Velocity of Ecological System Trajectory

A new method for dimension reduction and ecological regime shift detection

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Ecosystems are Complex

(and complicated)

- high dimensional

- many (∞ ?) interactions

- non-linear

- non-ergodic (open)

- dynamic

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- high dimensional

- many (∞ ?) interactions

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- dynamic

- difficult to model mathematically

Ecosystems are Complex

Image credit: coolkeywest.com

The Holy Grail of Ecology

forecasting change in time to prevent or mitigate undesirable consequences

The Holy Grail of Ecology

Predicting undesirable change

Image credit: The Ocean Agency

Ecological Regime Shifts

what? a persistent change in the structure or functioning of a system

how? loss of negative feedback(s) maintaining the system

goal? predict in time to prevent

Methods for Detecting Regime Shifts

> 70 (!) methods proposed in literature

10 suitable for multivariable data

few explicitly handle sparsedata

few handle irregular sampling

Regime Shifts Detection Methods

Variance Index (max eigenvalue of covariance matrix)

Principal Coordinates Analysis

Fisher Information

Regime Shifts Detection Methods

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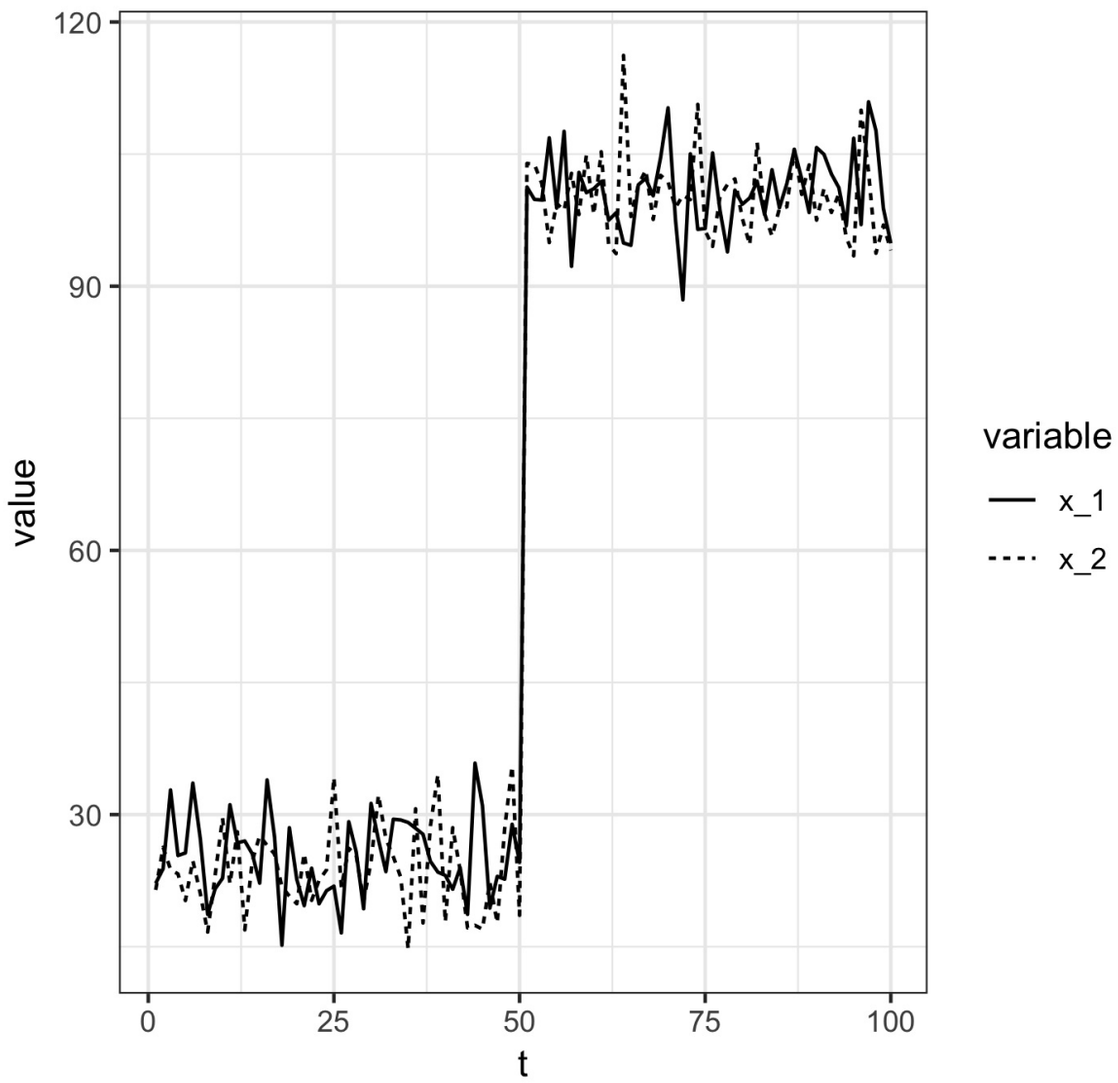
Toy System

