Online Supplementary Material

Appendices to *Looking for compensation at multiple scales in a wetland bird community.* Barraquand F., Picoche C., Aluome C., Carassou L., and Feigné C.

Appendix 1 - List of species

Group	Latin name	English name	% occurrence	% abundance
FREQ	Accipiter nisus	Eurasian sparrowhawk	12.7	0.003
	Actitis hypoleucos	Common sandpiper	25.2	0.054
	Alcedo atthis	Common kingfisher	12.1	0.017
	Anas acuta	Northern pintail	59.9	1.708
	Anas clypeata	Northern shoveler	63.4	1.580
	Anas crecca	Eurasian teal	63.9	6.613
	Anas penelope	Eurasian wigeon	36.4	0.055
	Anas platyrhynchos	Mallard	63.7	3.388
	Anas querquedula	Garganey	25.9	0.032
	Anas strepera	Gadwall	48.7	0.308
	Anser anser	Greylag goose	47.3	1.135
	Ardea cinerea	Grey heron	62.9	2.476
	Arenaria interpres	Ruddy turnstone	14.6	0.020
	Aythya ferina	Common pochard	57.1	1.053
	Aythya fuligula	Tufted duck	45.7	0.467
	Bubulcus ibis	Western cattle egret	37.8	0.381
	Calidris alpina	Dunlin	37.2	26.395
	Calidris canutus	Red knot	22.5	0.406
	Calidris ferruginea	Curlew sandpiper	14.8	0.067
	Calidris minuta	Little stint	25.1	0.129
	Casmerodius albus	Great egret	29.9	0.150
	Charadrius dubius	Little ringed plover	18.2	0.040
	Charadrius hiaticula	Common ringed plover	34.1	0.921
	Chroicocephalus ridibundus	Black-headed gull	51.2	9.645
	Ciconia ciconia	White stork	51.2	0.905
	Circus aeruginosus	Western marsh harrier	23.3	0.017
	Cygnus olor	Mute swan	49.9	0.618
	Egretta garzetta	Little egret	55.0	6.511
	Falco perigrinus	Peregrine falcon	13.8	0.003
	Fulica atra	Eurasian coot	64.2	16.008
	Gallinago gallinago	Common snipe	23.1	0.184
	Gallinula chloropus	Common moorhen	42.2	1.106
	Himantopus himantopus	Black-winged stilt	12.1	0.079

Table 1: Composition of the functional groups considered in the study

Group	Latin name	English name	% occurrence	% abundance
	Larus argentatus	European herring gull	36.3	3.414
	Larus fuscus	Lesser black-backed gull	32.1	0.088
	Larus marinus	Great black-backed gull	38.9	0.039
	Larus michahellis	Yellow-legged gull	17.5	0.210
	Limosa lapponica	Bar-tailed godwit	18.3	0.327
	Limosa limosa	Black-tailed godwit	29.7	1.802
	Milvus migrans	Black kite	12.7	0.106
	Netta rufina	Red-crested pochard	27.0	0.030
	Numenius arquata	Eurasian curlew	1.167	16.9
	Numenius phaeopus	Whimbrel	0.102	11.1
	Nycticorax nycticorax	Black-crowned night heron	0.160	58.3
	Phalacrocorax carbo	Great cormorant	3.616	57.6
	Philomachus pugnax	Ruff	0.010	11.3
	Platalea leucorodia	Eurasian spoonbill	0.721	48.2
	Pluvialis squatarola	Grey plover	0.669	32.9
	Podiceps cristatus	Great crested grebe	0.033	28.5
	Podiceps nigricollis	Black-necked grebe	0.008	12.0
	Rallus aquaticus	Water rail	0.594	40.4
	Recurvirostra avosetta	Pied avocet	0.775	25.0
	Tachybaptus ruficollis	Little grebe	0.403	44.7
	Tadorna tadorna	Common shelduck	0.870	53.0
	Threskiornis aethiopicus	African sacred ibis	0.019	12.5
	Tringa erythropus	Spotted redshank	0.133	23.8
	Tringa nebularia	Common greenshank	0.173	25.0
	Tringa ochropus	Green sandpiper	0.014	15.4
	Tringa totanus	Common redshank	0.670	32.4
	Vanellus vanellus	Northern lapwing	0.265	22.8
WADERS	**Actitis hypoleucos**	**Common sandpiper**	**25.2**	**0.054**
	Arenaria interpres	**Ruddy turnstone**	**14.6**	**0.020**
	Calidris alba	Sanderling	4.1	0.004
	Calidris alpina	**Dunlin**	**37.2**	**26.395**
	Calidris canutus	**Red knot**	**22.5**	**0.406**
	Calidris ferruginea	**Curlew sandpiper**	**14.8**	**0.067**
	Calidris minuta	**Little stint**	**25.1**	**0.129**
	Calidris temminckii	Temminck's stint	4.6	0.001
	Charadrius dubius	**Little ringed plover**	**18.2**	0.040
	Charadrius hiaticula	**Common ringed plover**	**34.1**	0.921
	Gallinago gallinago	**Common snipe**	**23.1**	**0.184**
	Himantopus himantopus	**Black-winged stilt**	**12.1**	**0.079**
	Limosa lapponica	**Bar-tailed godwit**	**18.3**	**0.327**
	Limosa limosa	**Black-tailed godwit**	**29.7**	**1.802**
	Numenius arquata	**Eurasian curlew**	**16.9**	**1.167**
	Numenius phaeopus	**Whimbrel**	**11.1**	**0.102**
	Philomachus pugnax	**Ruff**	**11.3**	**0.010**
	Pluvialis apricaria	European golden plover	5.0	0.002
	Pluvialis squatarola	**Grey plover**	**32.9**	**0.669**
	Recurvirostra avosetta	**Pied avocet**	**25.0**	**0.775**

