

Limits to the detection of early warning signals of population collapse

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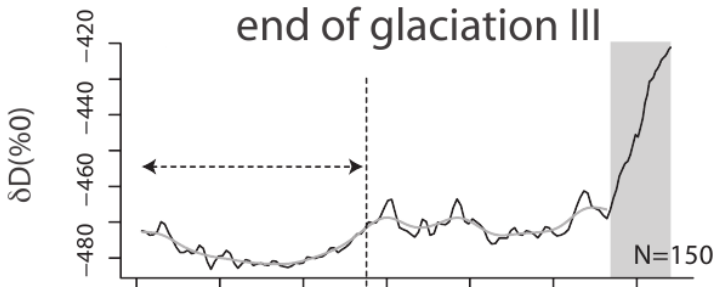
August 10, 2011



Tipping points: Sudden dramatic changes or regime shifts...



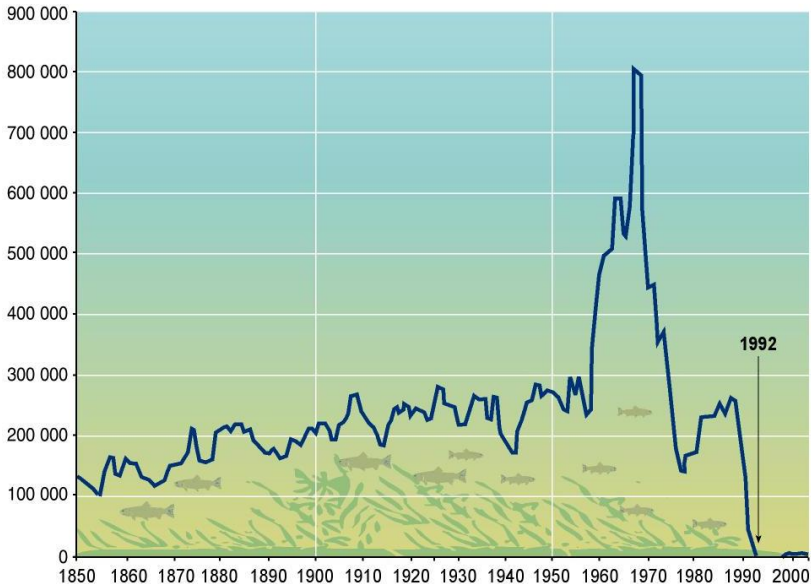
Some catastrophic transitions have already happened



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Precedings : doi:10.1038/npre.2012.6857.1 : Posted 31 Jan

Fish landings in tons



Source: Millennium Ecosystem Assessment

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Early Warning Signs

4/77

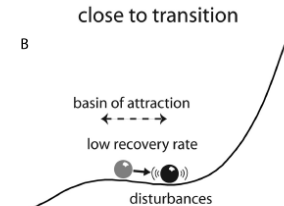
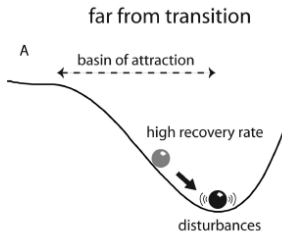
But, what if we could predict such sudden collapse?

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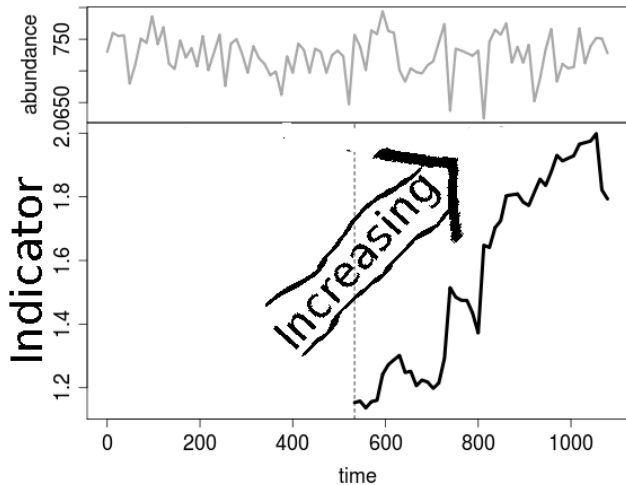
Can we?

A simple theory built on the mechanism of bifurcations



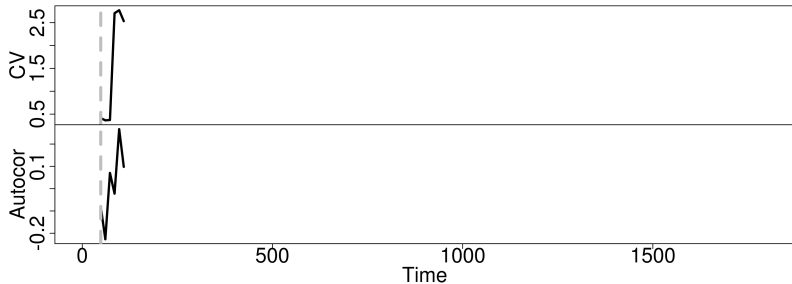
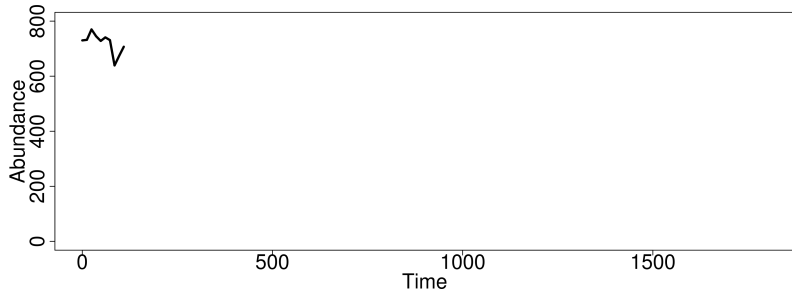
Scheffer *et al.* 2009

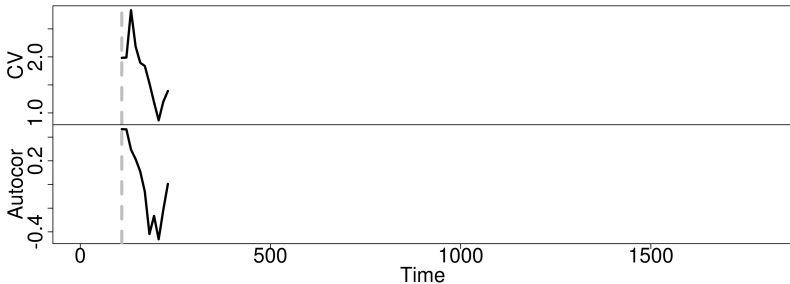
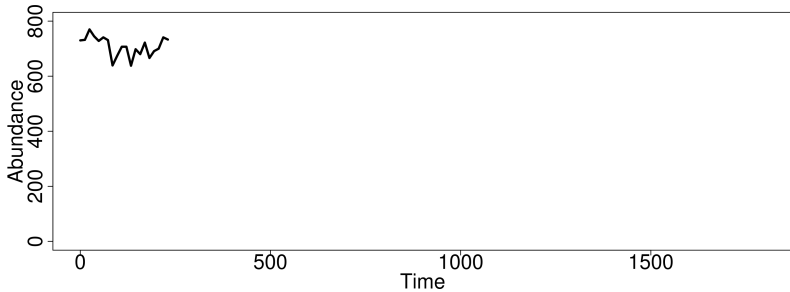
Early warning indicators