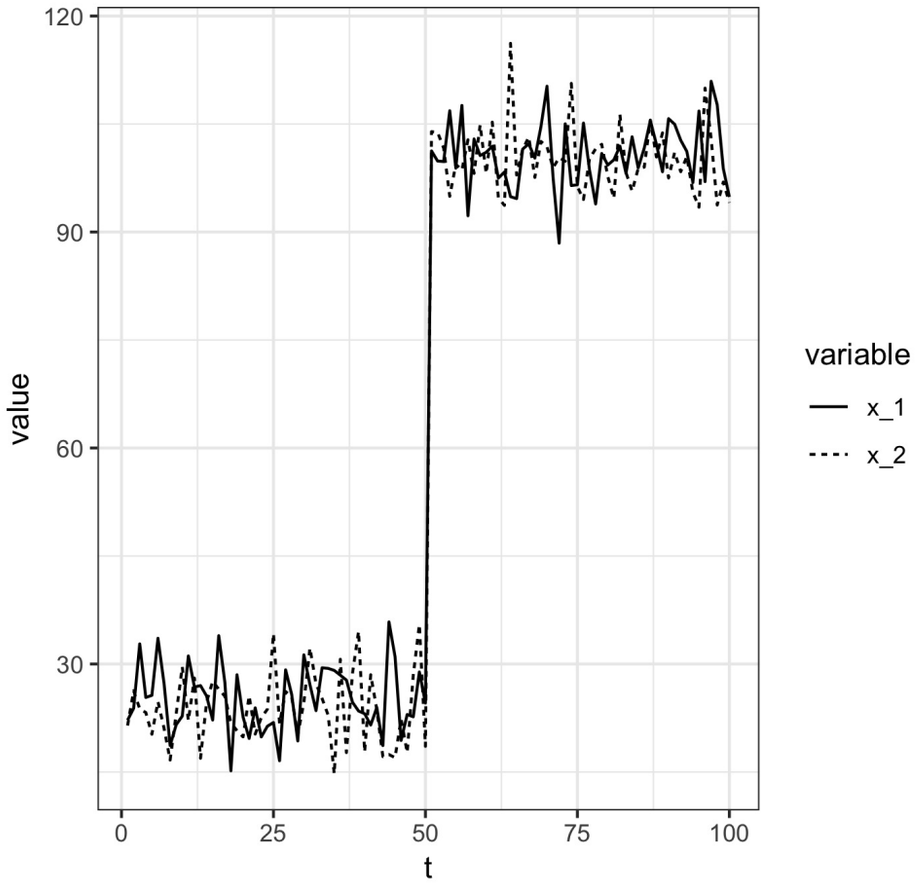


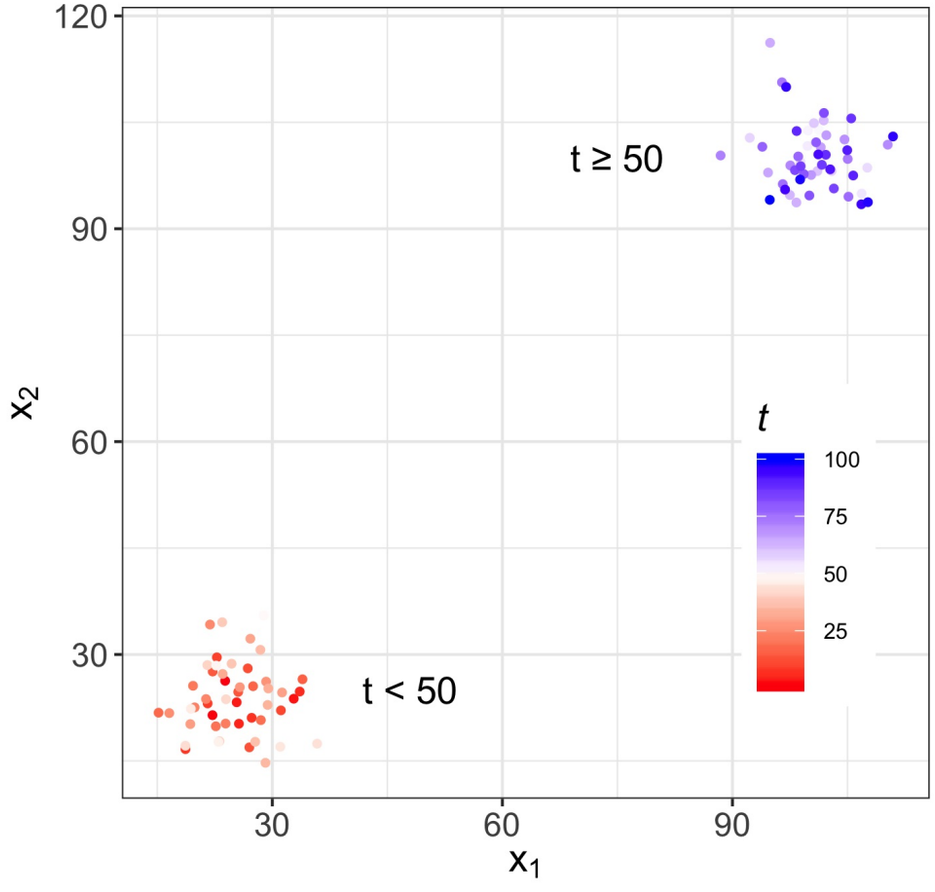
$$x \; normal(\mu = 25, \sigma = 5) \text{ for t } > 50$$