Table 2: Composition of the functional groups considered in the study. Species that are present in both frequent and wader/duck groups are in bold type.

Group	Latin name	English name	% occurrence	% abundance
	Tringa erythropus	**Spotted redshank**	**23.8**	**0.133**
	Tringa glareola	Wood sandpiper	9.6	0.008
	Tringa nebularia	**Common greenshank**	**25.0**	**0.173**
	Tringa ochropus	**Green sandpiper**	**15.4**	**0.014**
	Tringa totanus	**Common redshank**	**32.4**	**0.670**
	Vanellus vanellus	**Northern lapwing**	**22.8**	**0.265**
DUCKS	**Anas acuta**	**Northern pintail**	**59.9**	**1.708**
	Anas clypeata	**Northern shoveler**	**63.4**	**1.580**
	Anas crecca	**Eurasian teal**	**63.9**	**6.613**
	Anas penelope	**Eurasian wigeon**	**36.4**	**0.055**
	Anas platyrhynchos	**Mallard**	**63.7**	**3.388**
	Anas querquedula	**Garganey**	**25.9**	**0.032**
	Anas strepera	**Gadwall**	**48.7**	**0.308**
	Anser anser	**Greylag goose**	**47.3**	**1.135**
	Aythya ferina	**Common pochard**	**57.1**	**1.053**
	Aythya fuligula	**Tufted duck**	**45.7**	**0.467**
	Aythya marila	**Greater scaup**	**6.5**	**0.005**
	Branta bernicla	Brant	2.3	0.001
	Branta canadensis	Canada goose	5.1	0.002
	Cygnus olor	**Mute swan**	**49.9**	**0.618**
	Fulica atra	**Eurasian coot**	**64.2**	**16.008**
	Netta rufina	**Red-crested pochard**	**27.0**	**0.030**
	Tadorna tadorna	**Common shelduck**	**53.0**	**0.870**