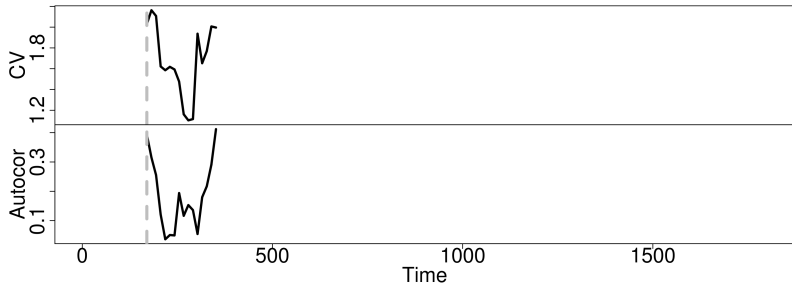
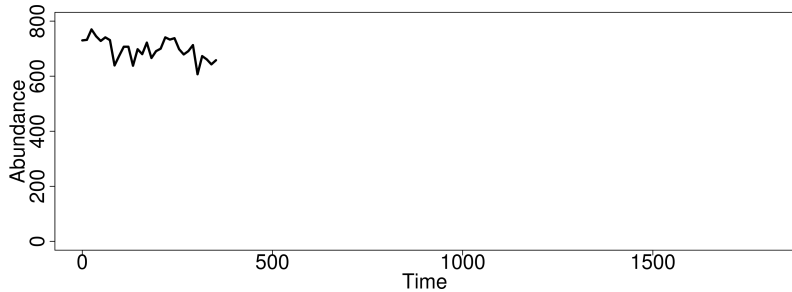


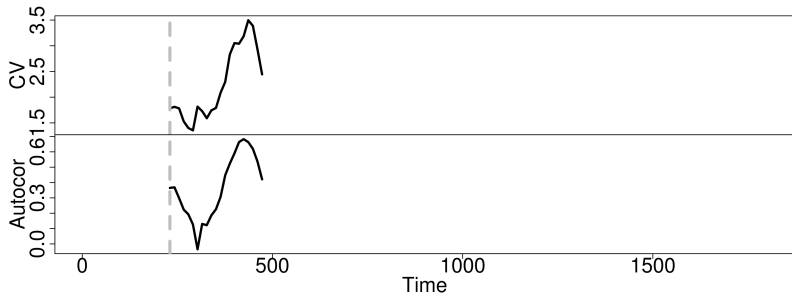
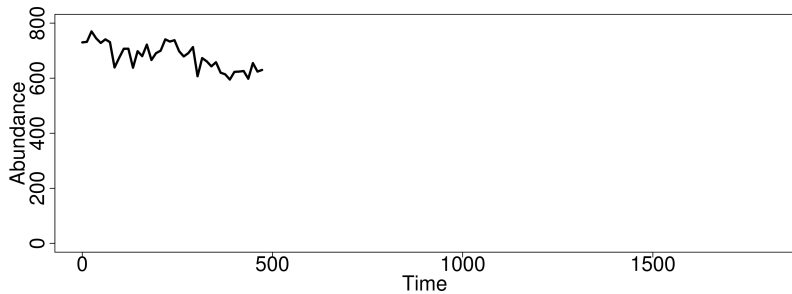
- e.g. Variance: Carpenter & Brock 2006;
- or Autocorrelation: Dakos *et al.* 2008; etc.

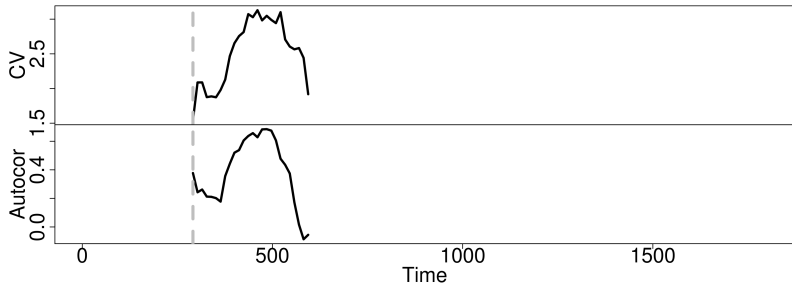
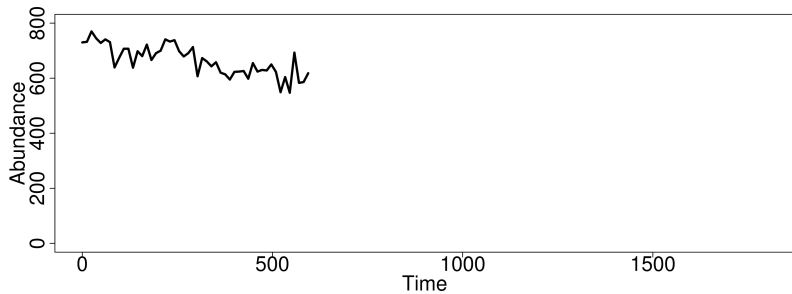
Let's give it a try...

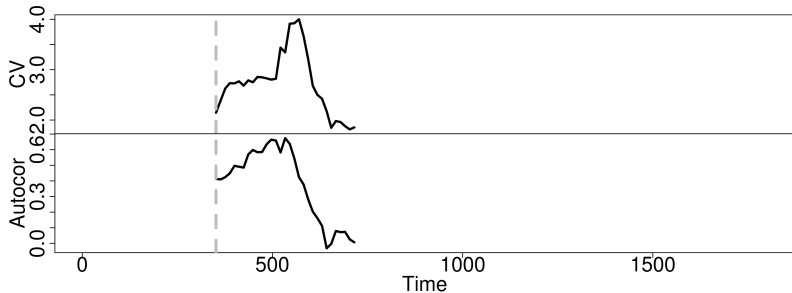
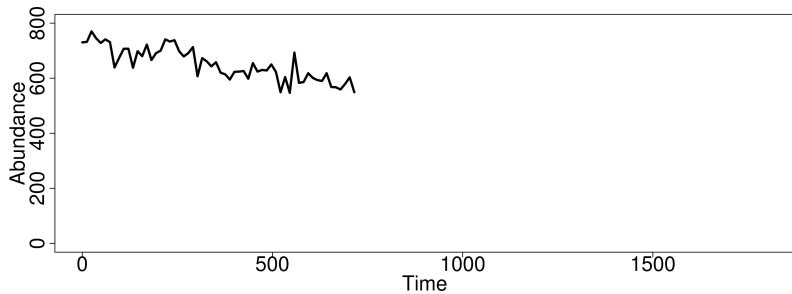


