

Further revisiting the bivalve and brachiopod saga; beyond pairwise analysis

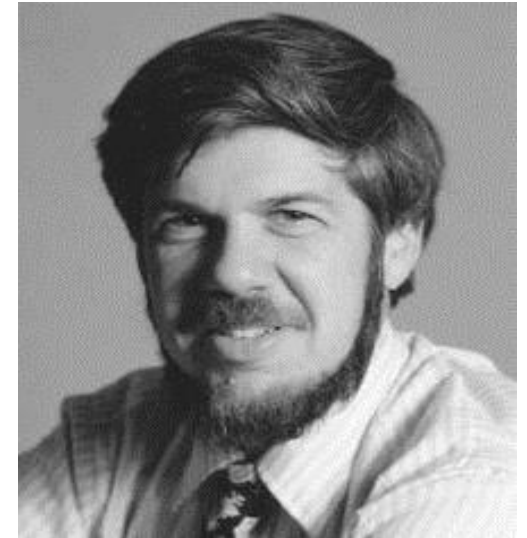
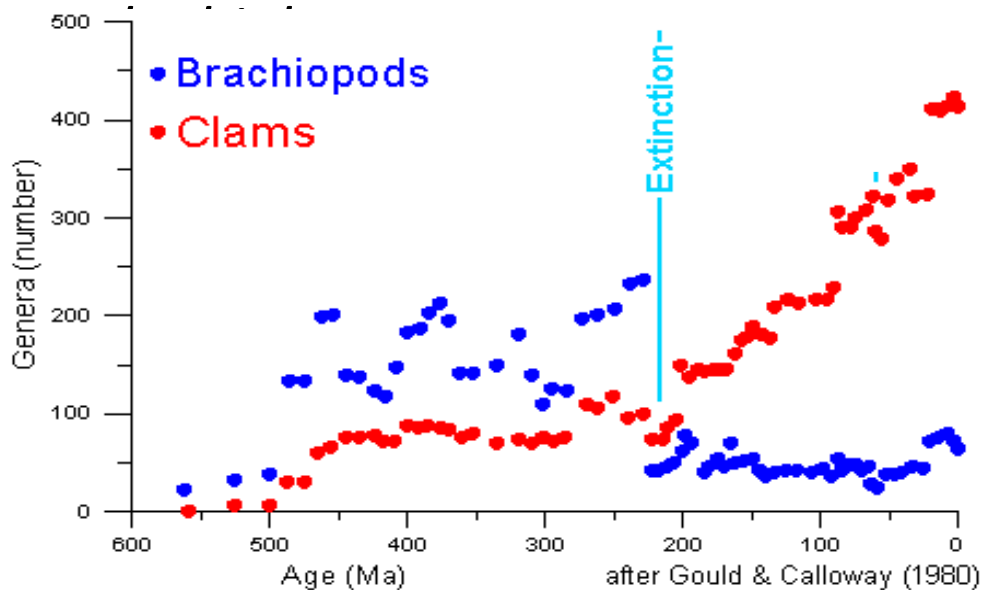
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Are brachiopods and bivalves ships that pass in the night?

Gould & Calloway 1980: Clams and brachiopods - ships that pass in the night.