Table 3: Composition of the functional groups considered in the study

Appendix S1 - Temporal patterns of in the Teich bird community

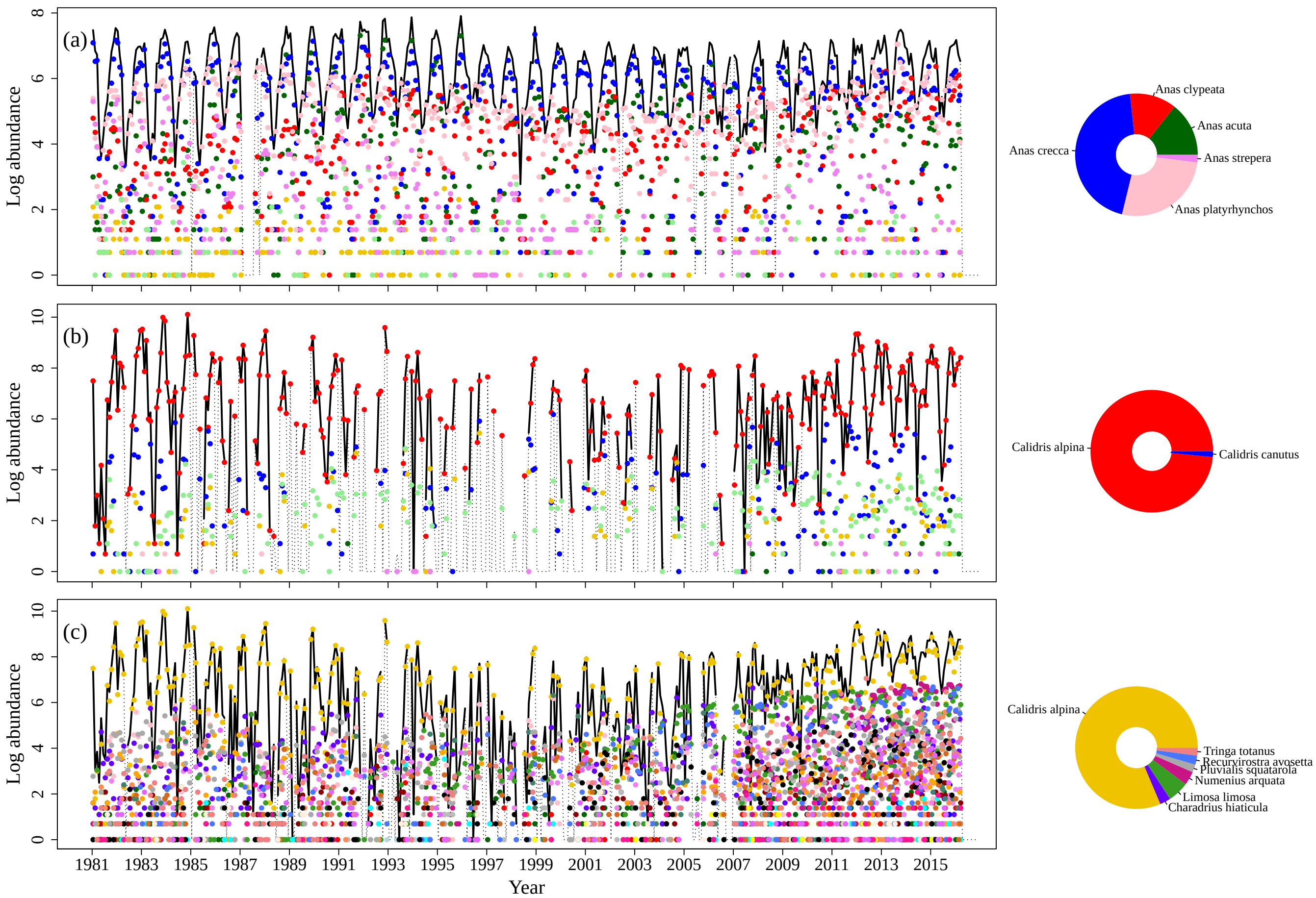


Figure S1: Time series of counts for ducks of the genus *Anas* (a), calidrids (b, *Calidris* genus), and all waders (c, including calidrids). The solid black lines represent trends in summed abundances for each guild when abundances are strictly positive, thin dotted lines connect positive to zero abundances. The coloured symbols below the curves represent each species abundances, with species composition on the right side on the donut plots for the most abundant species (over 1% of relative abundance in the group considered).