$$x \; normal(\mu = 100, \sigma = 50) \text{ for t } \geq 50$$

Velocity, $\frac{\Delta s}{\Delta t}$

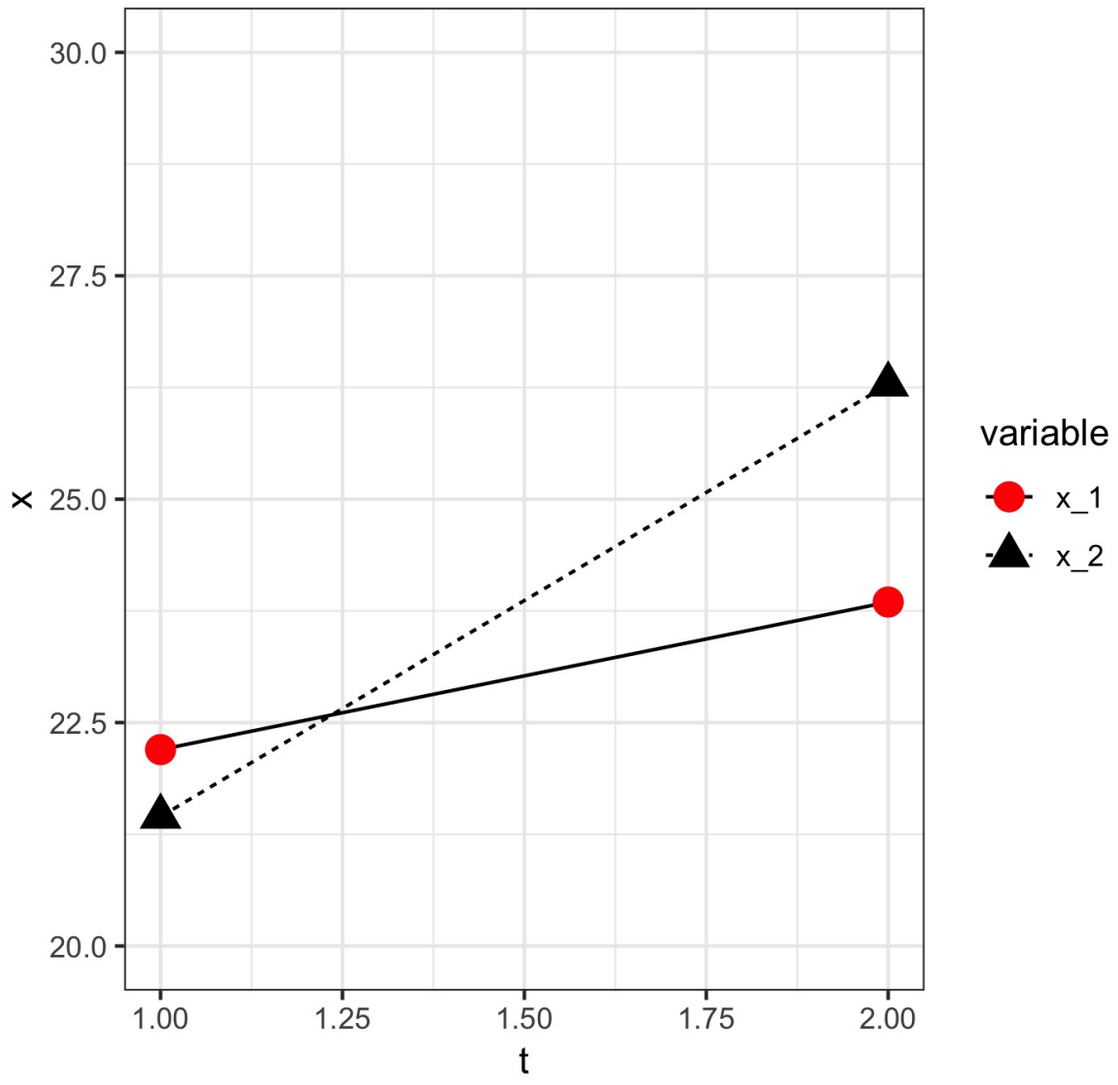
the linear speed of a system's trajectory in phase space





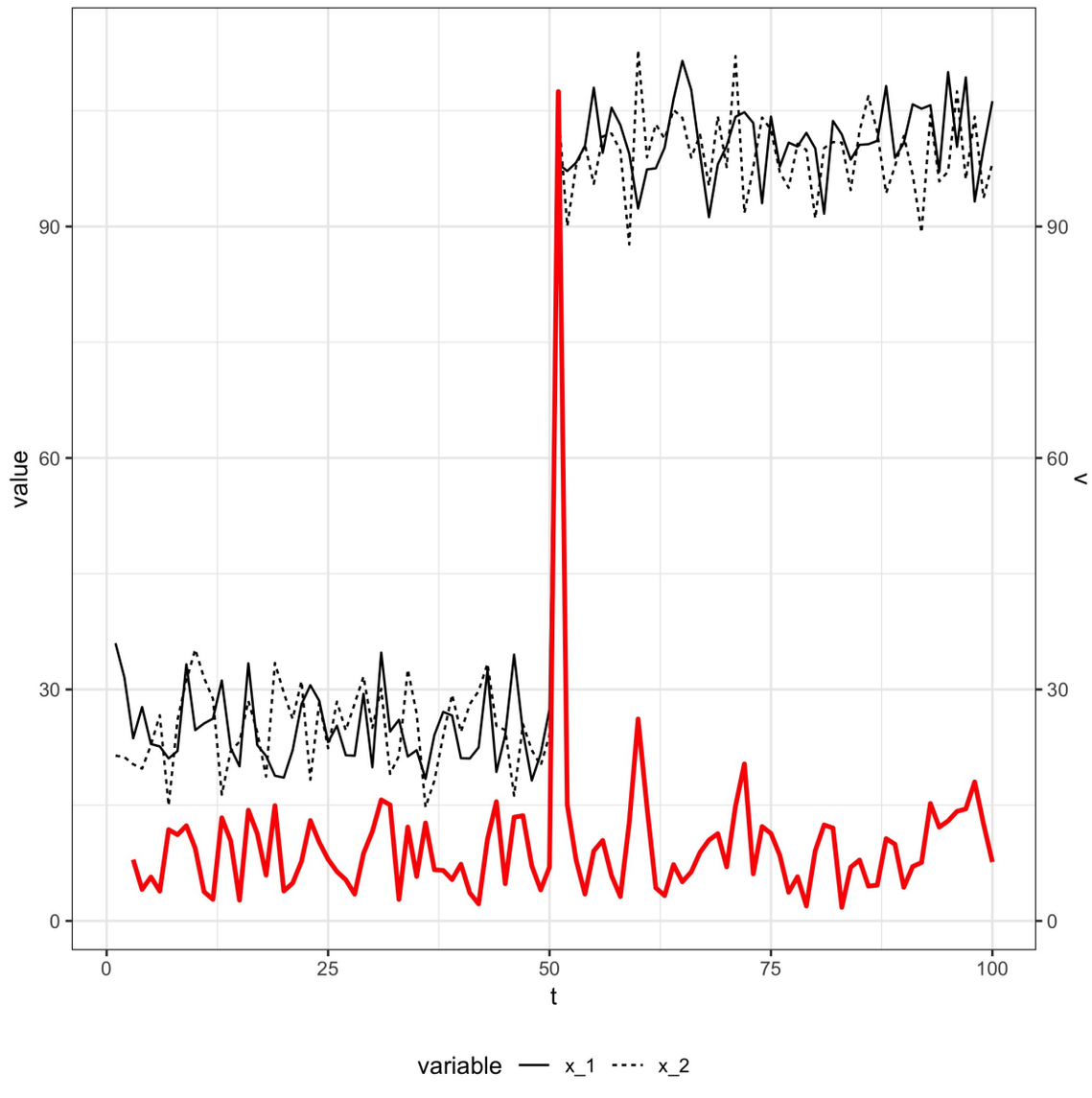
Step 1: Calculate s , 'distance travelled'