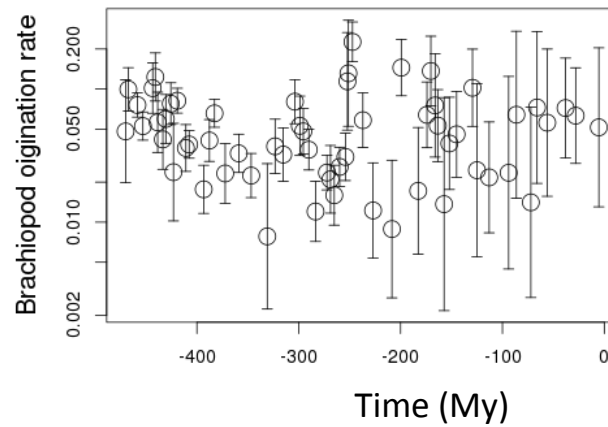
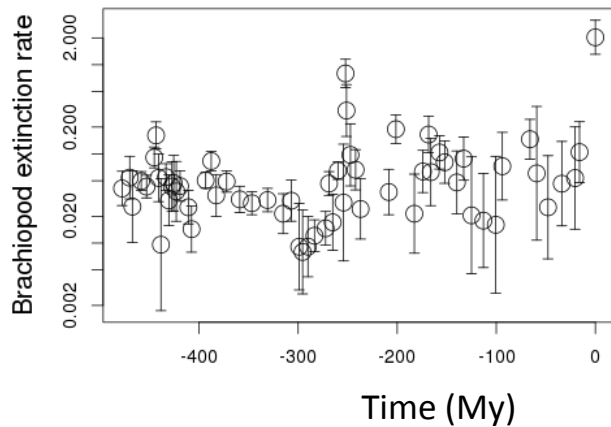
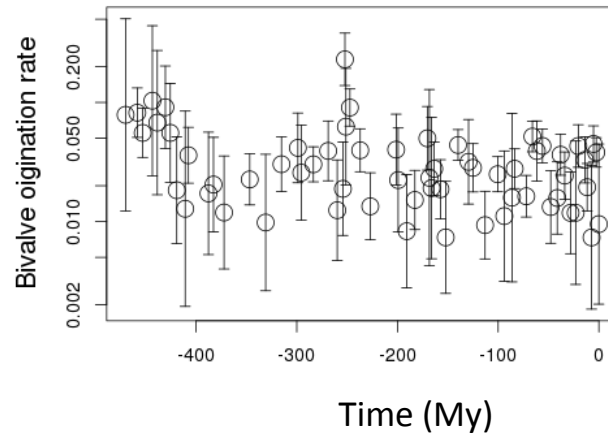
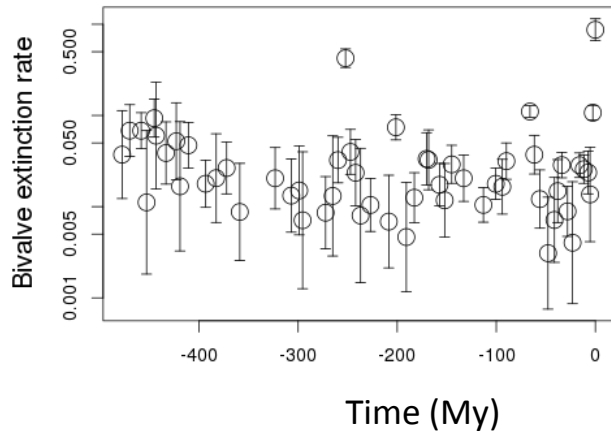


Idea: Use process modelling on recent extinction/origination rates to reexamine this.

The data

Extinction/origination rates estimated from fossil records
(Mark-recapture modelling).

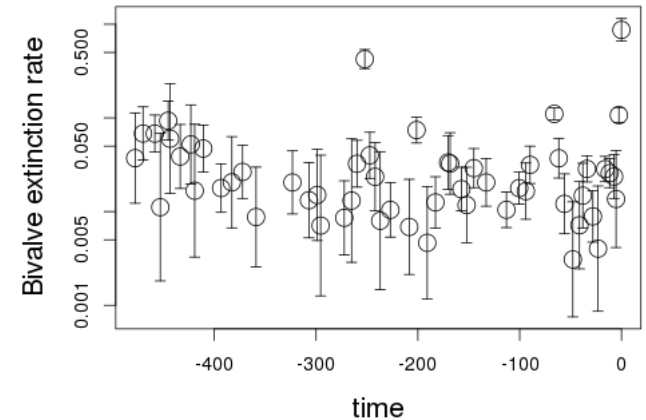
Two clades: bivalves and brachiopods.