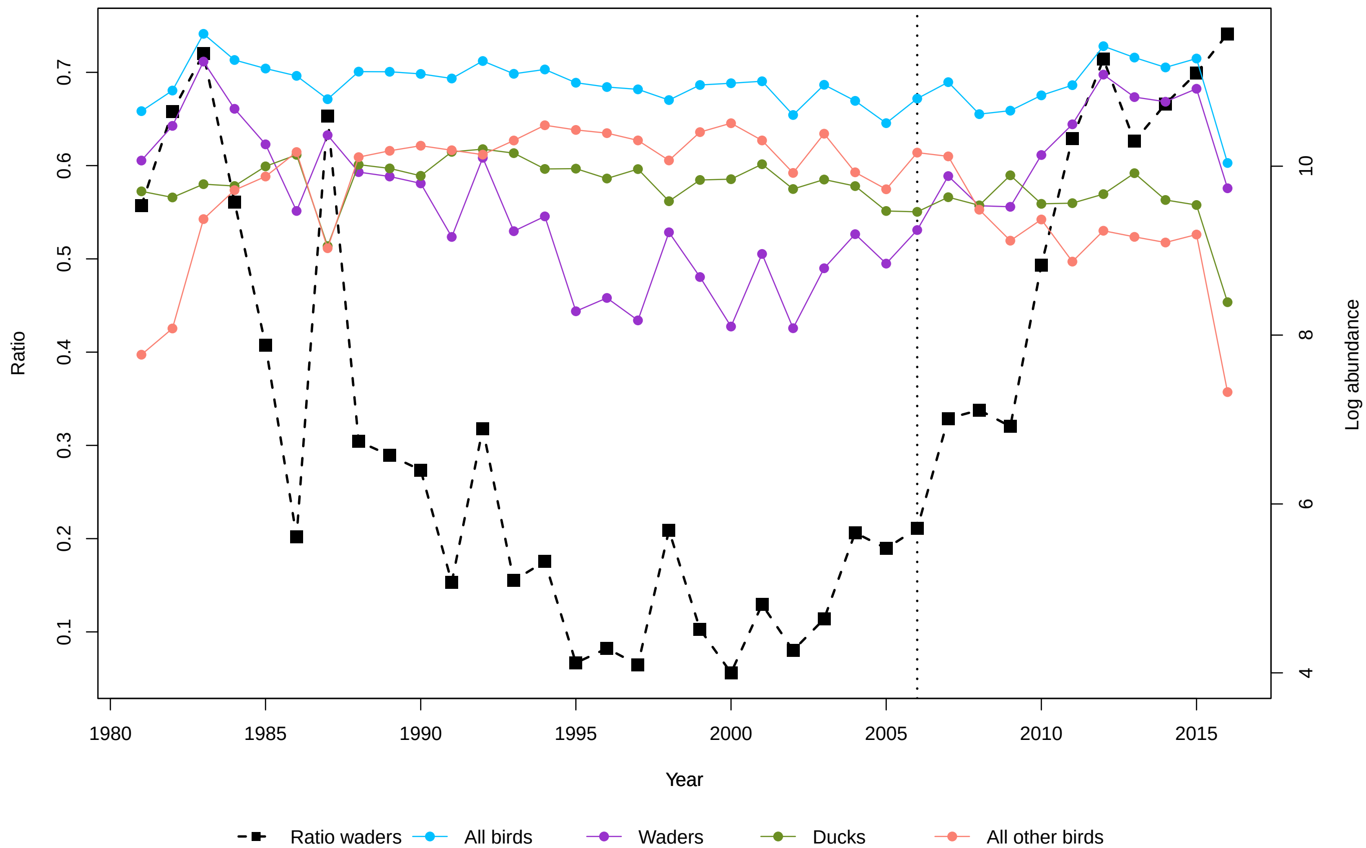


Figure S2: Temporal trends in the abundance of all birds and the main functional groups (waders and ducks), with one point per year. The duck category actually includes all species functionally similar to ducks (i.e., anatids and the common coot). The dashed line presents the ratio of wader individuals in the whole community, which changes over time.

Appendix S2 - Gross synchrony index at the whole community level

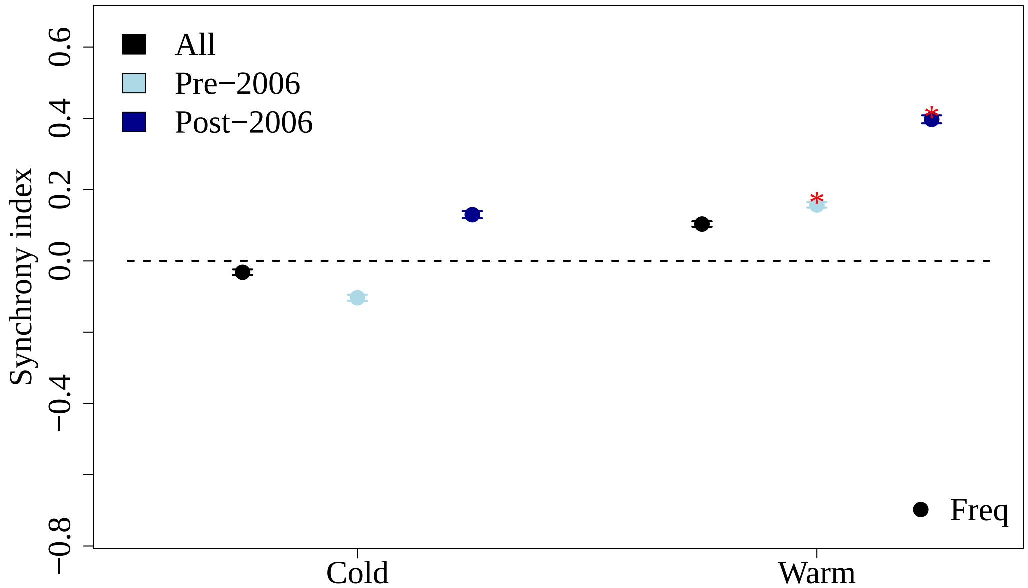


Figure S3: Gross' synchrony index as a function of the season (cold and warm seasons), calculated among the 60 most frequent species in the Teich reserve. The index was computed in each panel on the whole dataset (black) or using two periods: before and after 2006 (light and dark blue), the year of the change in water level management. Red stars correspond to synchrony values significantly different from the null model (independent species), at the Bonferroni-corrected 10% threshold.

Appendix S3 - Correlation in log-scale betwen cormorant and heron+egret

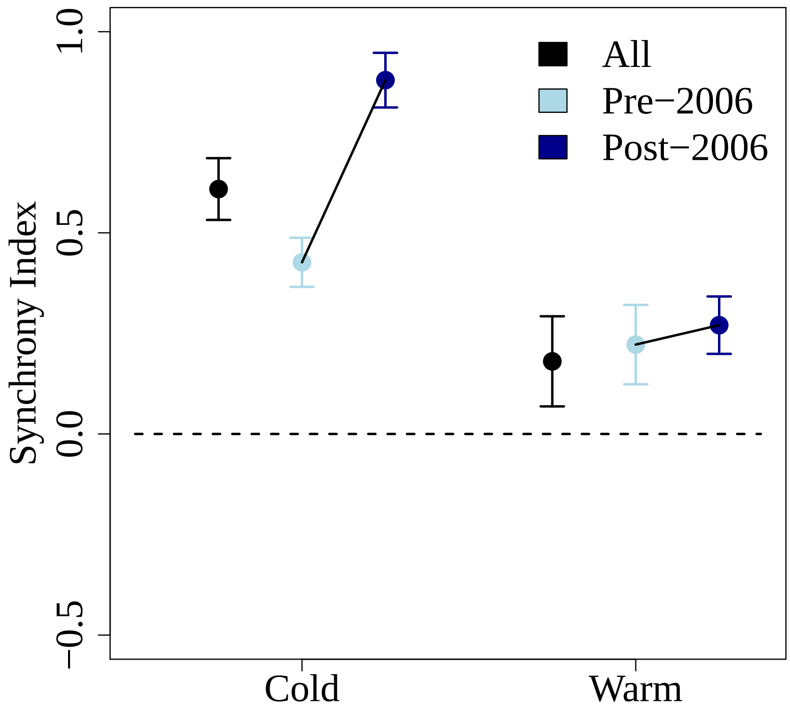


Figure S4: Gross' synchrony index as a function of the season (cold and warm seasons), calculated on log-transformed abundance data for the two groups formed by cormorant and heron+egret. The index was computed in each panel on the whole dataset (black) or using two periods: before and after 2006 (light and dark blue), the year of the change in water level management.