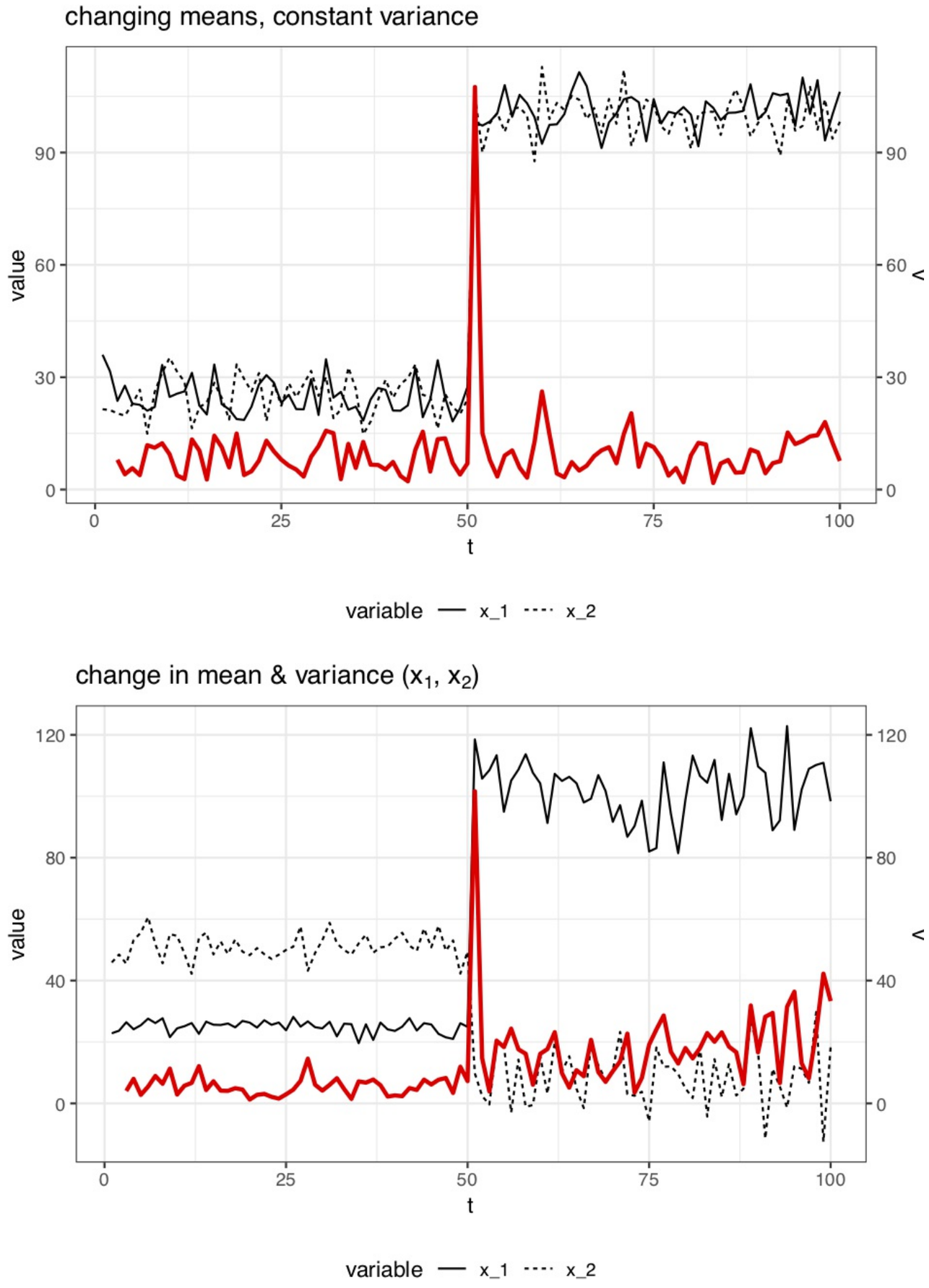
$$s_t = \sqrt{\sum_{i=1}^{X} (x_{it} - x_{it-1})^2}$$