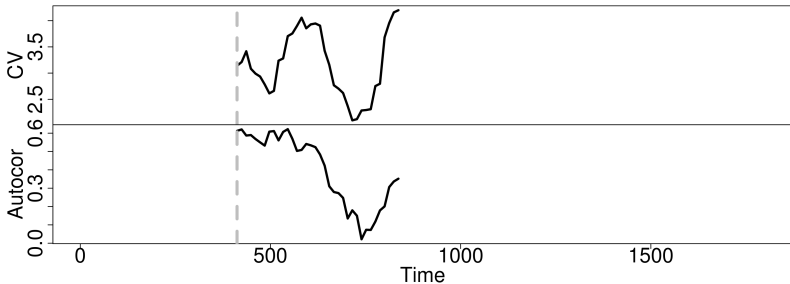
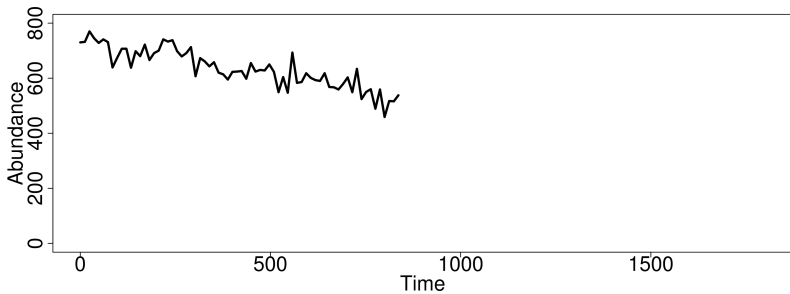


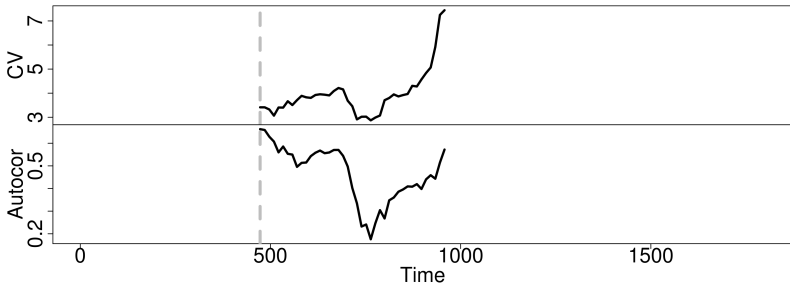
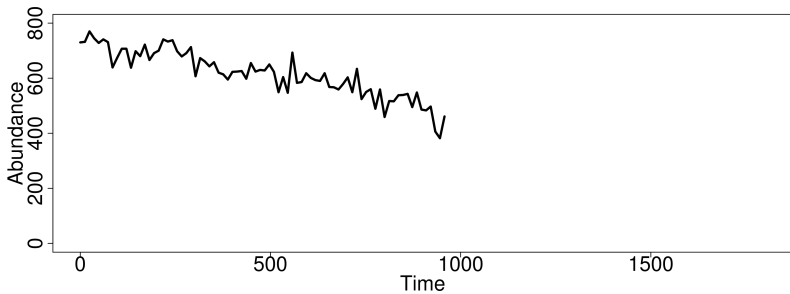


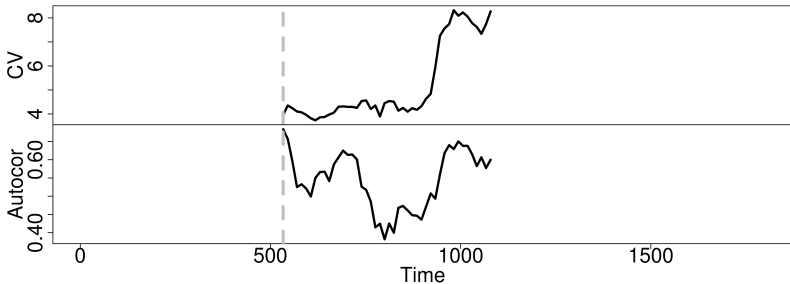
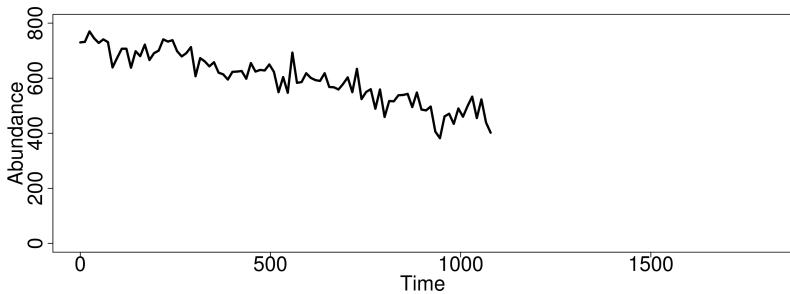


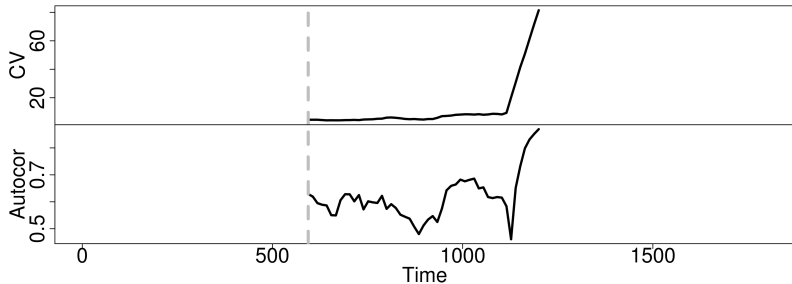
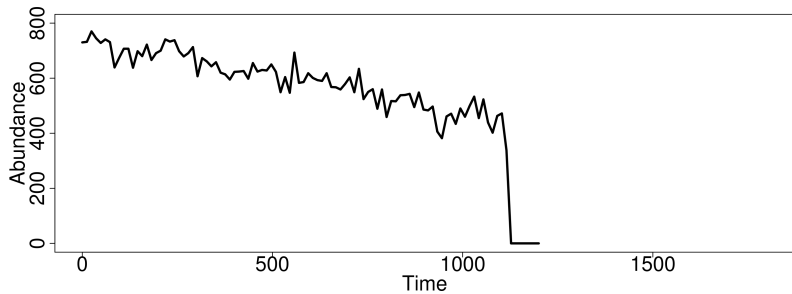












Prediction Debrief...