We noted on Fig. 4 in the main text that cormorants, herons and egrets seemed to compensate each other, at least for the first period of the time series. This compensation was seen on a log scale, and seemed conspicuous on that scale. We thus wondered if log-transforming the abundance would affect the values of the synchrony index observed for this group, and make compensation more likely. It appears to be the reverse: synchrony values are higher with log-transformed abundances.

Appendix S4 - Properties of the Gross whole community synchrony index η when two groups react in opposite ways

Here, we make η vary with the number of species, richness of the community, and the strength of the effect of the environment. Starting from the model developped by Gross et al. [1] (developed in their Appendix D), we explored the effect of a shared environmental driver on a community formed by two groups reacting oppositely to this driver.

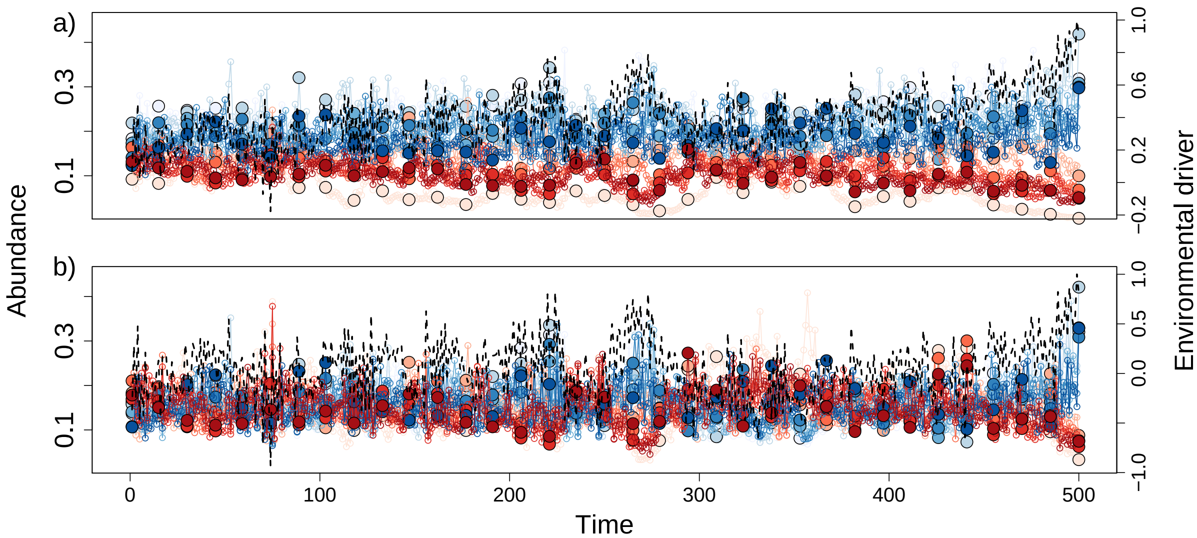


Figure S5: Time series for a community of 10 species, with a strong effect of the environment (b=0.75, see eq. 1) and a time series of 500 time steps. Open circles represent all points of the time series while large filled circles correspond to the sub-sampling of the time series (keeping only 35 points). Cold colors indicate species which react positively to the environmental signal and warm colors indicate species which have a negative reaction to the same signal. The environmental signal is shown in black, dashed lines, and indexed on the right axis. This signal either follows an increasing trend (a), or just an autocorrelated signal (b).

We assume that the environmental driver $U(t)$ is an autocorrelated signal (see below for details).

The dynamics of species i then follows the equation 1:

$$x_i(t+1) = x_i(t) \exp\left(r_i \left(1 - \frac{x_i(t) + \sum_{i \neq j}^{n} \alpha x_j(t)}{K} \right) + b_i U(t) + \epsilon_i(t) \right) \quad (1)$$

where the whole community is formed by $N = 2n$ species, with 2 groups of n species who have exactly opposite reaction to the environmental driver, that is $\forall i \in [1, n], \exists j \in [1, n], b_j = -b_i = b$. The growth rate r_i follows a normal distribution with mean 1 and standard deviation 0.25. All interaction coefficients α are set to 0.5 and $K = \frac{1+\alpha(N-1)}{N}$, to keep the model in other ways exactly similar to Gross et al. [1]. The noise $\epsilon_i(t)$ is normally distributed, centered on 0 with a standard deviation of 0.1.

