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Supplementary Window analysis: The balance of nature: Critical Role of Species Environmental Responses for Stability

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1 Introduction

We found that imbalance stabilised communities through asynchrony and population stability when including the entire time series (26 sampling days) in the analysis. Here, we investigated how/if these relationships changed over time throughout the experiment. To do so, we chose a moving window approach.

Expectations:

We expected the relationship of imbalance on population stability and on asynchrony to become weaker and eventually statistically insignificant as the experiment progressed:

1. Batch culture effect: Nutrient concentrations decrease with time and waist products increase, affecting the performance of species. Hence, imbalance will become less accurate since it is based on performances estimated from the first few sampling days of the monoculture experiment when batch culture effects were the weakest.
2. Extinctions: With time, many populations eventually went extinct. However, imbalance considers performances of all species and therefore does not account for those extinctions.

2 Load datasets, Data wrangling and Imbalance calculation

3 Window analysis

Window size is 13 days (1/2 of entire time series length). Windows moved by +1 sampling day, yielding a total of 14 windows.

We looked at all estimated coefficients of interest:

-synchrony_Gross ~ log10(balance)

pop_stab ~ log10(balance)

stability ~ -synchrony_Gross

stability ~ pop_stab

Note that due to extinctions the number of observations decreases from 241 in the first window to 94 (39% of total number of microcosms) in the last window. Samples were removed when total microcosm was extinct in a given window, or if only one species was remaining.

3.1 Run analysis

3.2 Window plots

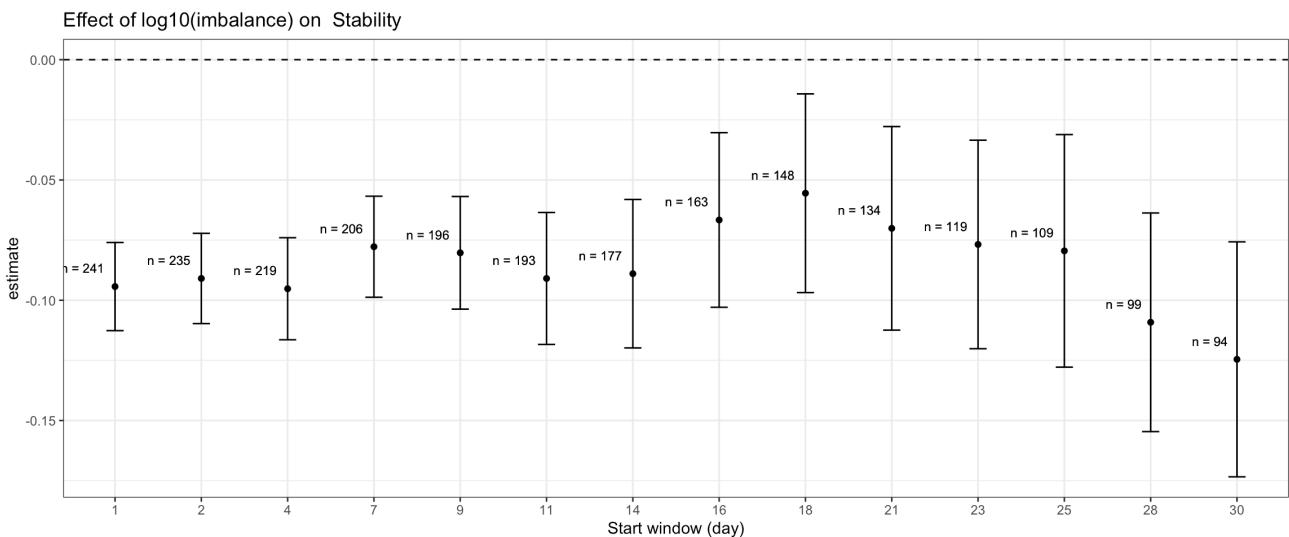
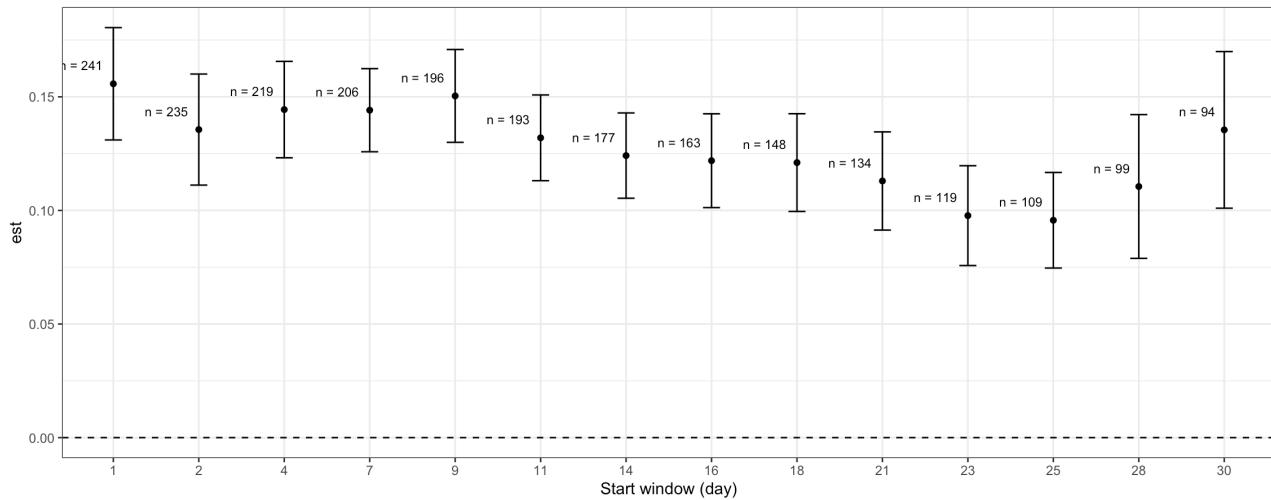


Figure 1 Estimated direct effect of imbalance on community stability in each window, using the linear mixed model from the main text. The effect was robust.