- So what's an increase?

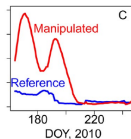
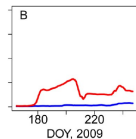
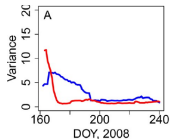
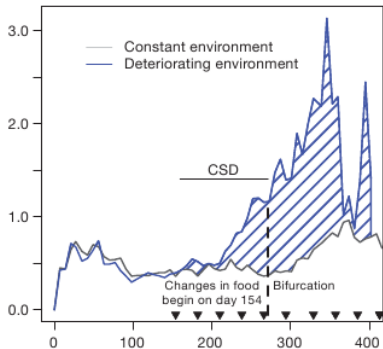
- So what's an increase?
- Do we have enough data to tell?

- So what's an increase?
- Do we have enough data to tell?
- Which indicators to trust most?

Empirical examples of early warning

doi:10.1038/npre.2012.6857.1 : Posted 31 Jan 2013

Have relied on comparison to a *control system*:

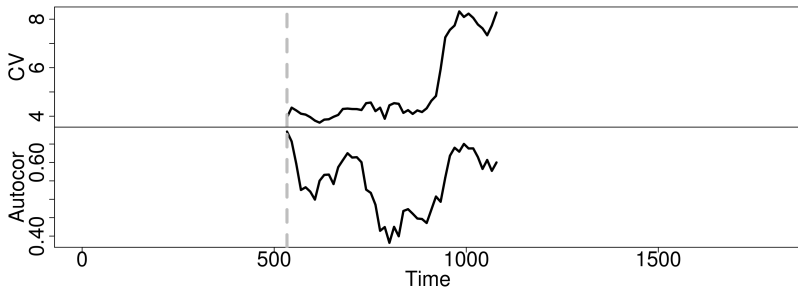


Carpenter *et al.* 2011

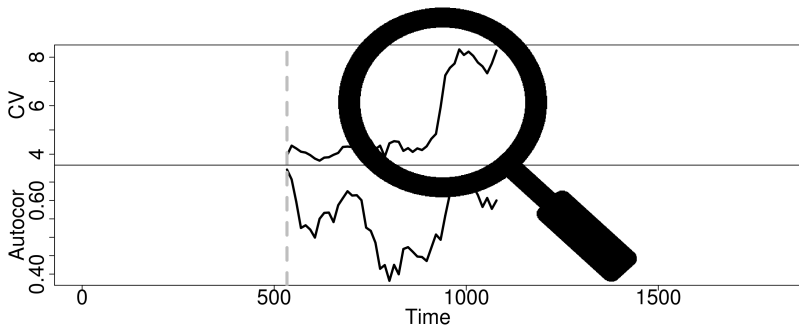
Drake & Griffen 2010

We don't have a control system. . .

All we have is a squiggle



All we have is a squiggle

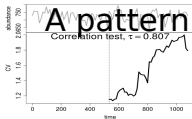


Making predictions from squiggles is *hard*

A pattern isn't enough

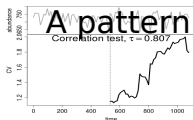
We need a framework

A framework for predicting catastrophe



Wissel 1984, Carpenter & Brock 2006, Dakos *et al.* 2008, Guttal *et al.* 2008, Scheffer *et al.* 2009, Dakos *et al.* 2009, Brock & Carpenter 2010, Drake & Griffen 2010, Carpenter *et al.* 2011, Carpenter & Brock 2011 ...

A framework for predicting catastrophe

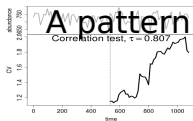


A statistic

τ

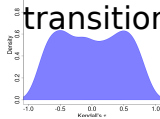
• Dakos *et al.* 2008, Dakos *et al.* 2009,

A framework for predicting catastrophe

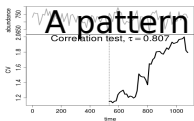


A statistic τ

Not approaching transition

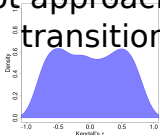


A framework for predicting catastrophe

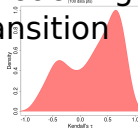


A statistic τ

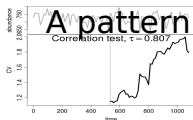
Not approaching transition



Approaching transition



A framework for predicting catastrophe

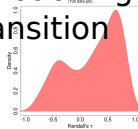


A statistic τ

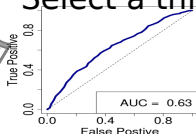
Not approaching transition



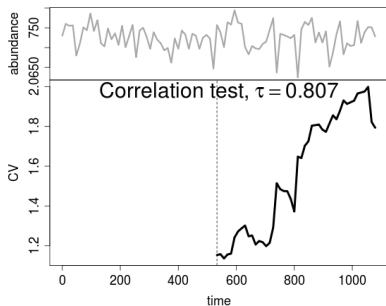
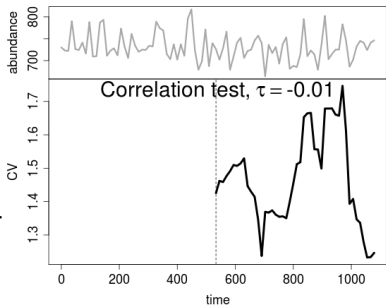
Approaching transition



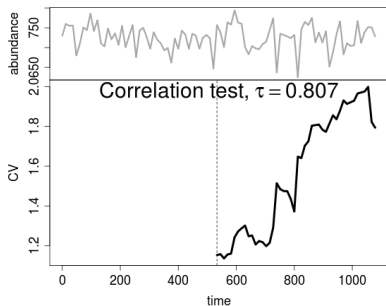
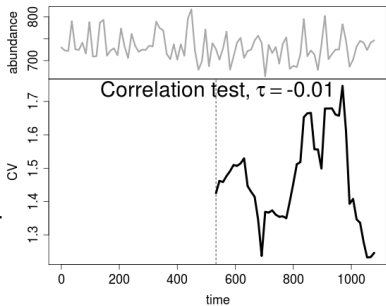
Select a threshold



What's an increase?

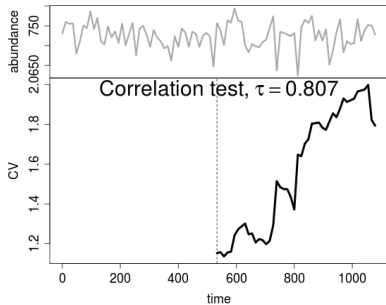
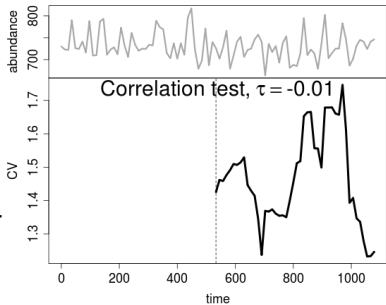


What's an increase?