We compared results for time series of length 35 (the length of our data set when computing η), 100 and 500. For all simulation experiments, the dynamics are first run for 500 time steps as a burn-in. To take into account different observational designs, we either take the first 35 or 100 time steps of the following 500-time steps series, or subsample the time series in order to get 35 or 100 time points (which removes some autocorrelation in the dynamics). We also considered several community richness (10, 30, 60 and 100 species), and several strengths of the response to the environmental signal (b =[0.1, 0.5, 0.75]). For each combination of parameters, we computed 10 repetitions (i.e., replicates).

We considered different types of environmental driver (simply autocorrelated or with a linear trend), crossed with subsampling / no subsampling as described above. We considered in total three scenarios, and present below how an increasing strength of response to the environment changes expectations for all three:

- Scenario 1: $U_t = u_t$ where u_t is an autocorrelated signal (standardized); no subsampling of the data

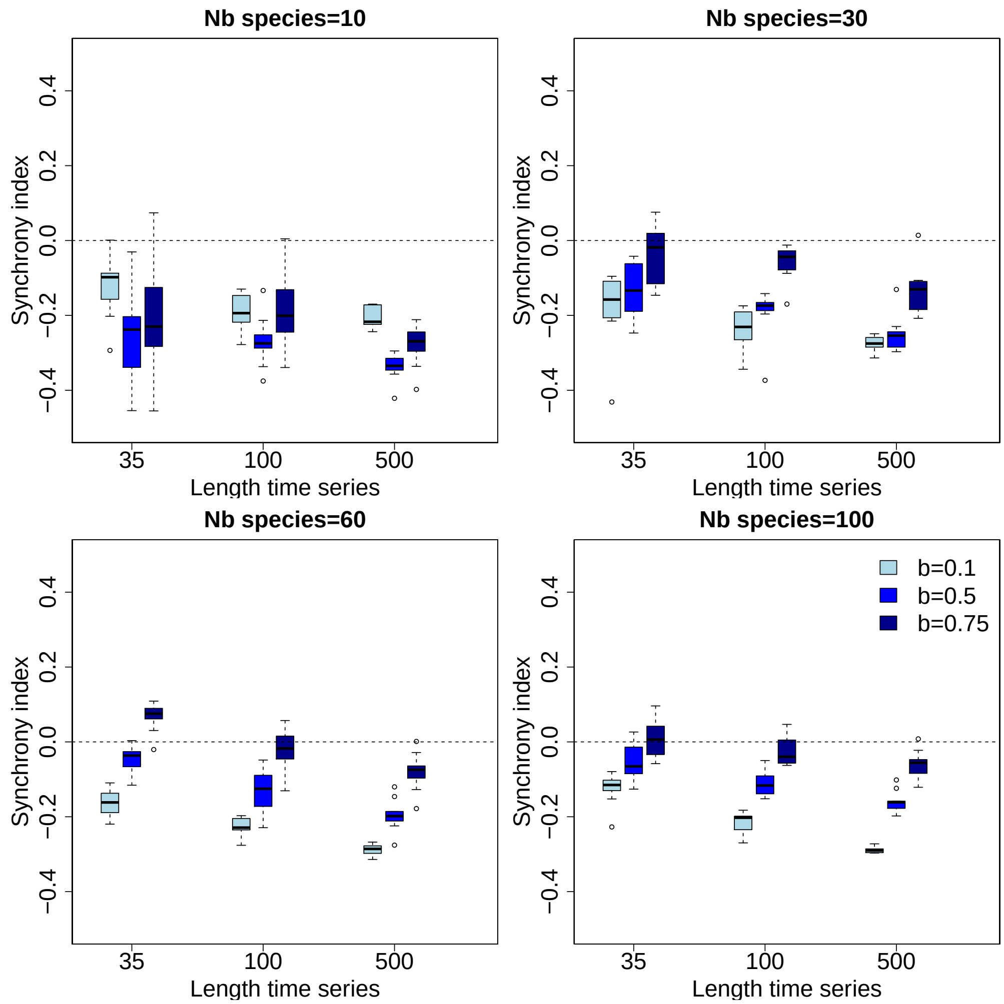


Figure S6: Evolution of Gross' synchrony index for different time series length and number of species in the community, in simulations where there is no trend in the environmental signal and the data is not subsampled, keeping the autocorrelation of the environment.