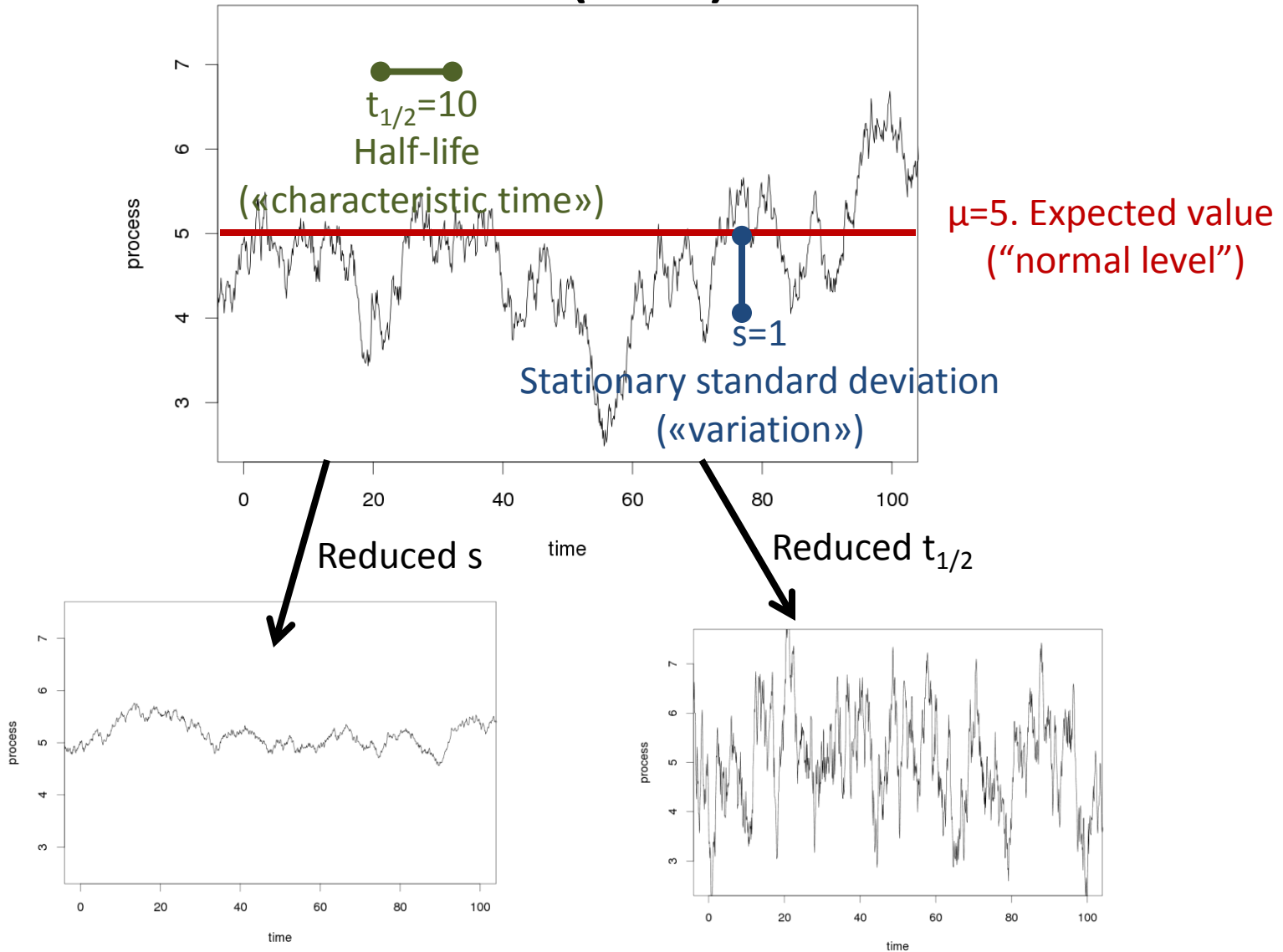
Lee Hsiang Liow

Process models - linear SDEs

- Can handle arbitrary gap lengths because linear stochastic differential equations deal with continuous time.
 - Random walk, OU and directional change are just special cases.
- Can handle differences in observational noise and unknown observational noise.
- Can look at multiple processes and connections between them.

