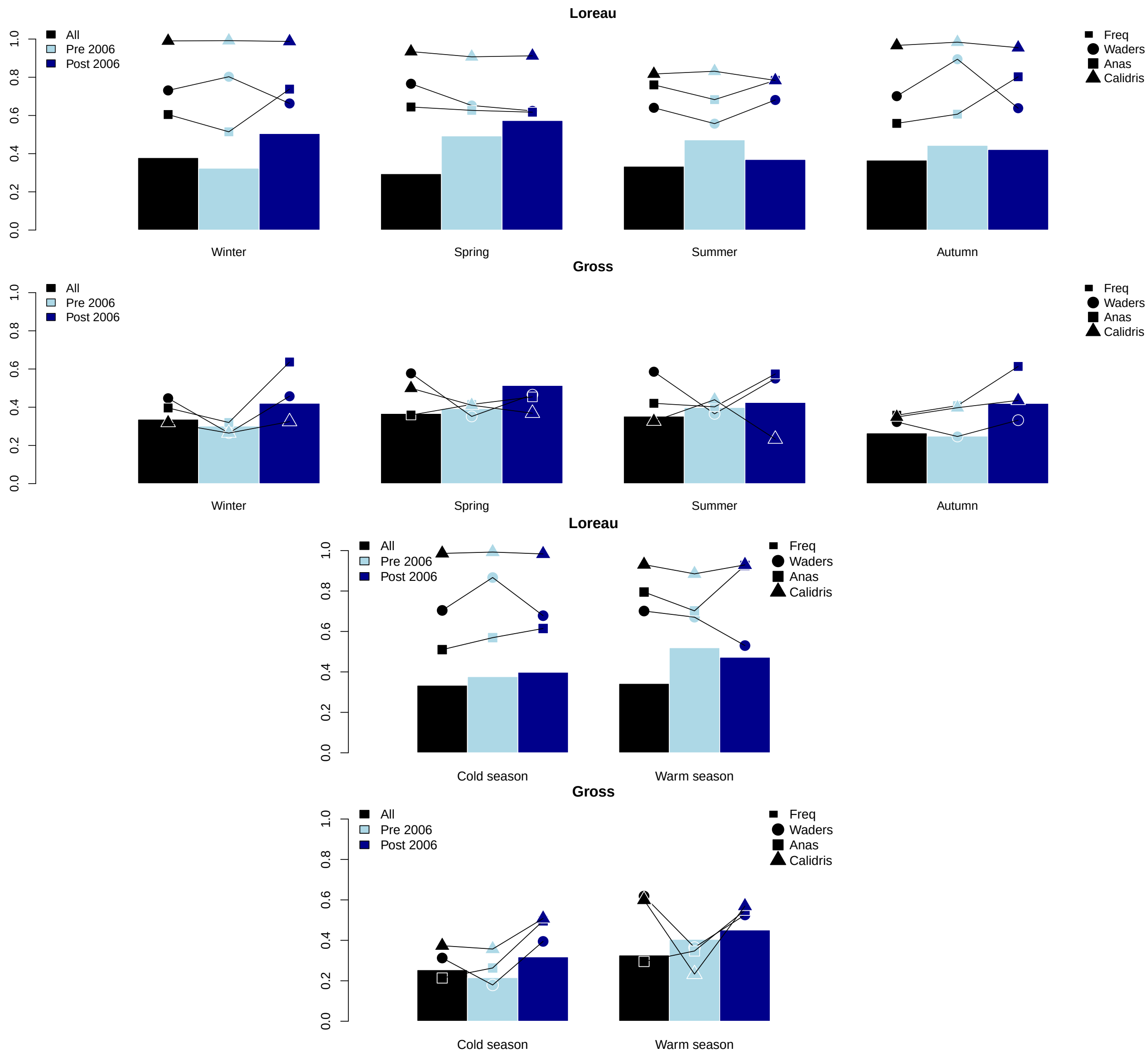


Figure 6: Comparison of synchronys in different bird communities, computed with Loreau and Gross methods, over 2 or 4 seasons

We also compared the statistics computed on average or maximum abundances in Fig. 7. Patterns within different periods (before and after 2006, or among seasons) remain globally the same, but using the maximum values tends to under-estimate the synchrony values, especially for Gross's index. This observation does not hold for the years following 2006.