- Scenario 2: $U_t = u_t$; data subsampling

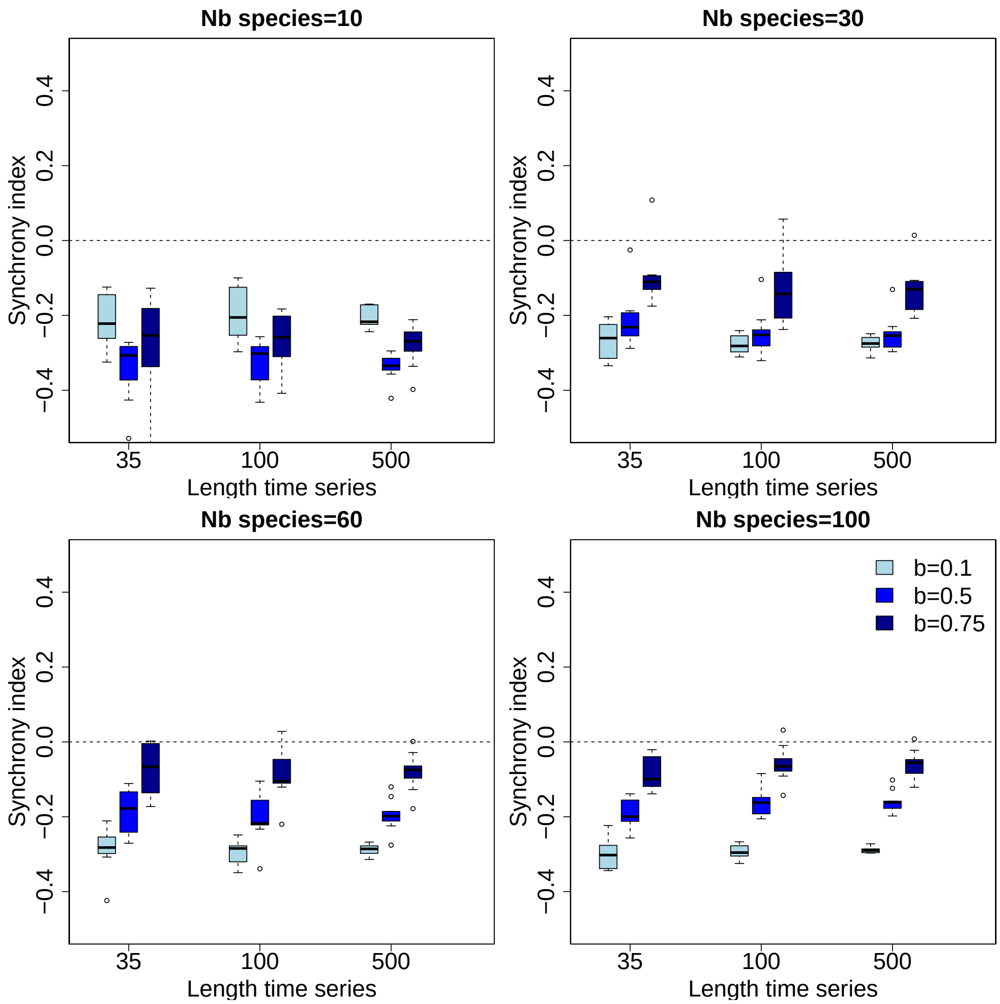


Figure S7: Gross' synchrony index for different time series length and number of species in the community, in simulations where there is no trend in the environmental signal and the data is subsampled (keeping 35 or 100 time steps), removing in effect the autocorrelation of the environment.

- Scenario 3: $U_t = U_{\min} + (U_{\max} - U_{\min})(u_t + x_t)/2$ where $x_t \in [0, 1]$ follows an increasing trend; data subsampling