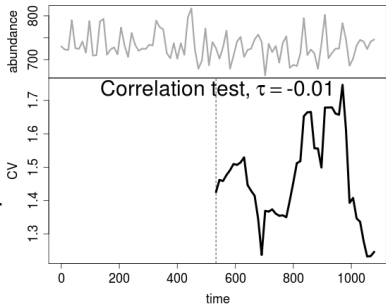
$\tau \in [-1, 1]$ quantifies the trend.

Unfortunately...

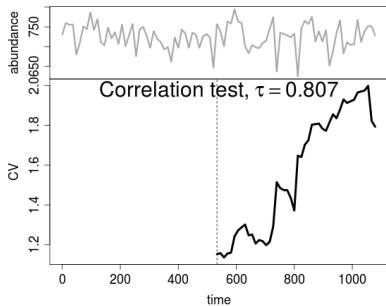


Both patterns come from a *stable* process!

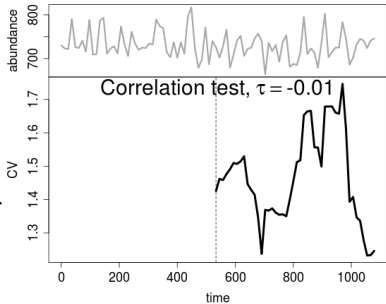
Typical?



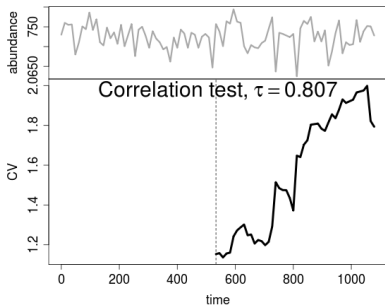
False alarm!



Typical?

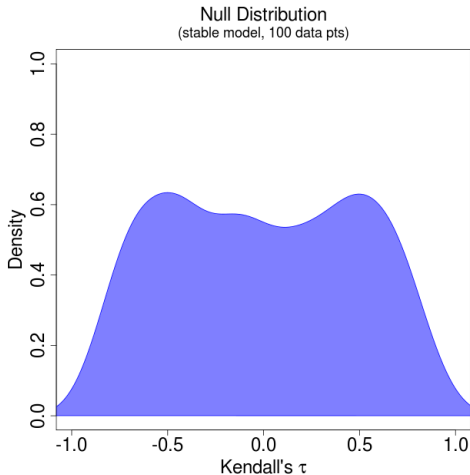


False alarm!



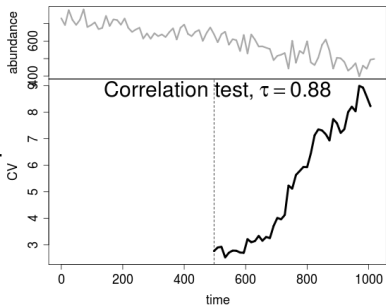
How often do we see false alarms?

Precedings : doi:10.1038/npre.2012.6857.1 : Posted 31 Jan
Often. τ can take any value in a stable system

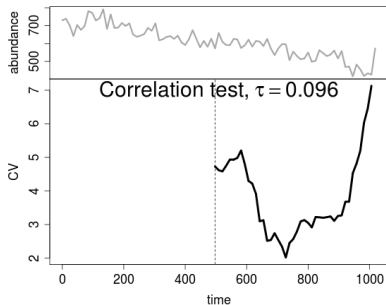


(We introduce a method to estimate this distribution on given data, \sim Dakos *et al.* 2008)

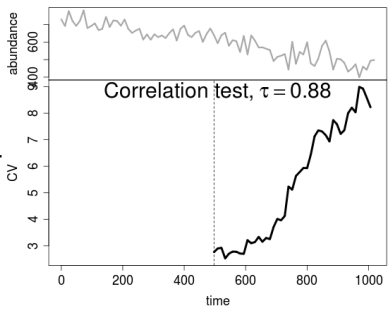
Warning Signal?



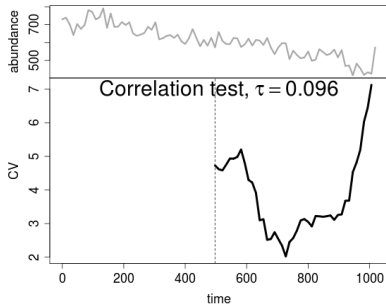
Failed Detection?



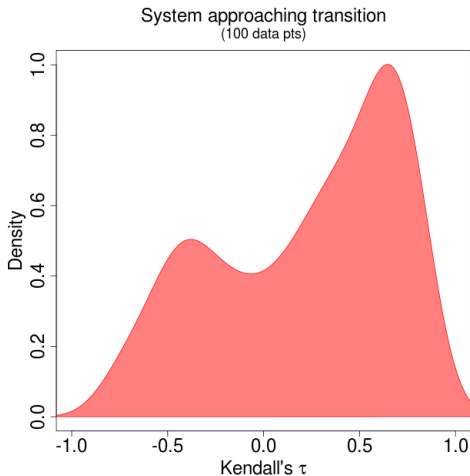
Warning Signal?



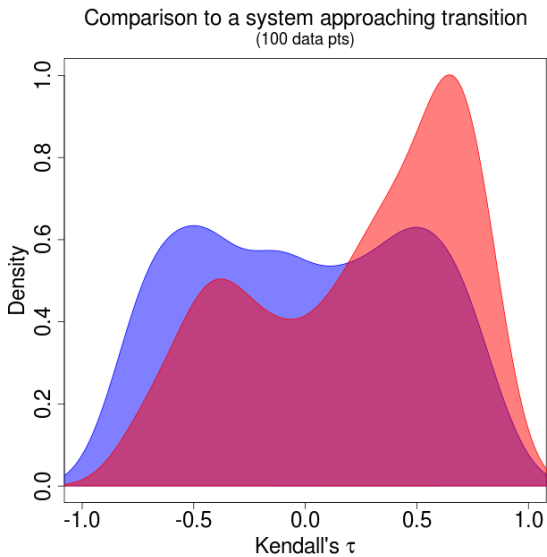
Failed Detection?