Effect of Asynchrony on Stability



Effect of Population Stability on Stability

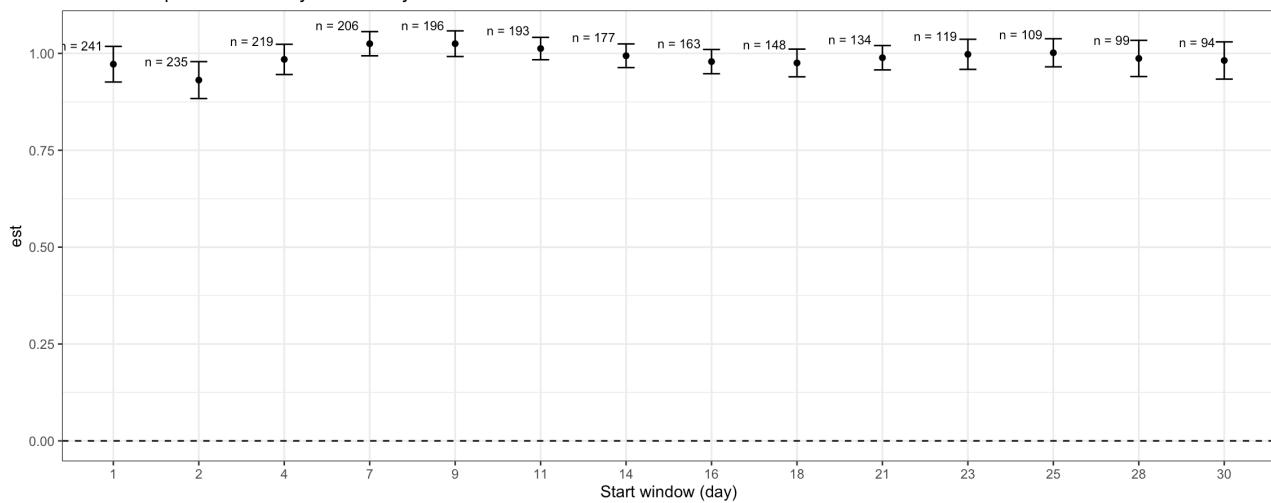


Figure 2 Estimated effect of asynchrony and population stability on community stability (SEM with same structure as in the main text). Effects were robust in all windows.

Effect of log(imbalance) on Population stability

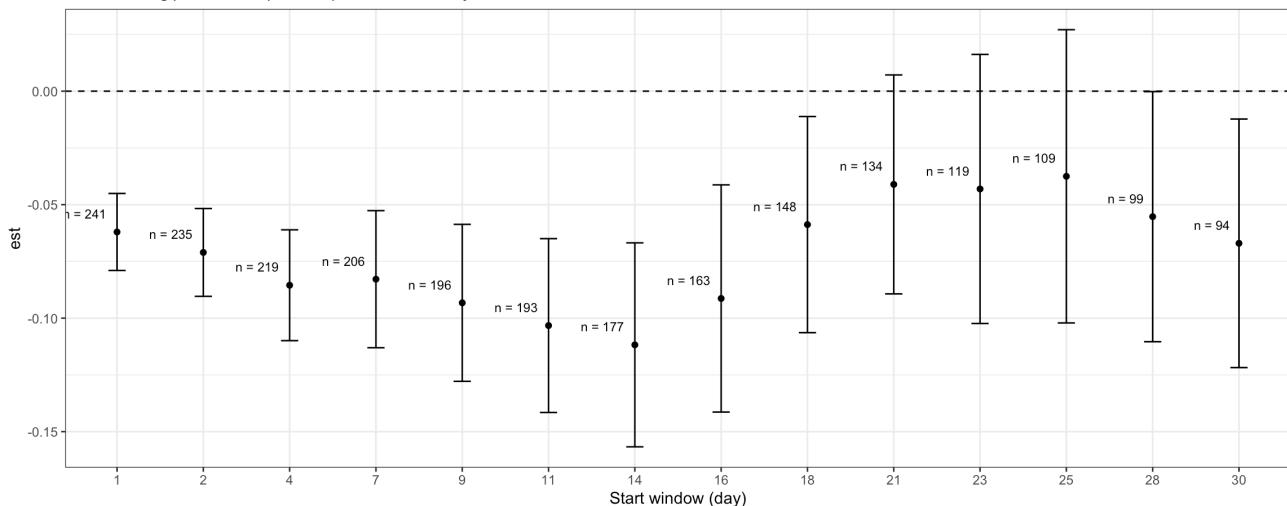


Figure 3 Estimated effect of imbalance on population stability (SEM with same structure as in the main text). The effect was robust and negative in most windows. As expected, the estimate became statistically insignificant toward the end of the experiment, in part due to the reduced number of samples (~50% remaining).