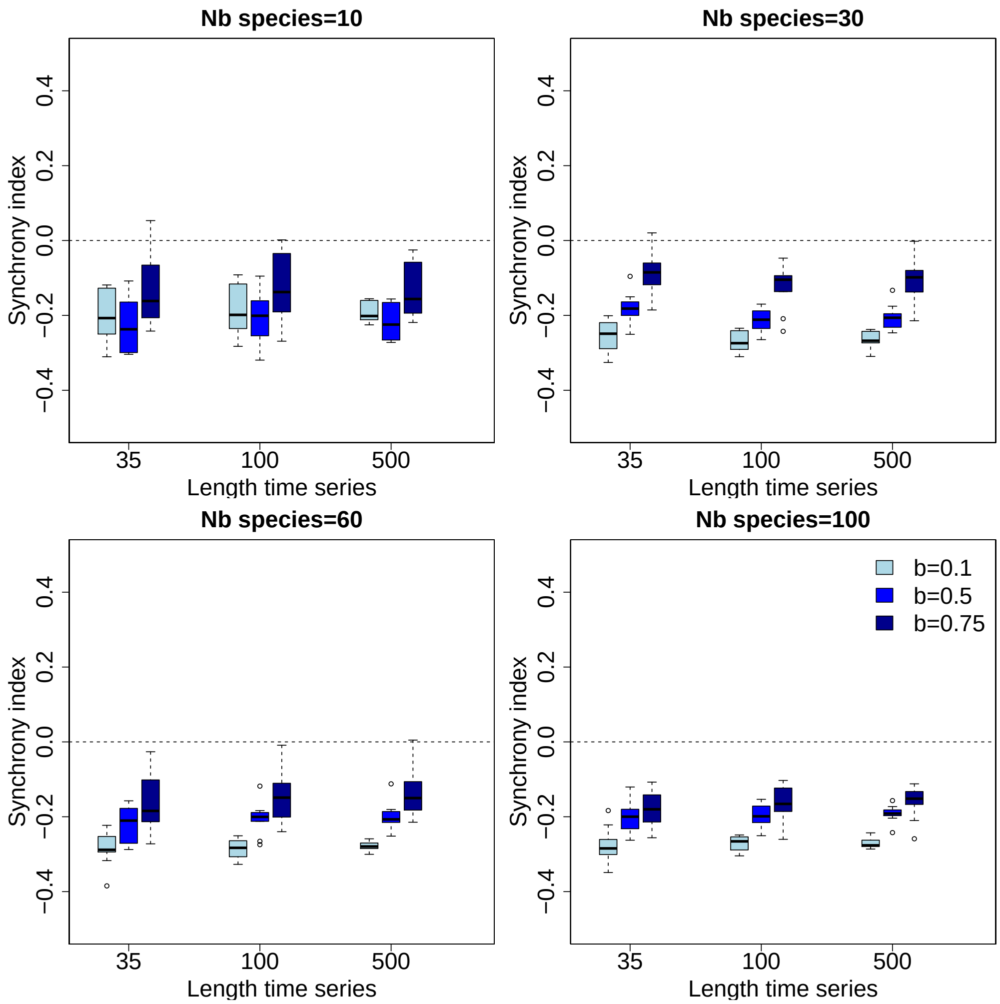
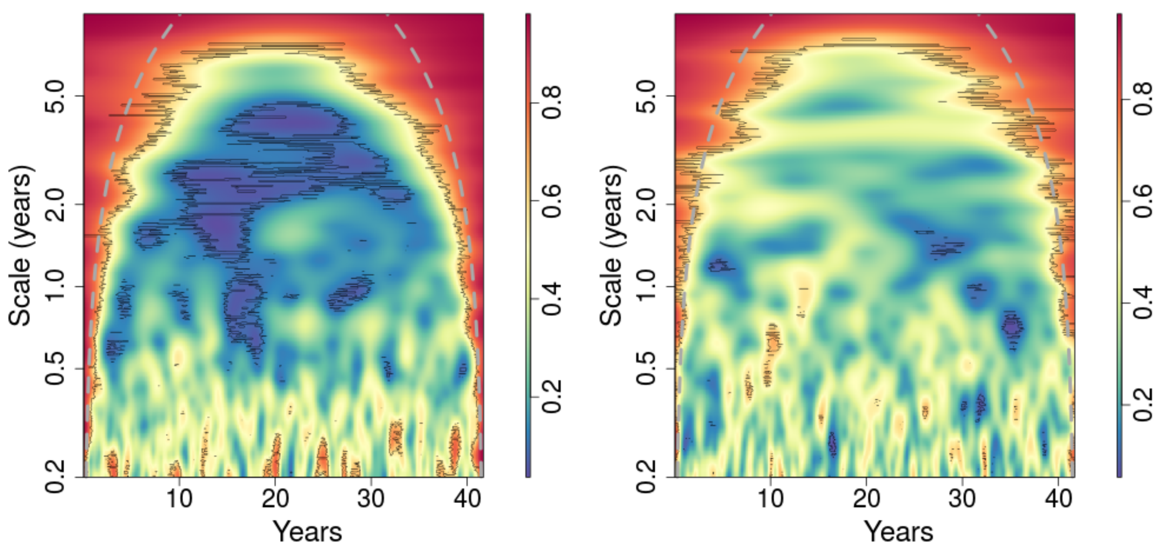


Figure S8: Gross' synchrony index for different time series length and number of species in the community, in simulations where there is an increasing trend in the environmental signal and the data is subsampled (for 35 or 100 time steps), removing part of the autocorrelation of the environment in the dynamics of the species

We first confirm that unless there is a very high temporal autocorrelation in the driver (as in Fig. S6), if we consider two groups which have opposite reactions to the same driver, the Gross index is not sensitive to the length of the time series or to the number of species in the community, in the sense that it will not indicate falsely synchrony. The main finding of these analyses, aside from the robustness of the η index, is that for large communities (over 10 species), synchrony is always higher when the response to the driver is stronger. Coming back to the interpretation of our results in the Teich reserve case, this means that the more bird population growth rates respond to changes in the water levels, the less we can expect compensation at the whole community level, even though compensation may be manifest at the functional group level (here, the group of species responding similarly to the environmental variable).

Appendix S5 - Effect of "missing" values on wavelet analyses

We investigate here if exactly-zero abundances can distort the compensation patterns evidenced by the wavelet coherence. We chose a "worst case" simulation with 10% missing values for all species, and few species below that 10% level. The results show that while the statistical significance of the values can change (i.e., the data is more compatible with the null hypothesis of time series uncorrelated between species, assuming the null is true), the occurrence of compensation (blue values in Fig.S9) does not. The wavelet coherence index is therefore robust to the presence of zeroes in the time series.



(a) Without missing data

(b) With missing data

Figure S9: Wavelet coherence for a community with compensatory dynamics, without (a) and with (b) missing data

References

[1] Gross, K., Cardinale, B. J., Fox, J. W., Gonzalez, A., Loreau, M., Wayne Polley, H., Reich, P. B. & van Ruijven, J., 2013 Species richness and the temporal stability of biomass production: a new analysis of recent biodiversity experiments. *The American Naturalist* **183**, 1–12.