Step 2: Calculate v , t he linear speed of s

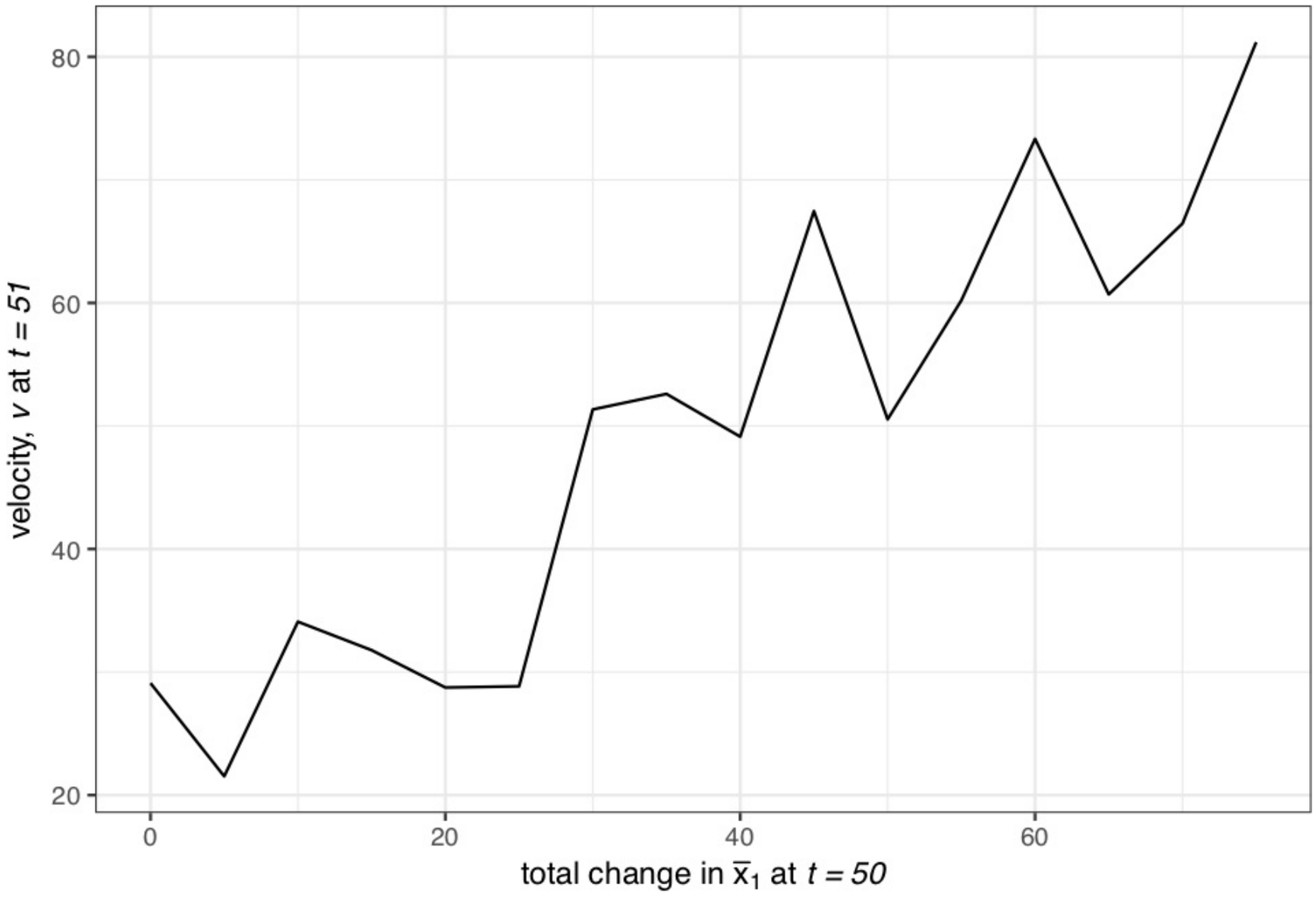
$$v = \frac{\Delta s}{\Delta t}$$



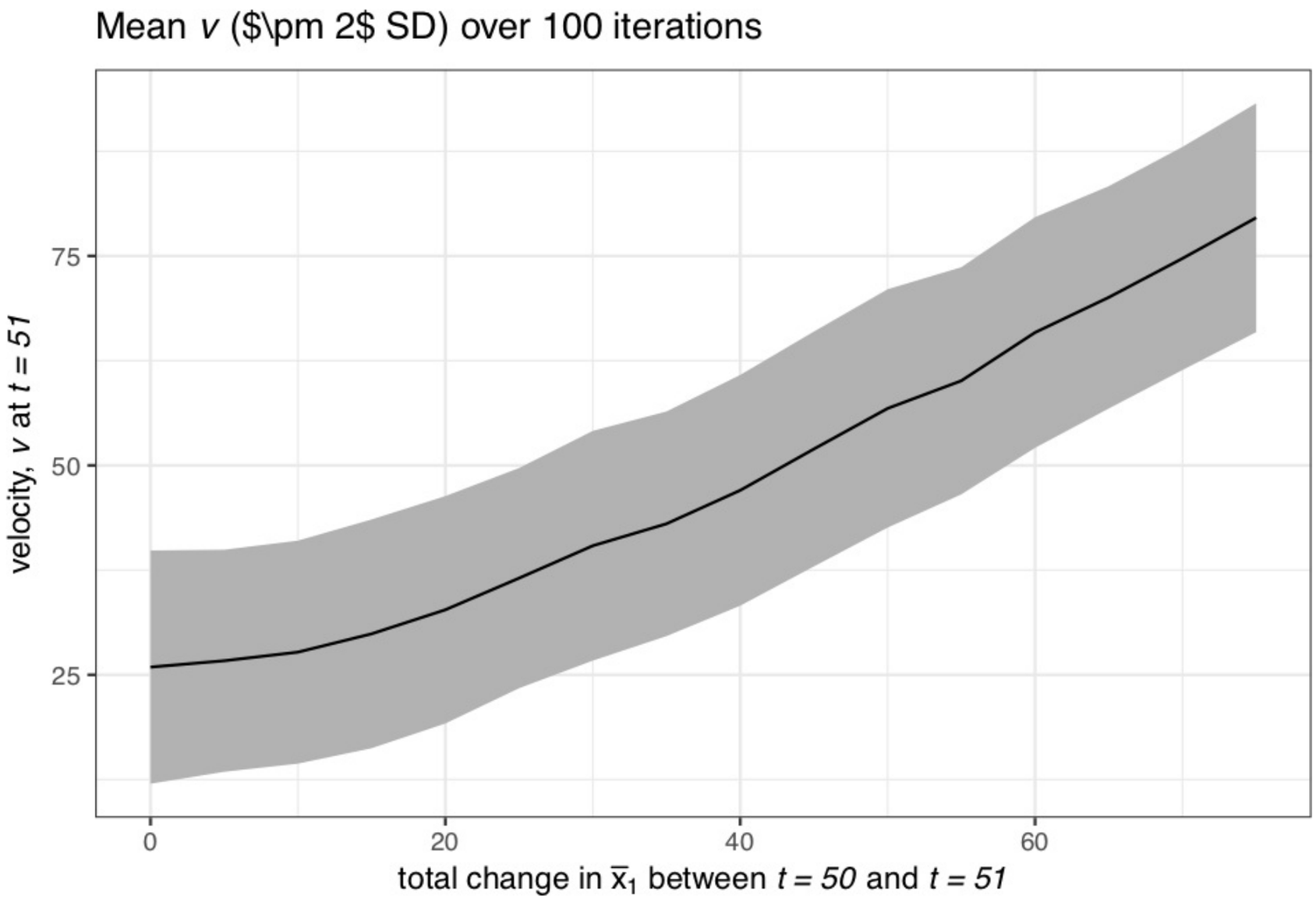

changing means, constant variance
value
t
0
30
60
90
0
25
50
75
100
variable
x_1
x_2
change in mean & variance (x_1, x_2)
value
t
0
40
80
120
0
25
50
75
100
variable
x_1
x_2