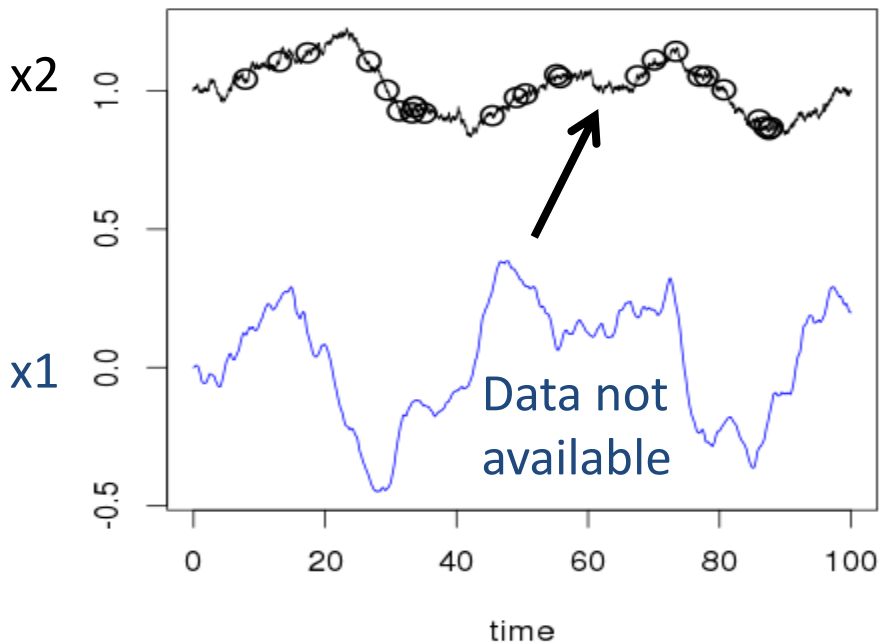


Properties of single linear SDE process (OU)