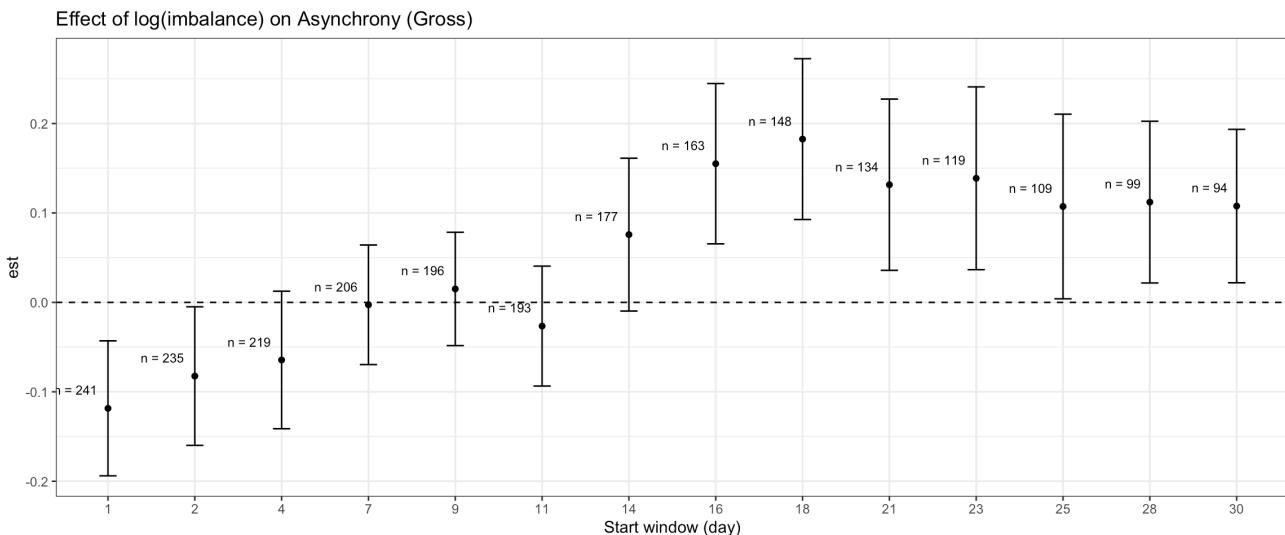


Figure 4 Estimated effect of imbalance on asynchrony in each window (SEM with same structure as in the main text). The effect changed from negative in the beginning to positive in the second half of the experiment.

I line with our expectations, the negative effect of imbalance was most pronounced in the beginning. Surprisingly, this effect changed abruptly to positive about half way through the experiment. This finding ran contrary to our proposed mechanism from the main text and hence warranted further investigation.

4 Switch in sign of effect of imbalance

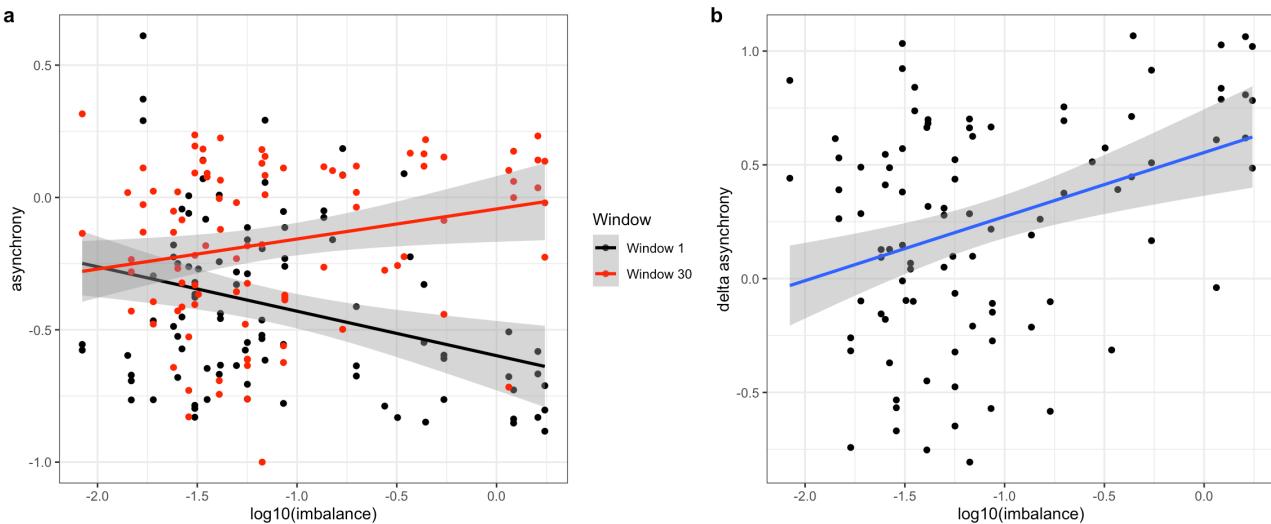


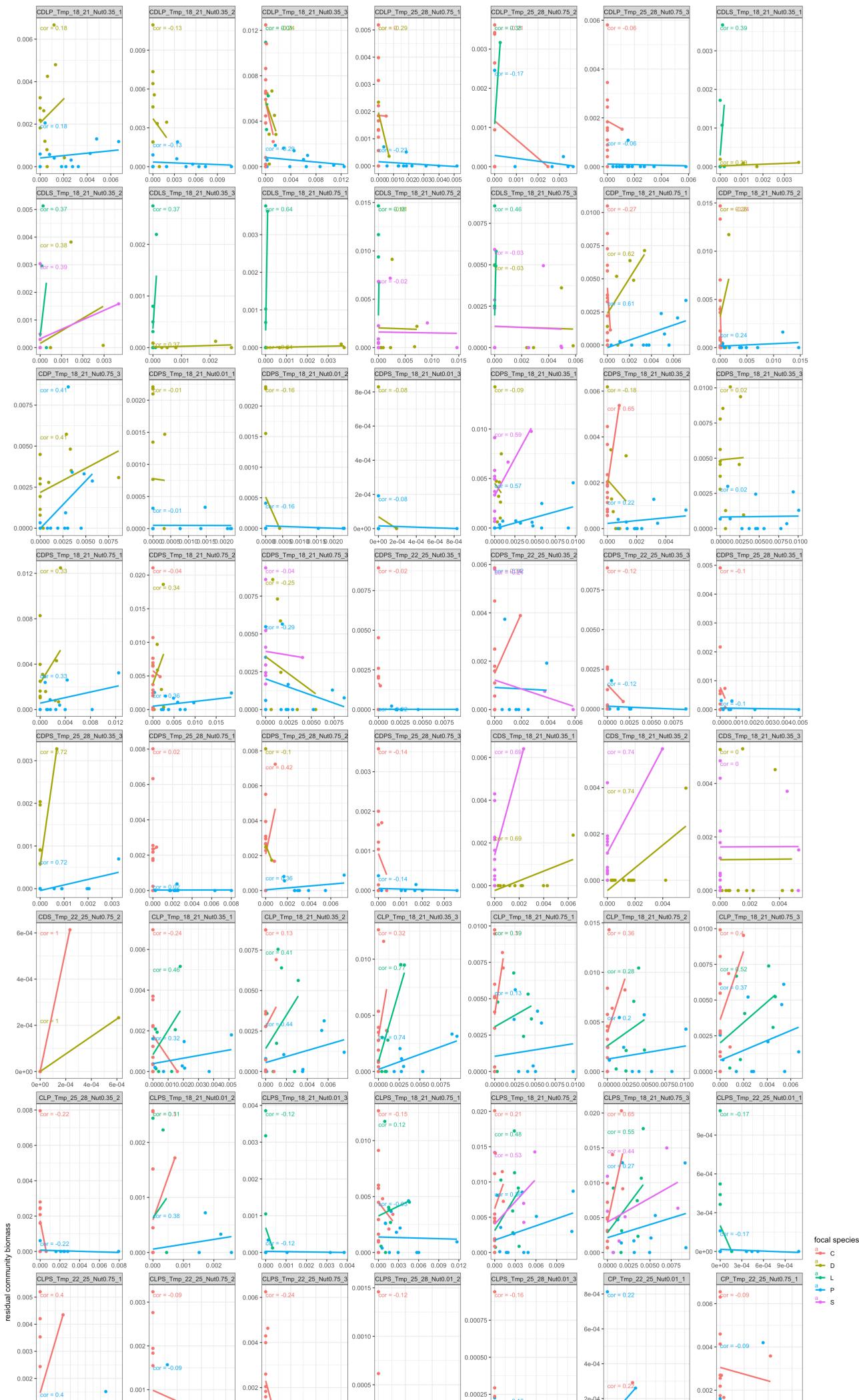
Figure 5 Effect of imbalance on asynchrony of all 94 communities that persisted until the end of the experiment (a), both in window 1 (black) and 30 (red). The effect changed from negative to positive. Relationship between imbalance and the change of asynchrony (delta asynchrony) between window 1 and window 30 (b).