Potential Limitations of v

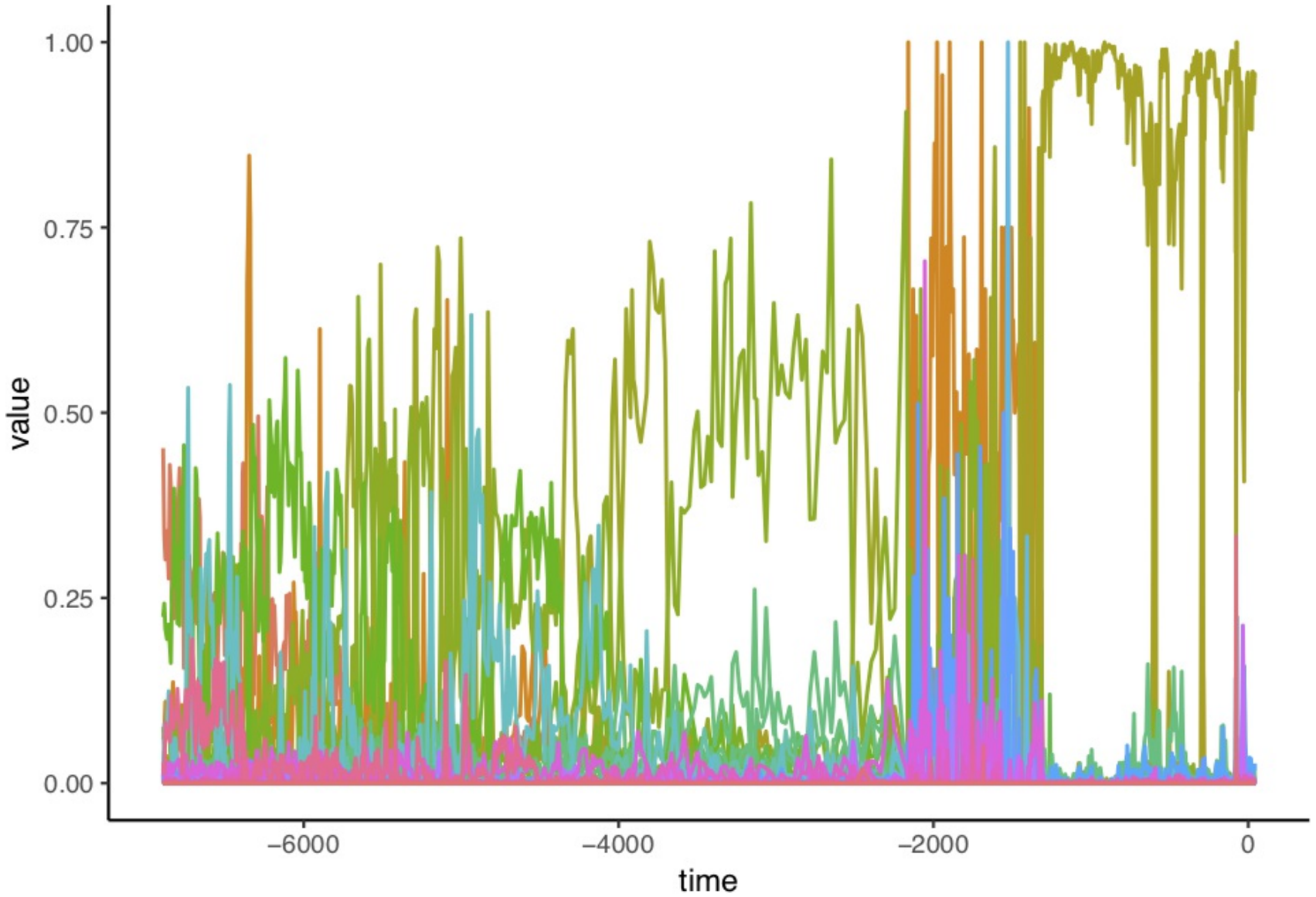
v increases with increasing effect size



v increases with increasing effect size

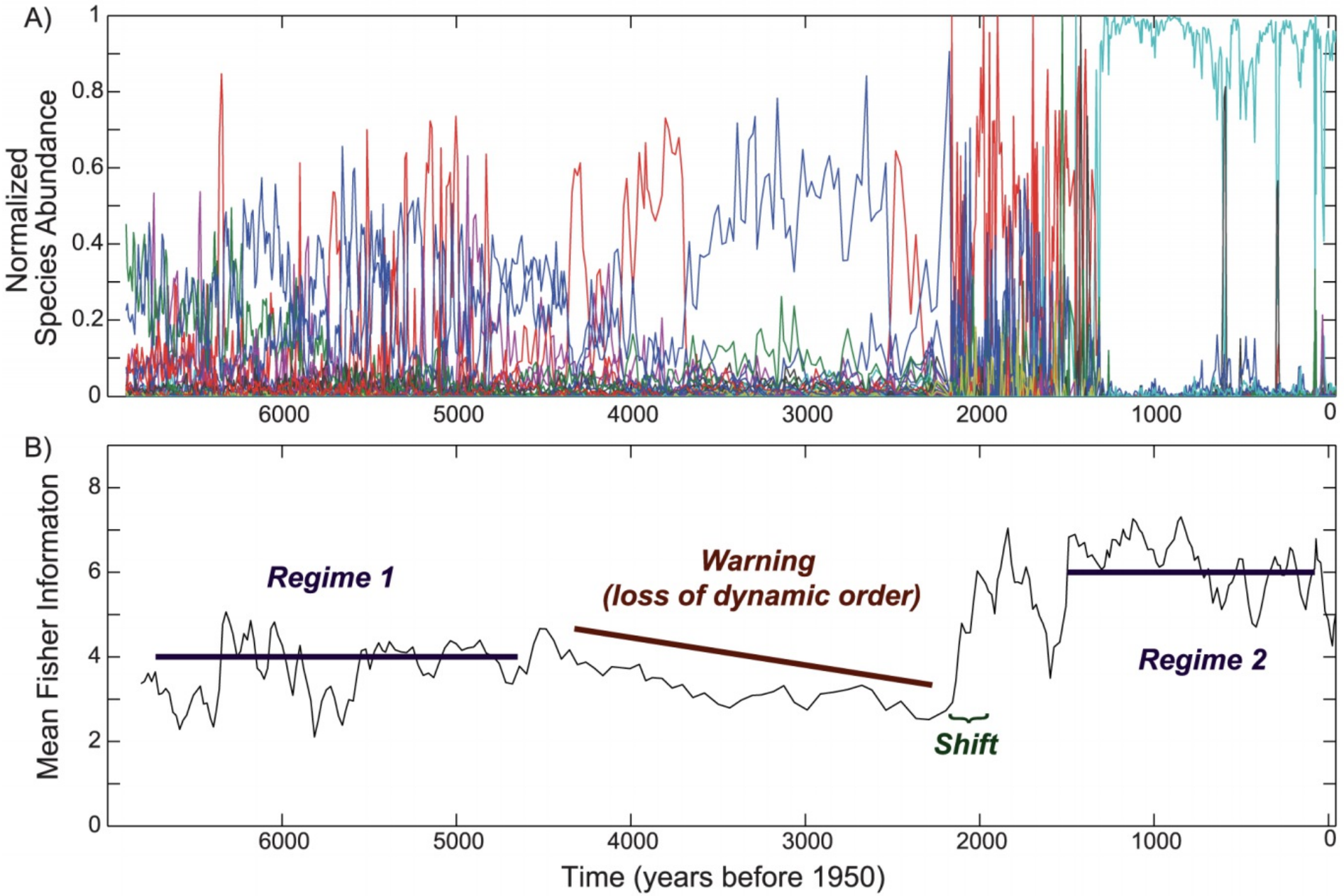