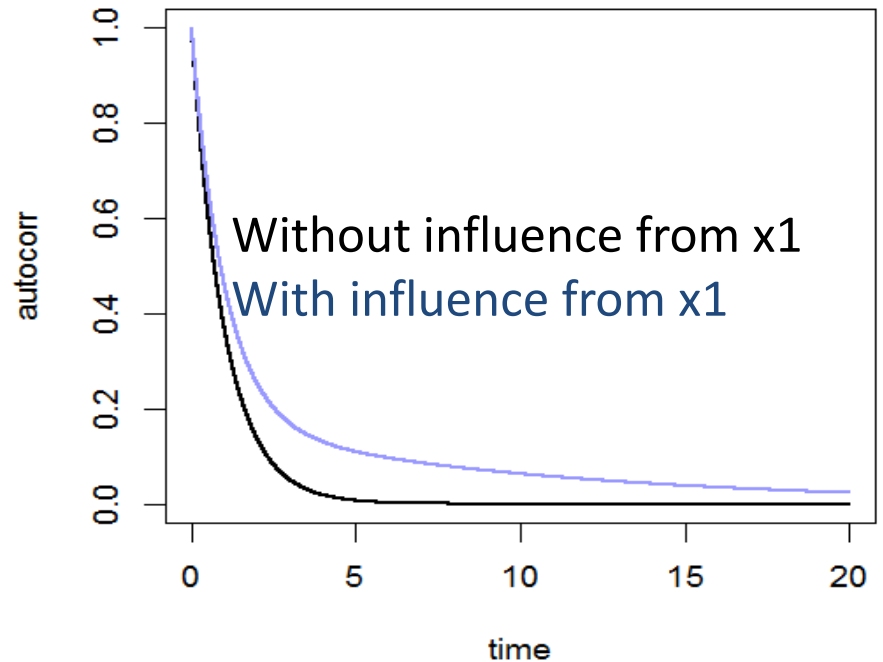


Process connections

- Can differentiate between causal and correlative connections of two processes.
- Can find connections even when the measurements of the two series are not at the same time. => No need to bin!
- Can find causal connections even when only the effect is measured => hidden layers.



Autocorrelation of x_2 different if x_2 influenced by x_1 .



Why go beyond pairwise analysis?

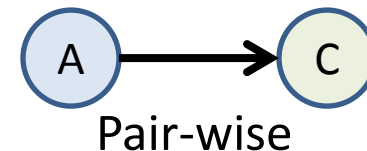
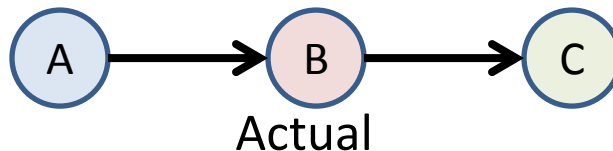
Pairwise comparisons:

1. Find internal structure for each rate process (standalone analysis).
2. Check for connections with climatic series.
3. Test all ways of connecting each pair of rate processes.

Lee Hsiang Liow, Trond Reitan and Paul G. Harnik (2015). Ecological interactions on macroevolutionary time scales: clams and brachiopods are more than ships that pass in the night, *Ecology Letters*
doi: 10.1111/ele.12485

Problems with pairwise analysis:

- A connection between process A and C can be explained by a connection from A to B and from B to C.



- Without correcting for one connection it can be more difficult to find another.
- We don't get a systematic picture of the dynamics of each series, when they are connected only pair-wise.