We find that highly imbalanced communities were driving the change in the sign of the relationship between imbalance and asynchrony. More specifically, imbalance was associated with a larger increase in asynchrony (Fig. 5b). We investigated in detail how asynchrony changed in the latter half of the experiment to understand whether this increase in asynchrony was a real biological phenomena, or just a consequence of generally low abundances in later windows. We quantified asynchrony as proposed by Gross et al. (2014):

$$\text{asynchrony} = \frac{1}{n} \sum_i \text{corr}(Y_i, \sum_{j \neq i} Y_j)$$

where n is total number of species in the community and Y_i is biomass of the focal species. Importantly,

this measure is based on correlations and is therefore sensitive to many zero-biomass observations in the time series, which was the case for a lot of communities in the latter half of the experiment. Looking at all the remaining 94 communities in the last window (which covers the second half of the experiment), we can see that for many communities, the correlation values were not meaningful anymore as there were many zero-observations (Fig. 6).



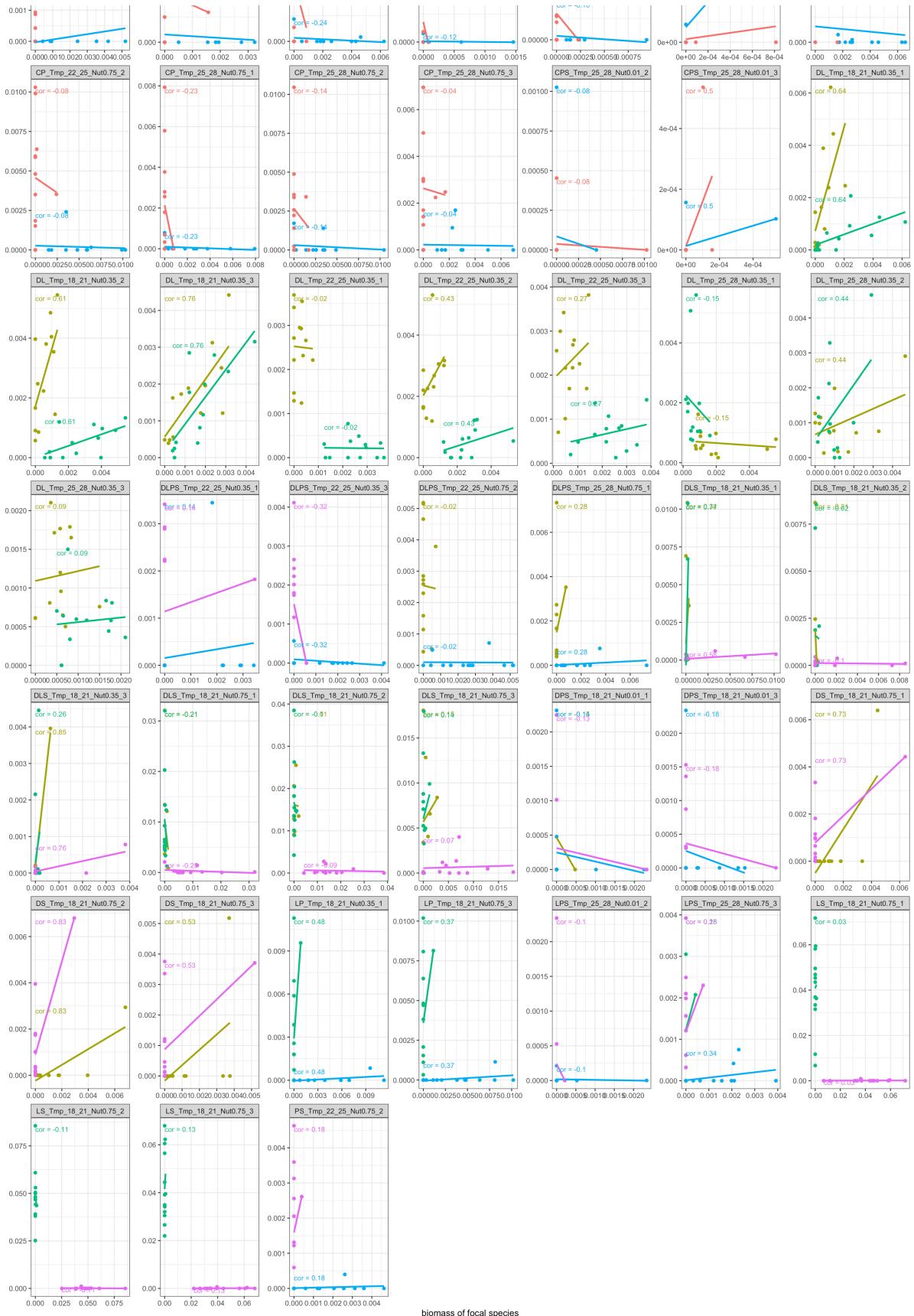