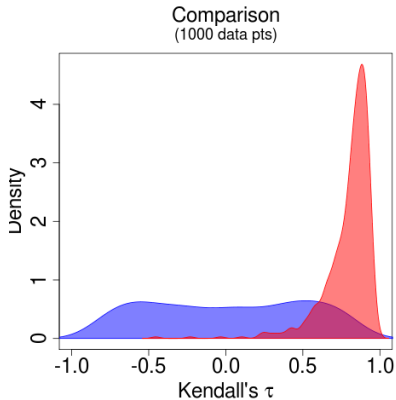
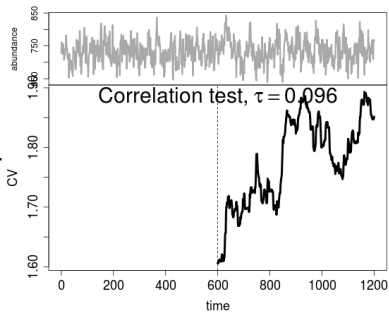
can take any value in a collapsing system



(Using a novel, general stochastic model to estimate)



How much data is necessary?



Beyond the Squiggles

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- general models by likelihood: **stable** and **critical**

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- general models by likelihood: **stable** and **critical**
- simulated replicates for **null** and **test** cases

Beyond the Squiggles

- general models by likelihood: **stable** and **critical**
- simulated replicates for **null** and **test** cases
- Use model likelihood as an indicator (Cox 1962)

So how are we doing?

False Alarm?



Failed Detection?



Do we have enough data to tell?



How about Type I/II error?

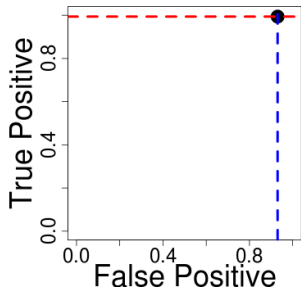
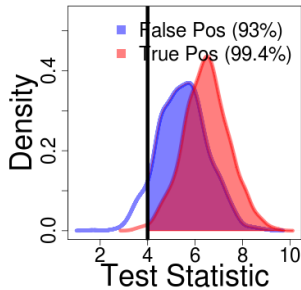
Formally, identical.

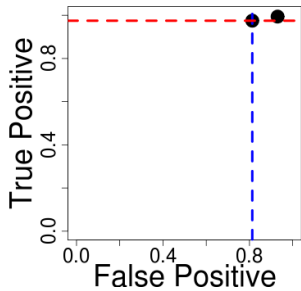
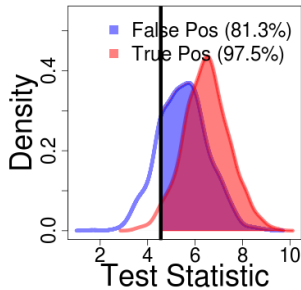
Linguistically, a disaster.

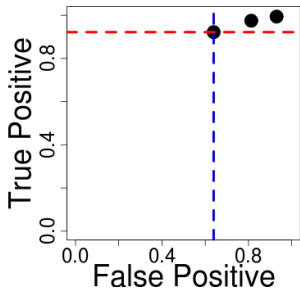
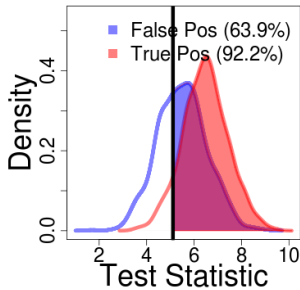
Instead: focus on trade-off

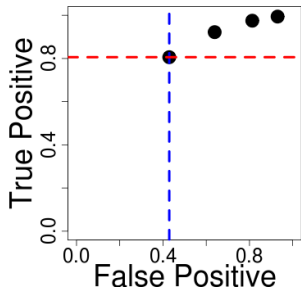
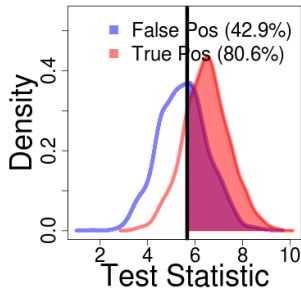
Receiver-operator characteristics (ROCs):

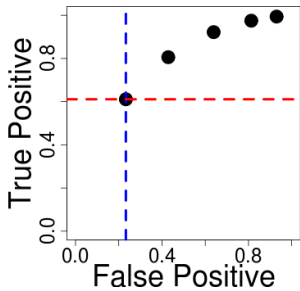
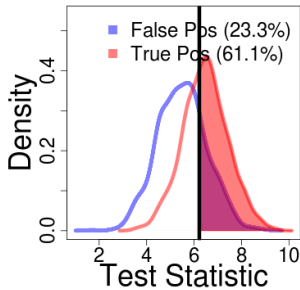
Visualize the trade-off between
false alarms and failed detection

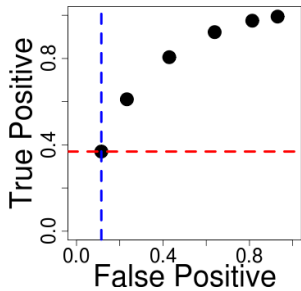
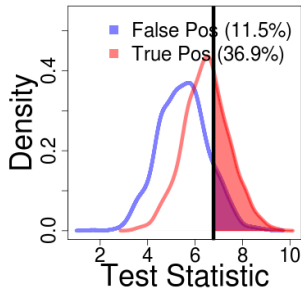


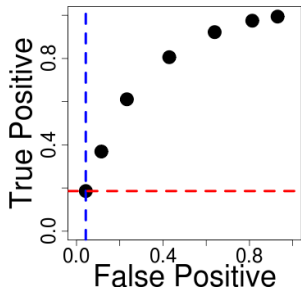
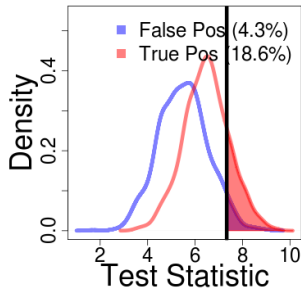


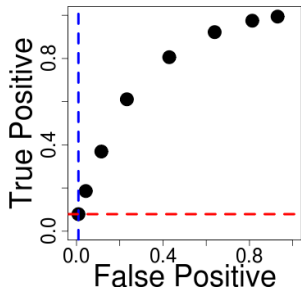
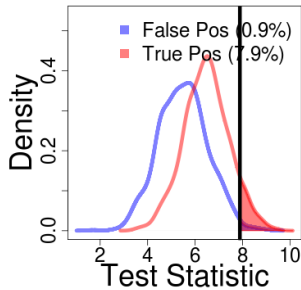


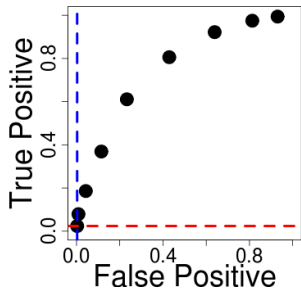
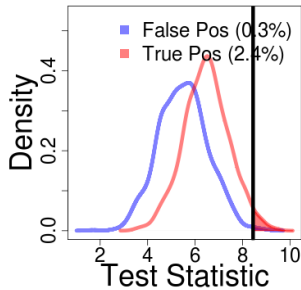