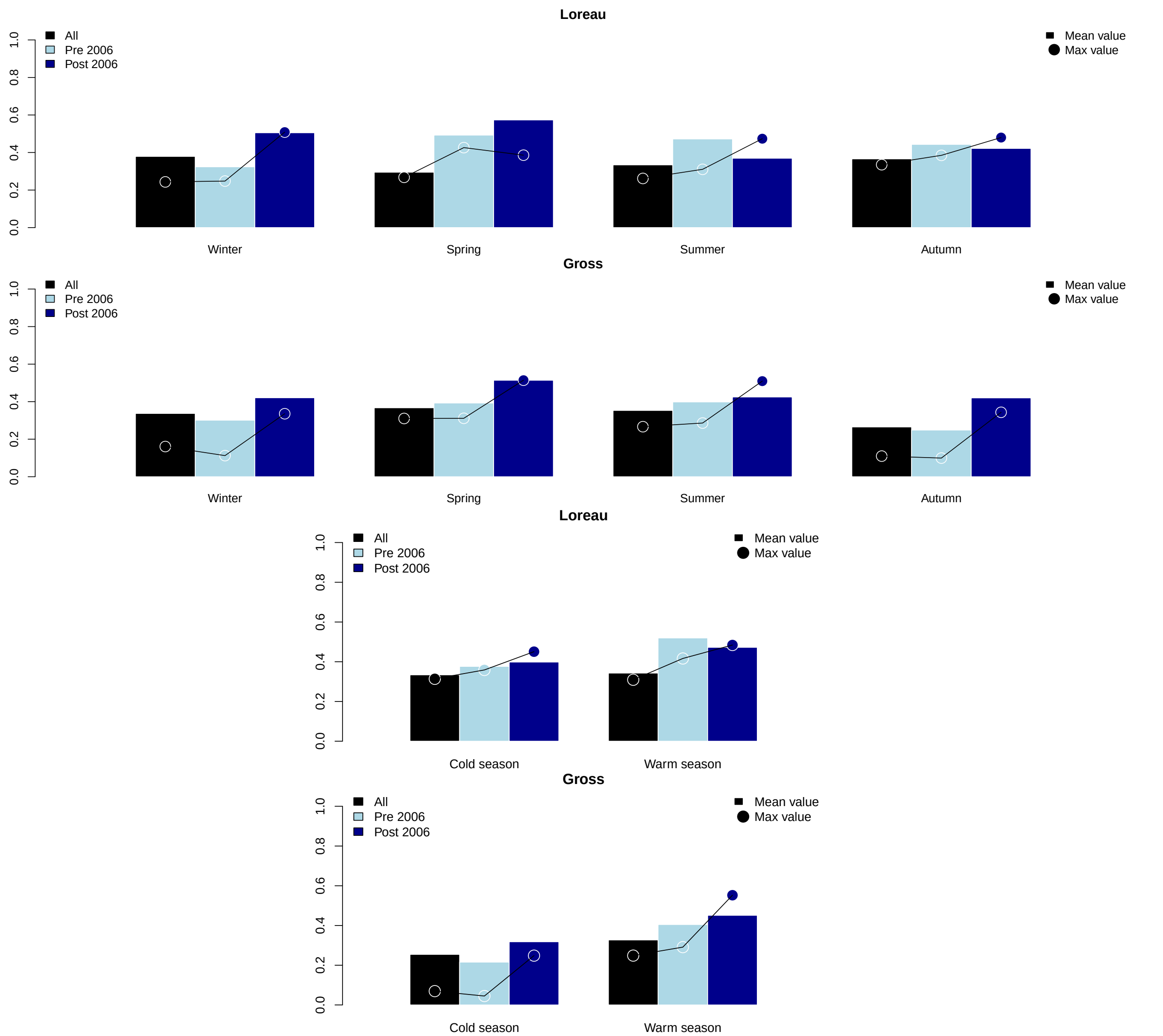


Figure 7: Comparison of synchronys among frequent birds only, computed with Loreau and Gross methods, taking the mean or maximum abundance, over 2 or 4 seasons

4 seasons Defining the mean abundance as the average observed values consistently leads to smaller values than using all months and possible missing observations as 0 (Fig. 8). This difference in averaging also leads to different patterns in the synchrony evolution with season. There is however a common feature as synchrony computed with all years is always smaller than two different synchronys with a threshold around 2006[5].