Figure 6 Correlations between focal species and residual community biomass in the last window (sampling day 30 - 58). Asynchrony is calculated as the average of those values.

4.1 Change in Gross of selected communities

Now let us look at a selection of communities and how asynchrony changes over time

4.1.1 CDL_Tmp_22_25_Nut0.35_1

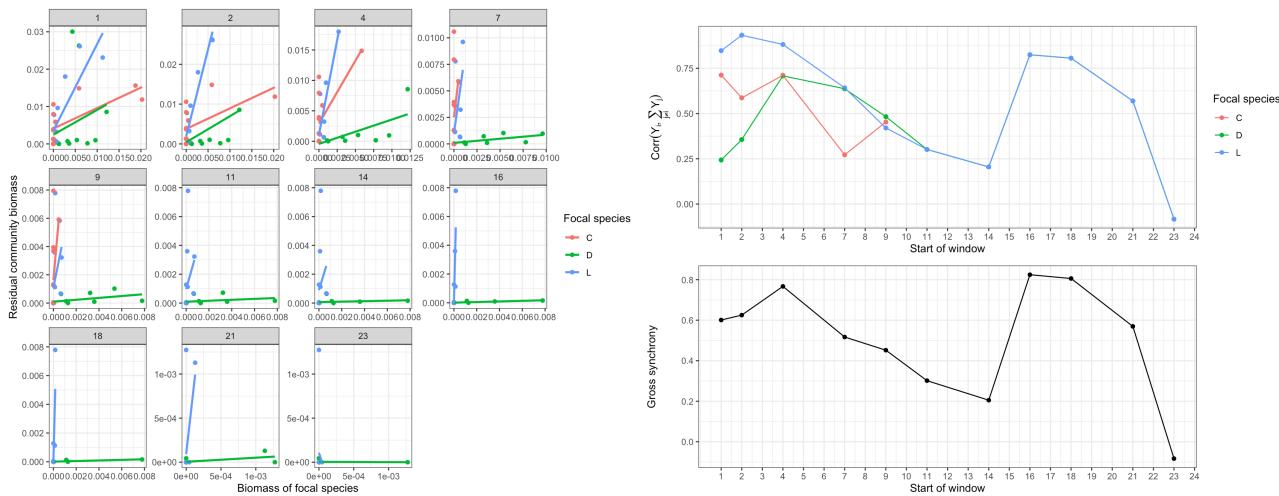


Figure 7 Correlations between focal species and residual species biomass and the resulting asynchrony over time. The increase in number of zero-biomass observations eventually led to an abrupt spike in synchrony after window 14. This was caused by the window moving past a particular sampling day, illustrating how influential individual data points become when many zero-biomass observations are present. After window 23, only one species was left and asynchrony could not be calculated anymore.

4.1.2 CLPS_Tmp_18_21_Nut0.75_2

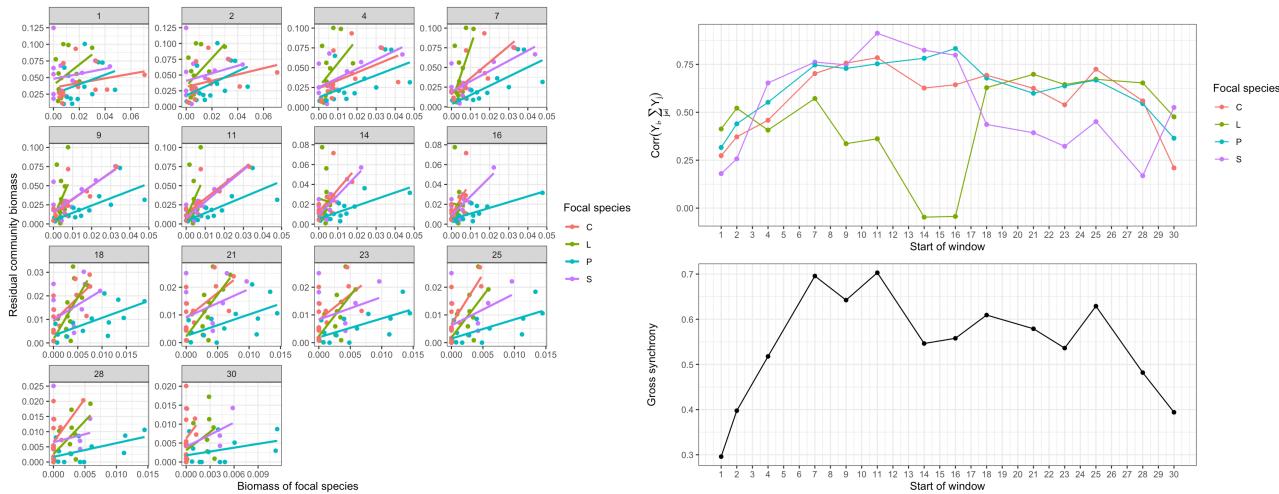


Figure 8 Example of a community where the number of zero-biomass observations did not increase enough to render the asynchrony measure meaningless. While asynchrony did change over time, these dynamics likely resulted from real biological processes.