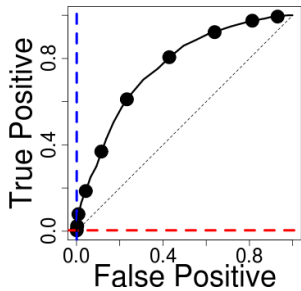
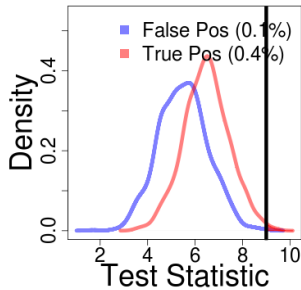


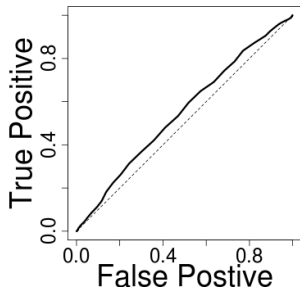
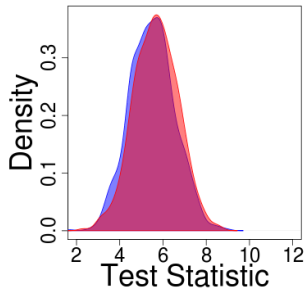


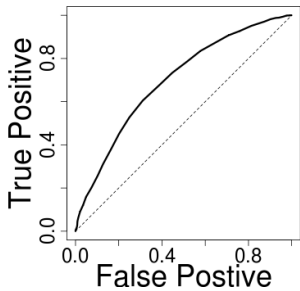
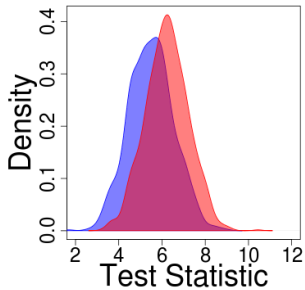


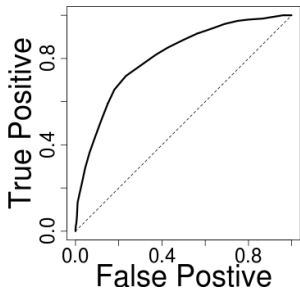
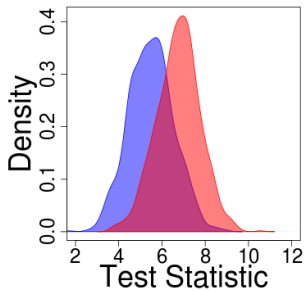


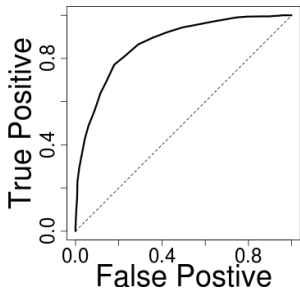
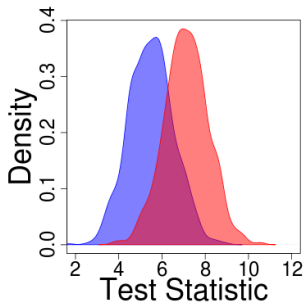


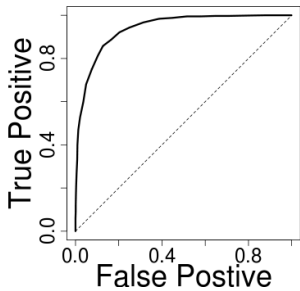
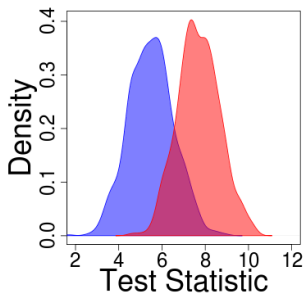


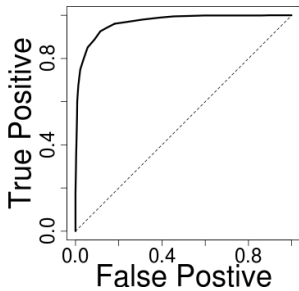
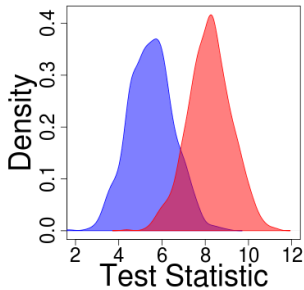


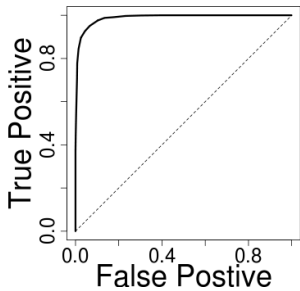
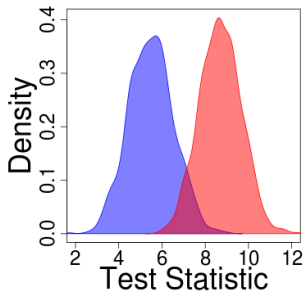


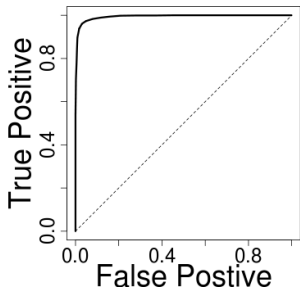
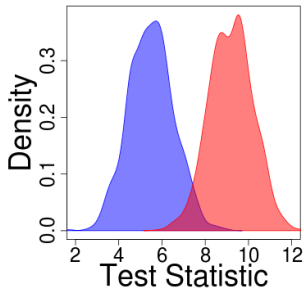


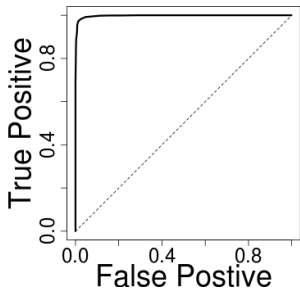
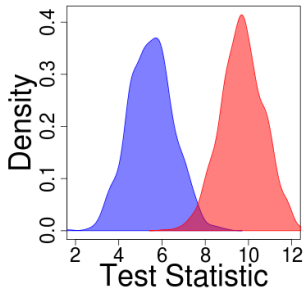


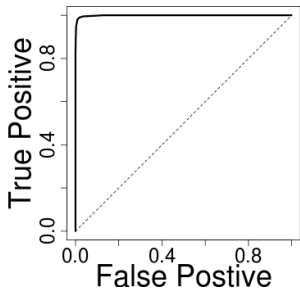
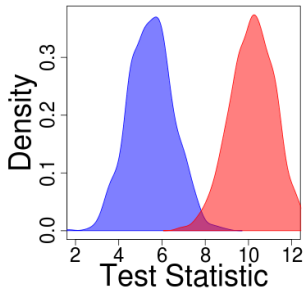