Comprehensive analysis procedure

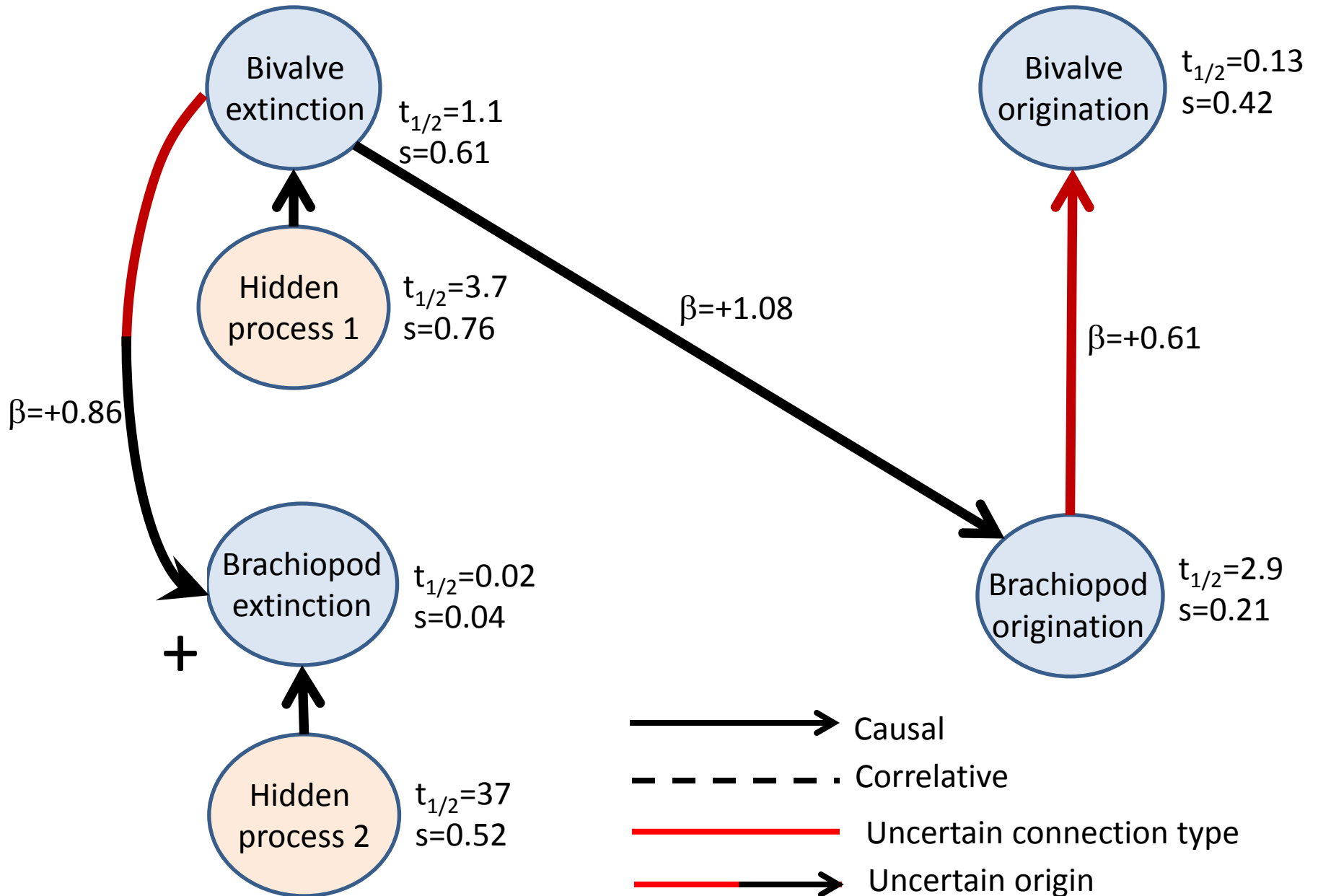
Possible combinations of connections is too large to examine systematically:
 $5^{13} \approx 1.2$ billion. Do step-wise search instead.

1. Find internal structure for each time series (standalone analysis).
2. Start with a model for all 4+2 time series with no connection.
3. Try all models with one connection more.
4. If one is better, set that as the model to beat and go back to 3. (Step-wise up).

Modifications: Also allow do change a connection, remove a connection or modify the model structure in step 3.

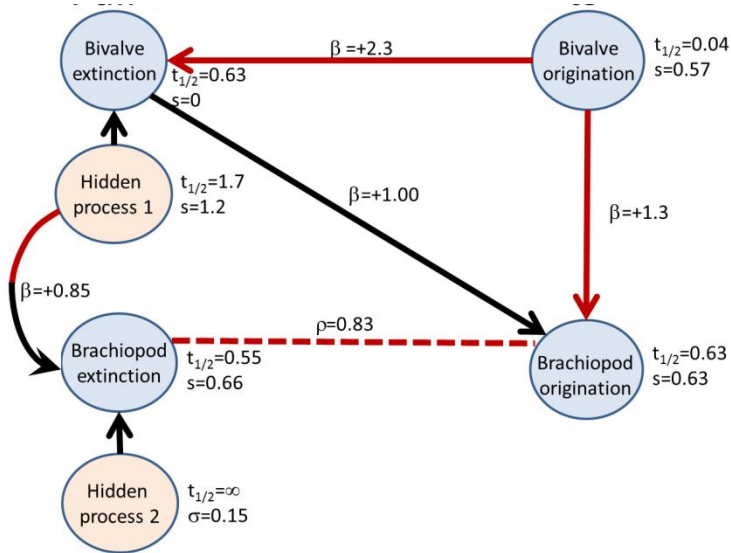
Con: There can be a model that is better than the one found in a step-wise search.