4.2 High imbalance communities

Above, we presented evidence that asynchrony estimates become unreliable in later windows. Yet this alone does not explain the observed inversion of the imbalance–asynchrony relationship halfway through the experiment (Fig. 4). To unravel this, recall that the sign switch is driven by the most highly imbalanced communities (Fig. 5). We therefore turn our attention to a subset of those extreme cases:

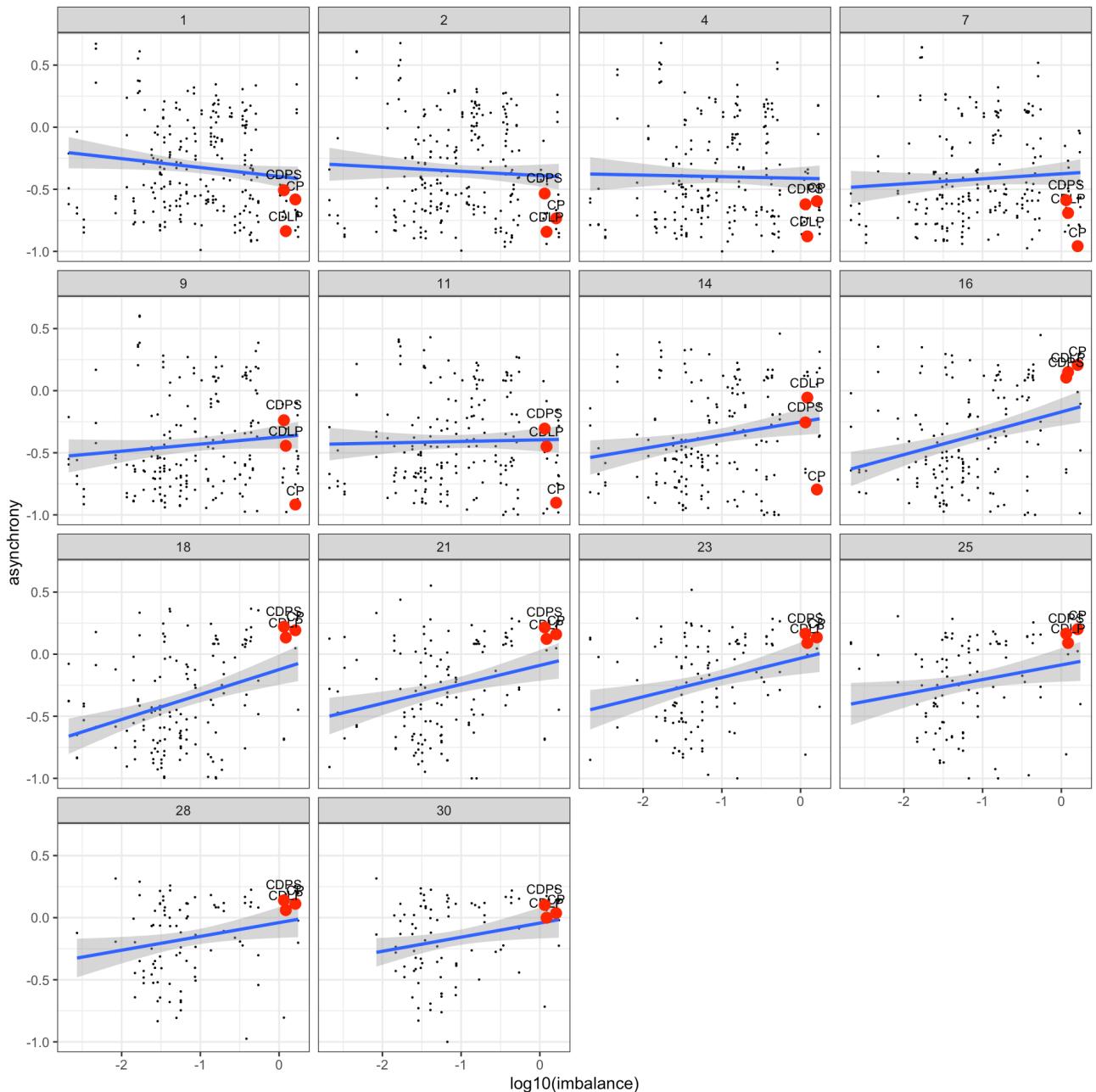


Figure 9 Relationship of imbalance and asynchrony in each window (without accounting for the nutrient effect). Subset of highly imbalanced communities in red and labelled with community composition.

We can see that those communities switch from synchronous to slightly asynchronous, and with them the sign of the relationship between imbalance and asynchrony from negative to positive. This switch was caused by an increase in number of zero-observations:

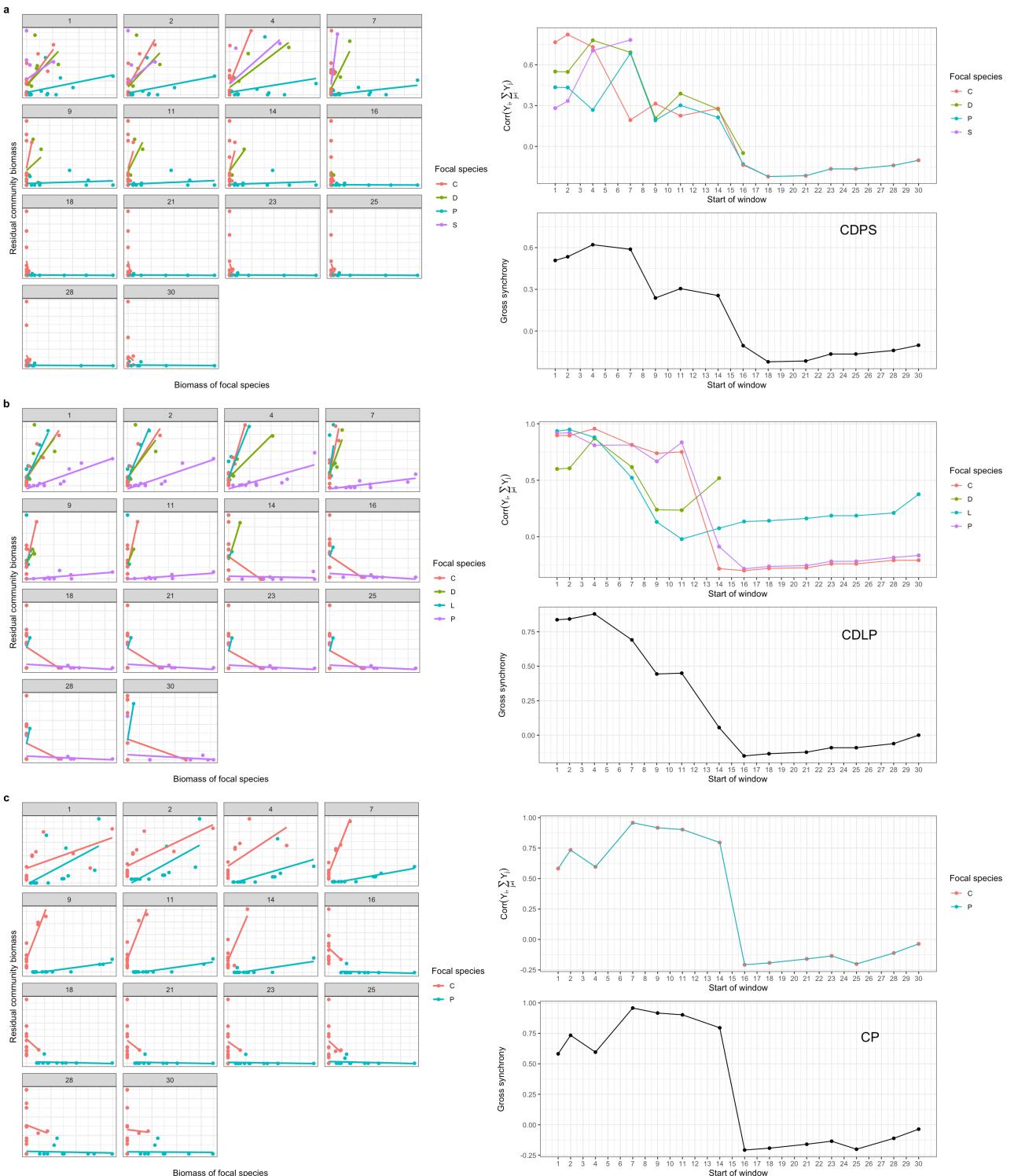


Figure 10 Change of synchronous to asynchronous dynamics for three highly imbalanced communities.

All of those communities appear to become more asynchronous and thereby contribute to the inversion of the negative imbalance-asynchrony relationship. However, these asynchrony values are no longer meaningful because of the increased number of zero-biomass observations. Therefore, our confidence in estimates from windows covering the latter part of the time series is low, and we argue that they no longer describe the relationship between imbalance and asynchrony.

4.3 Distribution of zero-observations

The previous section illustrates that for many communities, asynchrony became meaningless after a certain amount of time, and that this was the result of an increasing amount of zero-biomass observations. Later windows had more and more of these zero-observations (Fig. 11). Hence, estimates of the relationship between imbalance and asynchrony from those windows also became less reliable.