Empirical System: Paleodiatoms



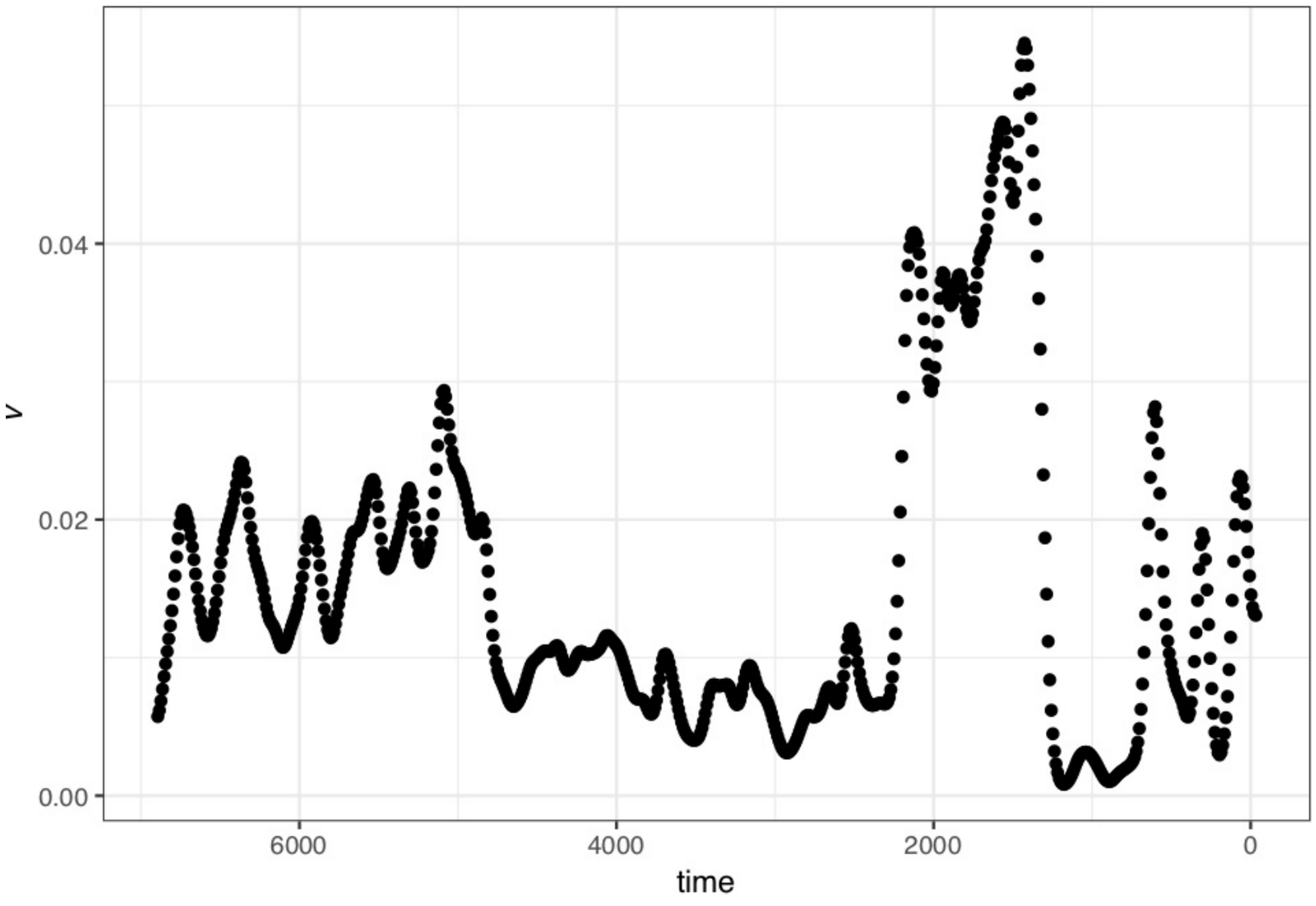
Data published in Spanbauer *et al.* 2014. Prolonged Instability Prior to a Regime Shift. PLoS One