Best rates model

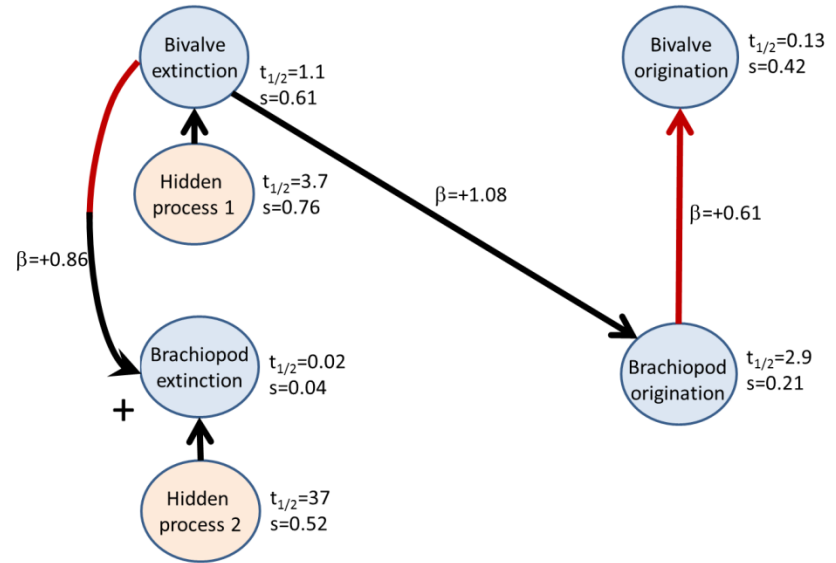


Improvements in analysis

Pair-wise (multi-layered)



Comprehensive

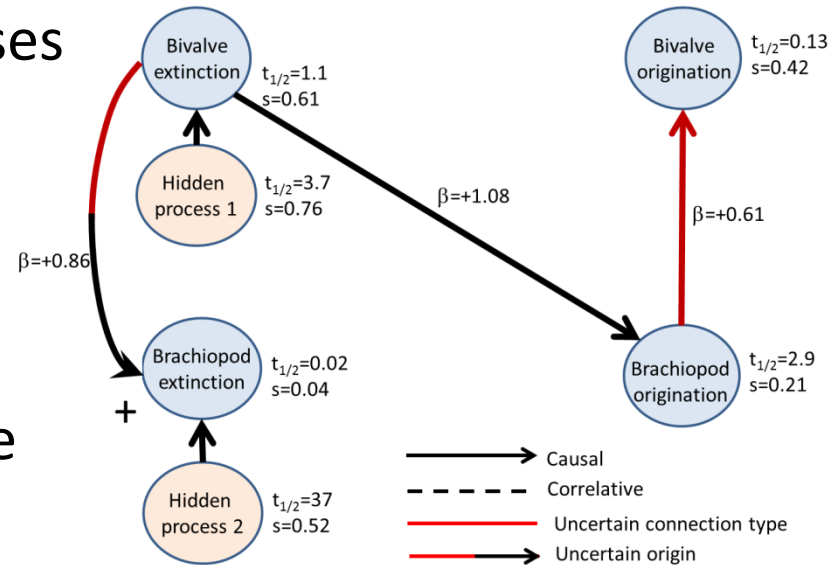


- Checking for the other effects in play means some connections can be removed.
- Consistency in time series description.
 - Variation due to internal fluctuations and due to external influence can be separated. => Reduced internal fluctuations in series affected by others.

PS: The great complexity in modelling alternatives means either using an enormous amount of computer resources or having to do with stepwise searches, though!

Biotic interactions

- Low bivalve extinction rate suppresses brachiopod origination. Bivalve extinctions opens up brachiopod niches?
- Common extinction process. Brachiopod extinction rate adds some unknown slower process.
- => Brachiopod diversity becomes more volatile with increased bivalve extinctions.
- Common origination process also, (but noisy bivalve process).



Thank you!

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