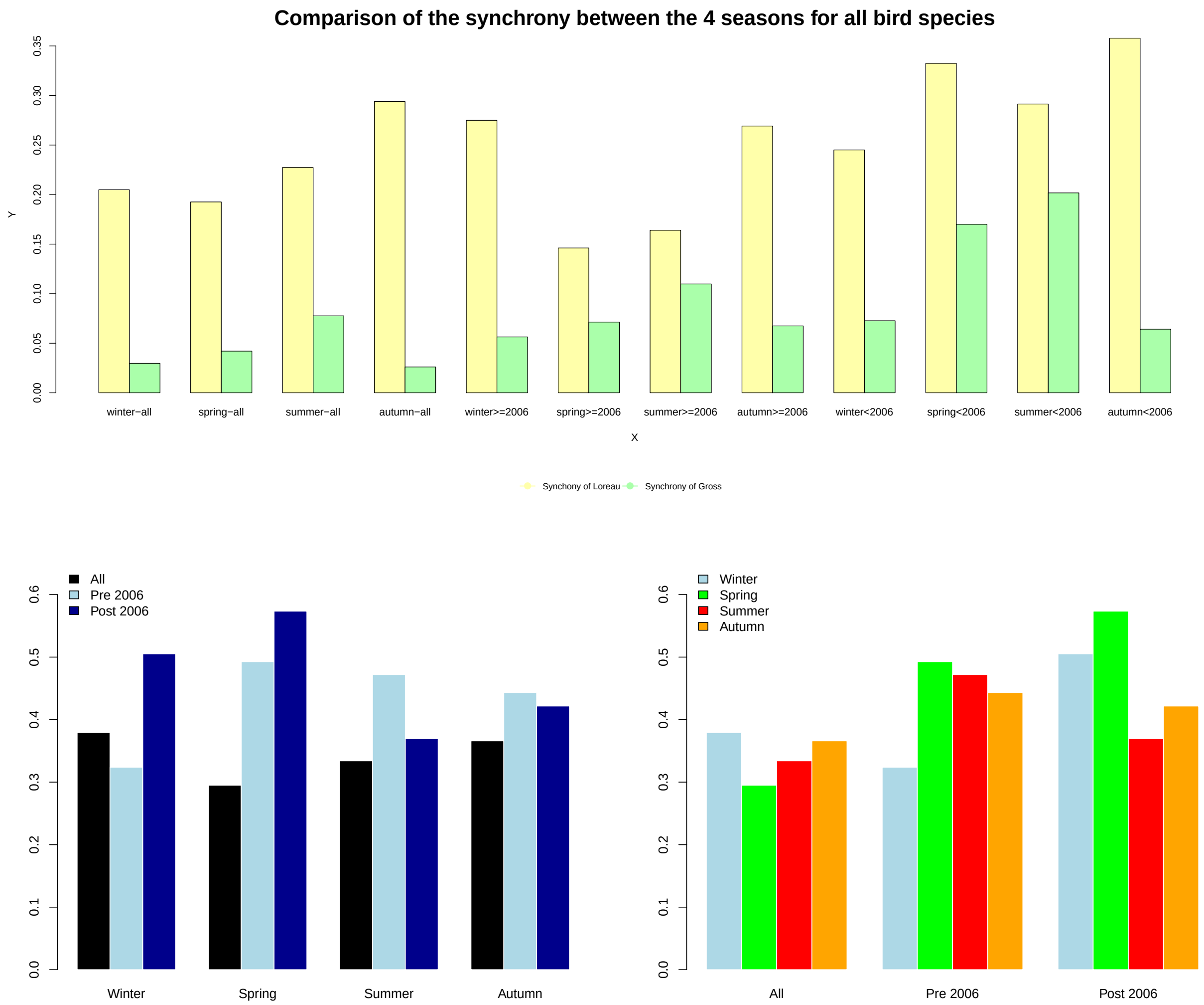


Figure 8: Comparison of Loreau indices for frequent species averaged over seasons, considering average observed values (top, so-called 'first version' in the Method section) or average values including missing months (bottom, so-called 'second version' in the Method section)

[5]I feel like we need to choose a method before commenting on the differences between the seasons, as the conclusions would not be the same

2 seasons We present the synchrony indices as a function of the wintering/breeding (or cold/warm) seasons on Fig. 9. If we consider only frequent birds, relative patterns do not change for the two indices (ie, the summer synchrony is higher than the winter synchrony for all years and years before 2006, but it's the contrary for years after 2006, with Loreau index only). The absence of negative values for Gross indices should be noticed: according to this index, the small values of synchrony that we observe can be attributed to independent dynamics, but not to compensation.