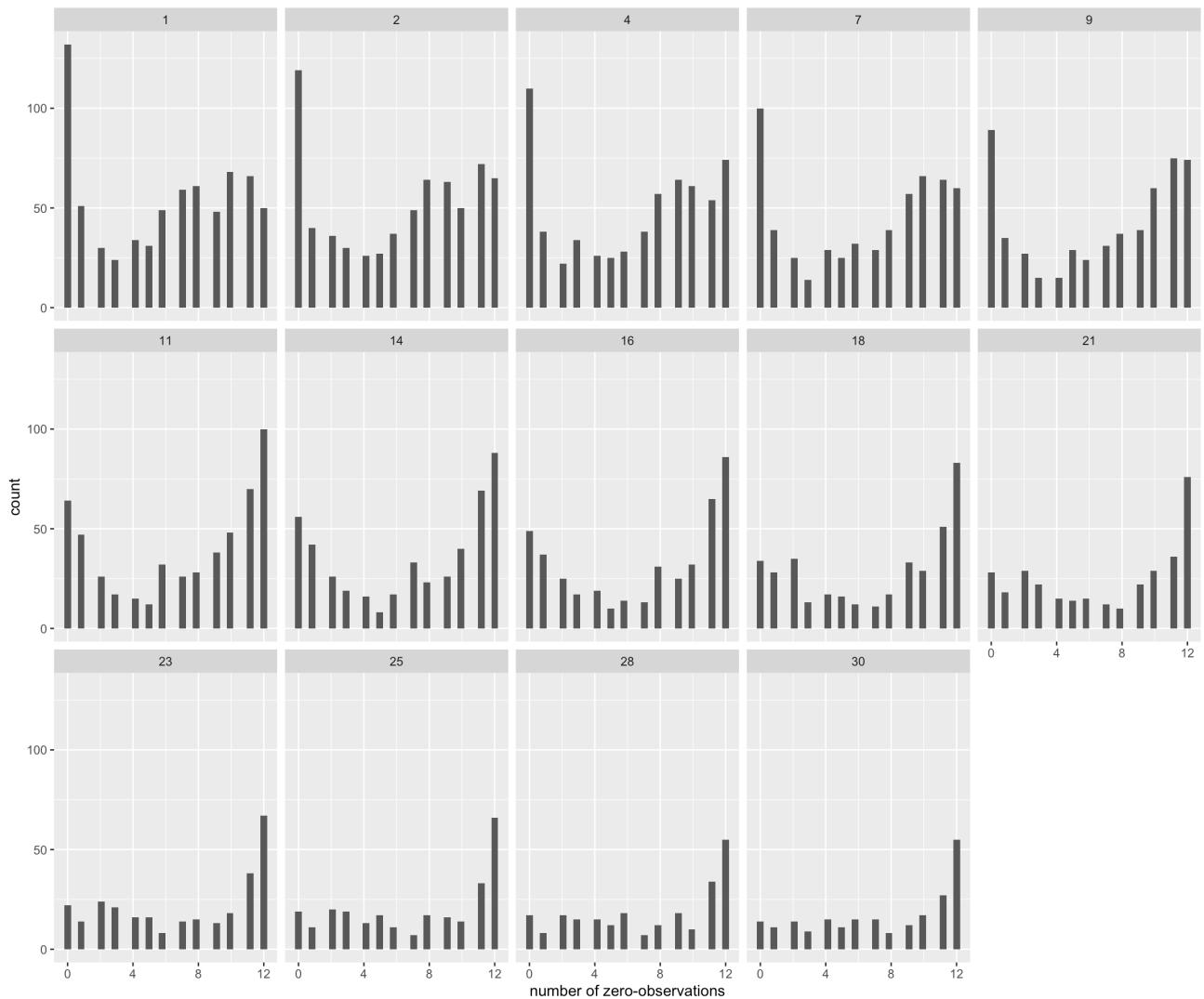


Figure 11 Distribution of number of zero-biomass observations for each population included for each window.

Looking at the distributions of correlations between the focal species and residual community biomass, we can see how the shape and position of the mean changes starting at window 14 (or about half way through the experiment). This change in the shape and mean coincided with the emergence of the positive relationship between imbalance and asynchrony (Fig. 4):

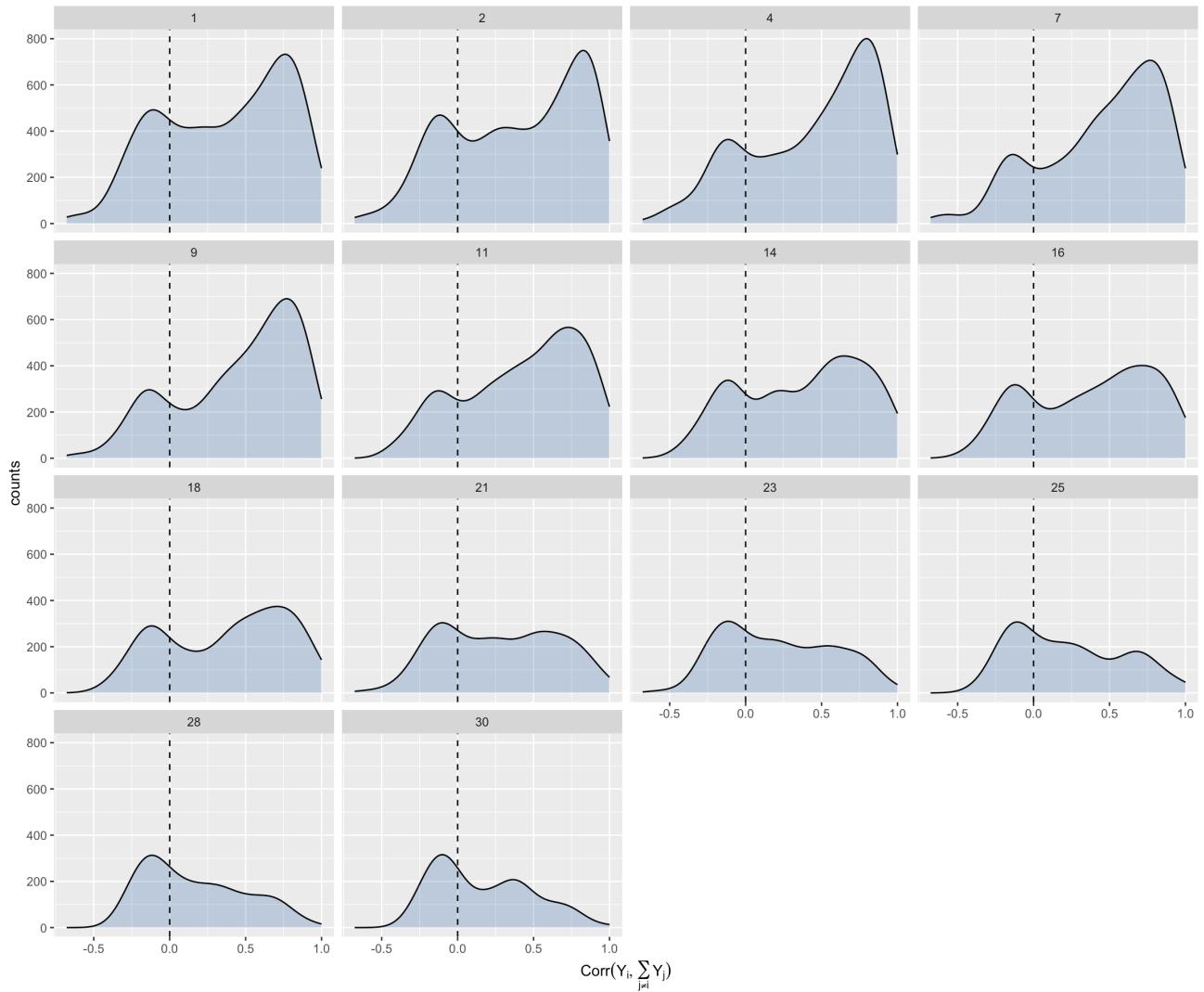


Figure 12 Distribution of Correlations between focal species and residual community for each window.

5 Conclusion

We found that the effect of imbalance on population stability was robust, while the effect on asynchrony was not. Asynchrony seemed positively related to imbalance in the second half of the experiment. However, this relationship was unreliable due to many zero-observations (because of low abundances), which caused the asynchrony measure to behave erratically.