Empirical System: Paleodiatoms

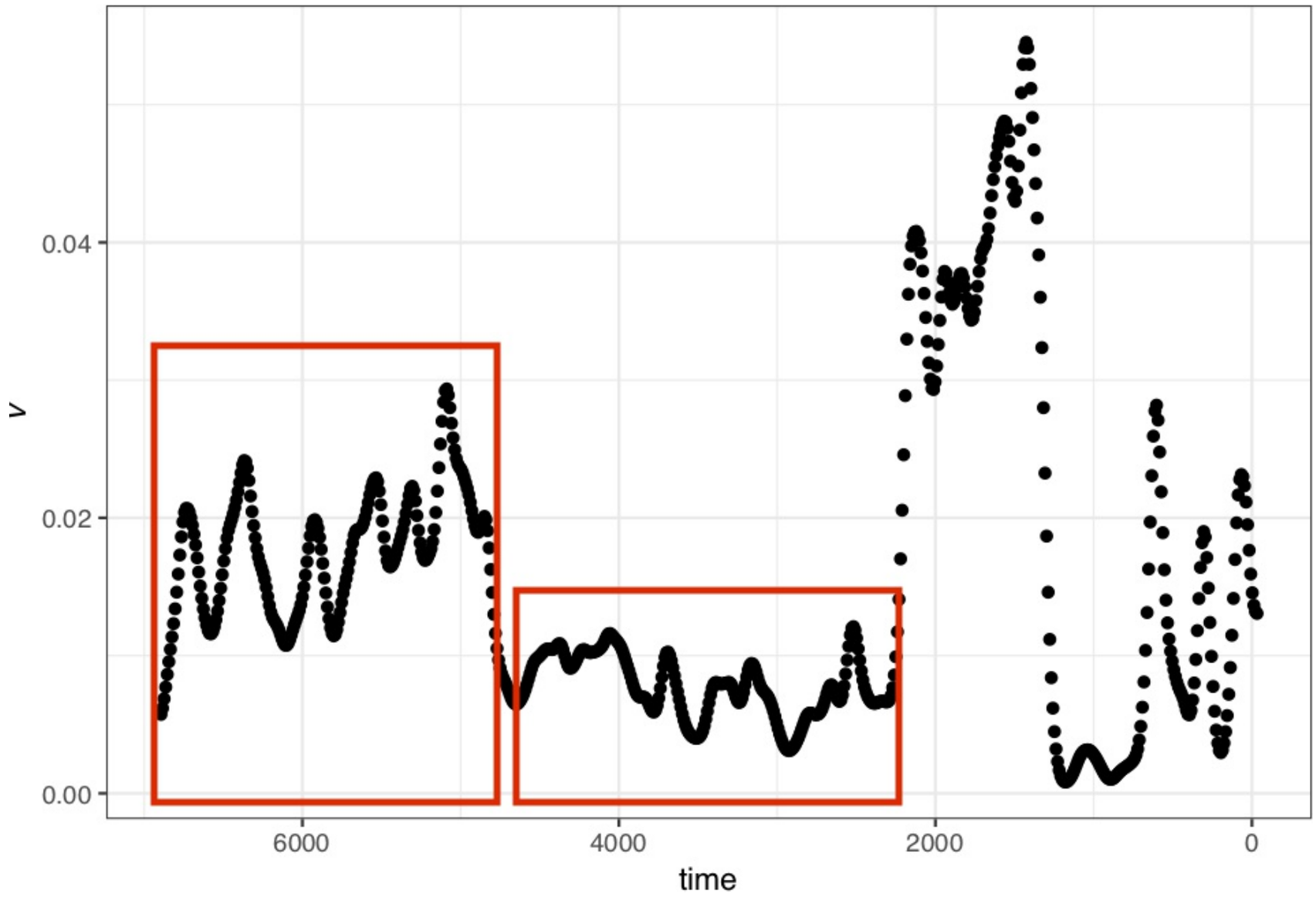


Distance travelled s & Velocity v identify these turnover events

Smoothing Noisy Data Before Calculating v



ν Identifies Potential Periodicities in Certain Regimes



Conclusions: ν is Simple, Intuitive

Reduction of high dimensional data

Capable of handling noisy data

Is not sensitive to data quality issues common in ecology

Best when mean > variance

Identifies regime shifts known a priori

Next Steps

Numerical identification of change point in v

Compare to distance-based metrics (feedback?)

Compare to ordination techniques

Predictive capacity

Related Software

R packages (dev versions):

`trashbirdecology/distanceTravelled` **(calculate s and v)**

`trashbirdecology/regimeDetectionMeasures` **(calculate multiple regime detection metrics)**

`trashbirdecology/bbsRDM` **(application to spatial data)**

`natbprice/tvdiff` **(regularized differentiation)**