The lack of difference in relative indices, due to the beginning or the duration of the two seasons considered encourages us to focus on one definition only of the two different seasons, following our first observations.[6]

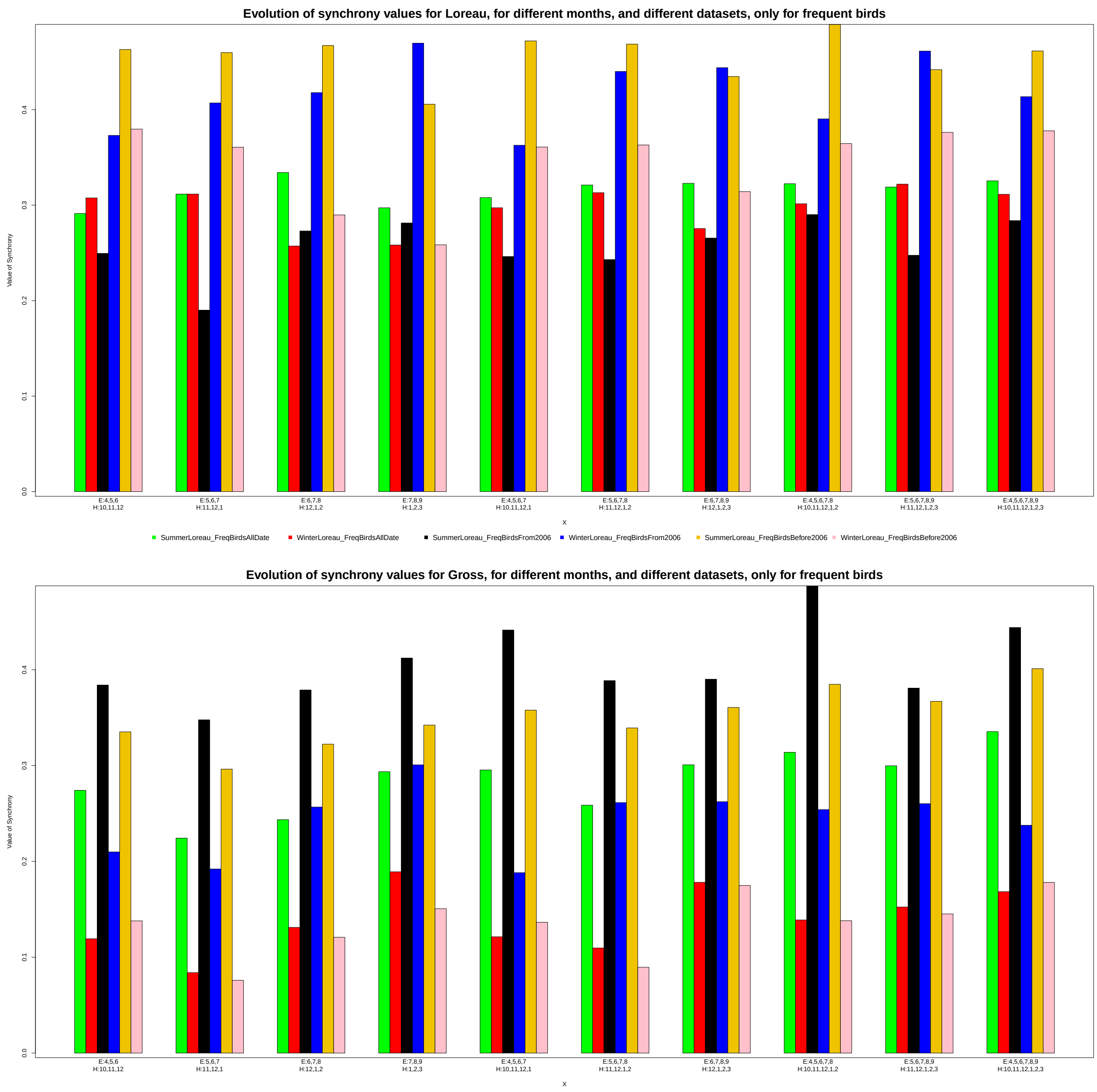


Figure 9: Comparison of indices for Loreau (top) and Gross (bottom) with different definition of the season

[6]BUT the first definition we proposed had different length: the wintering period lasted 5 months and the breeding season lasted 4 months. Differences are small, see Fig. 10.