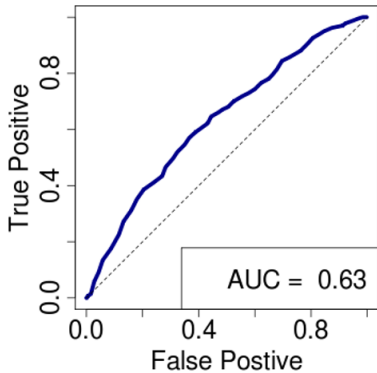
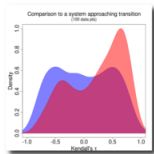
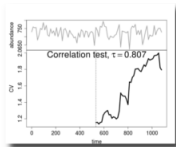


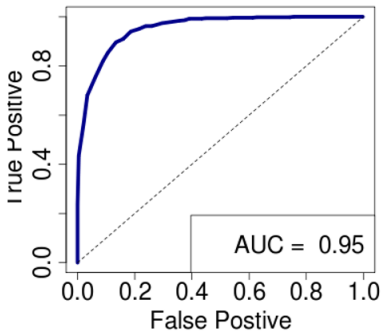
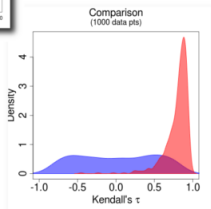
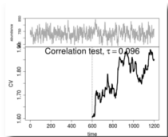


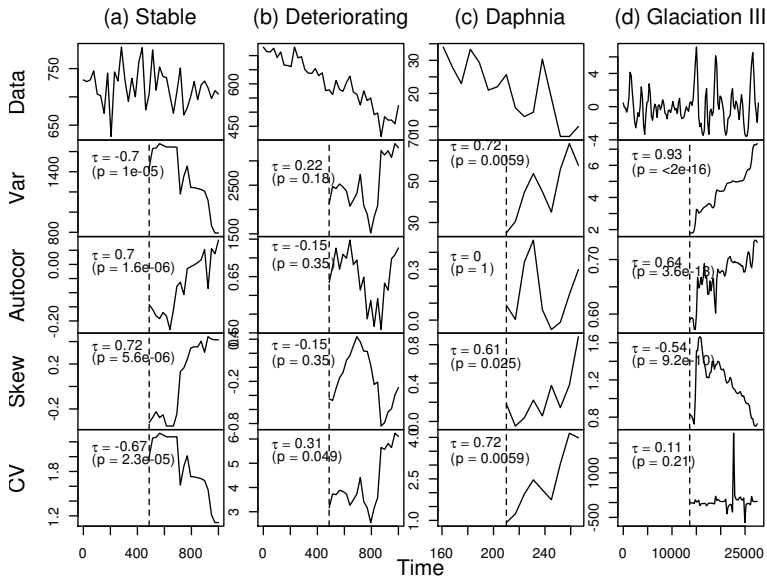




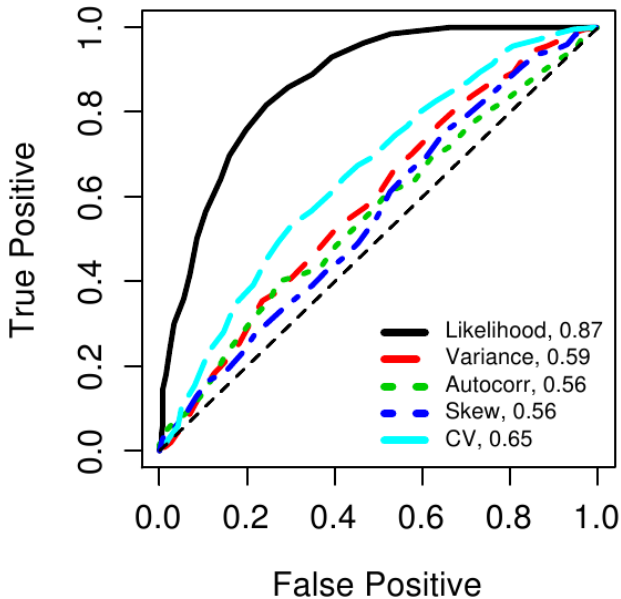


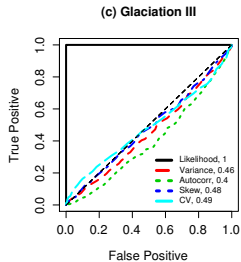
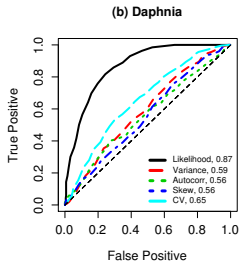
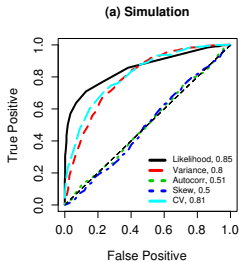


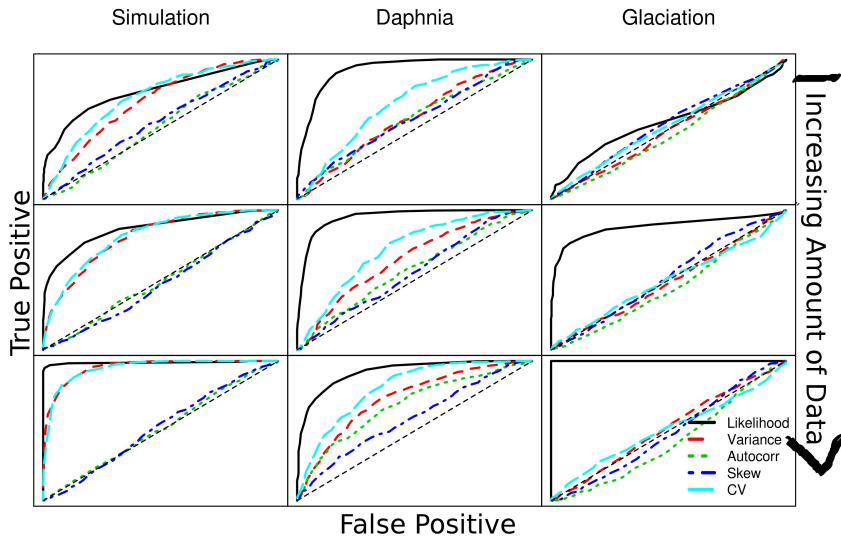




(b) Daphnia







Conclusions

- Estimate false alarms & failed detections
- Identify which indicators are best
- Explore the influence of more data on these rates.

Acknowledgements

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