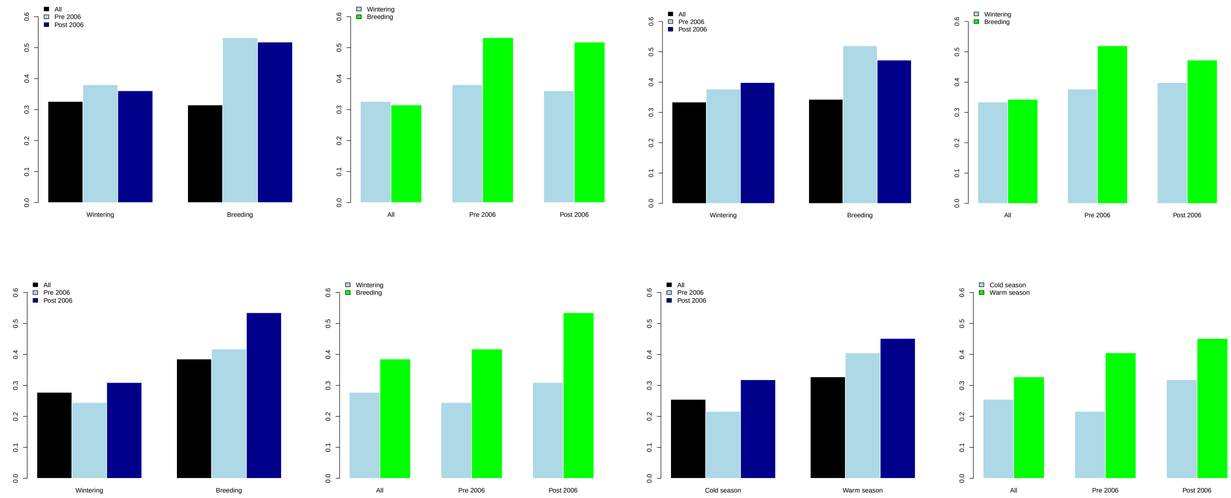


Figure 10: Comparison of Loreau (top) and Gross (bottom) indices for frequent species averaged over cold (October to February, left ; November to February, right) and warm (April to July, left ; May to August, right) seasons. The two columns oppose a case where seasons have been defined by pre-examining the time series, and have different durations (left) while the second one shows seasons with the same duration (right)

3.3 To do?

Could we test for specific values of synchronys, whether we want to estimate if birds are really synchronous (randomizing all values and computing the corresponding synchrony to have a null distribution) ; or to test if the months between April and September are really different (-> difference of distribution, then ?)

We need to choose:

- the taxonomic level. For now, we use the species level, but this should be confirmed
- the definition of the mean (see above).
- the definition of the season (it also depends whether we want to test 'wintering' or 'cold season') : lengths, beginning, separation between months
- do we always separate between before and after 2006 ?

References

Gross, Kevin et al. (2013). “Species richness and the temporal stability of biomass production: a new analysis of recent biodiversity experiments”. In: *The American Naturalist* 183.1, pp. 1–12.

Hallett, Lauren et al. (2016). *codyn: Community Dynamics Metrics.* R package version 1.1.0. DOI: `10.5063/F1542KJB`. URL: `https://github.com/laurenmh/codyn`.

Loreau, Michel and Claire de Mazancourt (2008). “Species Synchrony and Its Drivers: Neutral and Nonneutral Community Dynamics in Fluctuating Environments”. en. In: *The American Naturalist* 172.2, E48–E66. ISSN: 0003-0147, 1537-5323. DOI: `10.1086/589746`. URL: `http://www.journals.uchicago.edu/doi/10.1086/589746` (visited on 03/16/2017).