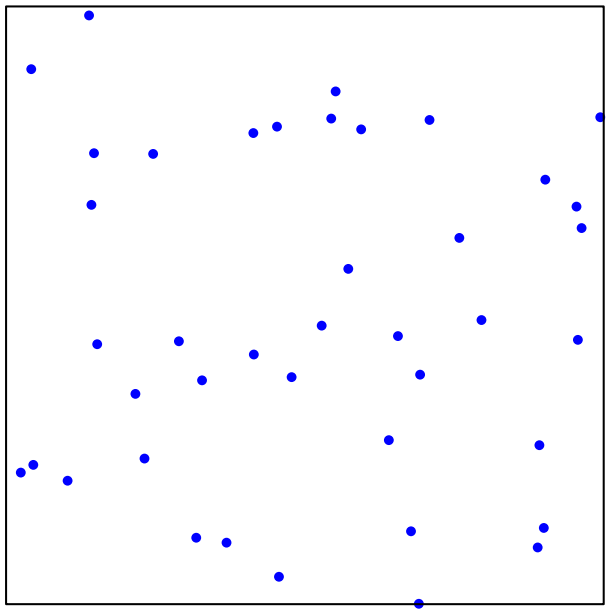
Robust sampling design for spatially explicit capture–recapture

Murray Efford

EURING, Montpellier, April 2023

SECR models

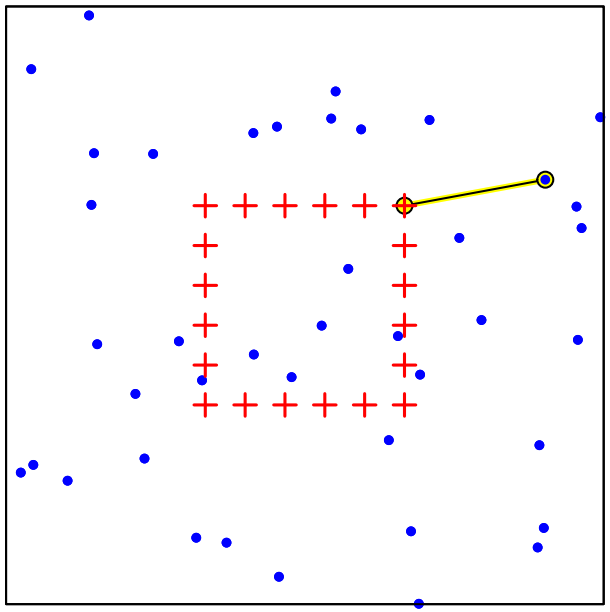
State model



Density D

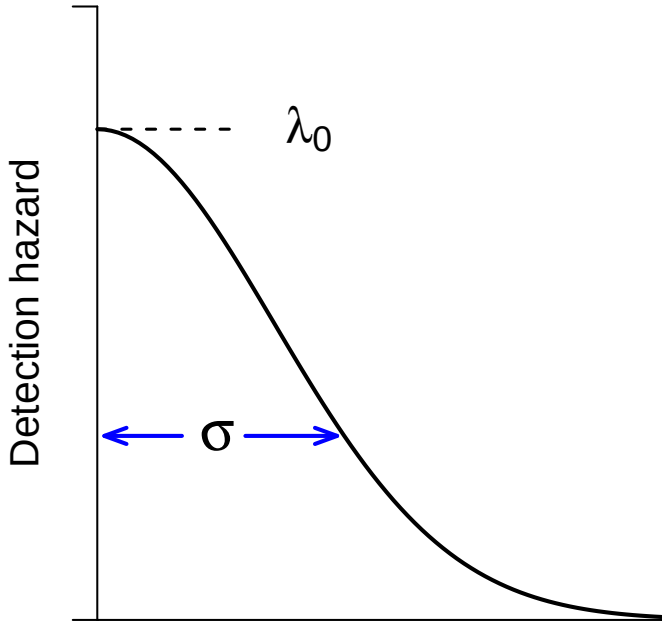
SECR models

State model



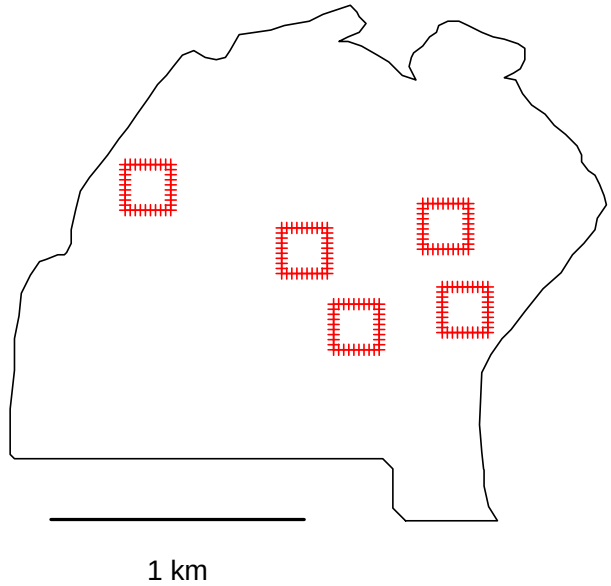
Density D

Observation model



Previously...

Efford et al. (2005)
Brushtail possums in New Zealand



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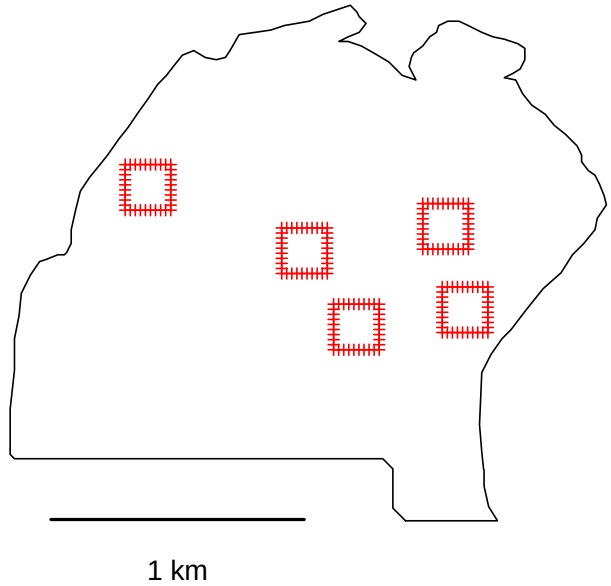

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Algorithmic solution (Dupont et al. 2021, Durbach et al. 2021):

- Seek optimal subset X of potential locations
- Genetic algorithm in R package kofnGA (Wolters 2015)
- Maximise an objective function e.g., $f(\mathrm{X}) = \min(\mathrm{E}(n), \mathrm{E}(r))$ using pilot values of λ_0, σ etc.

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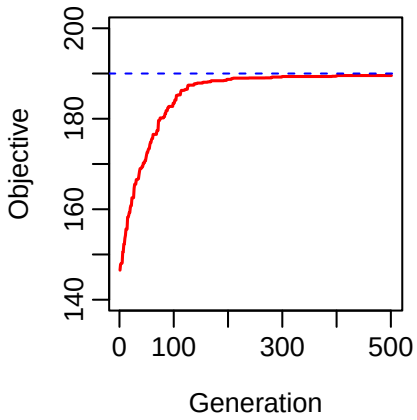
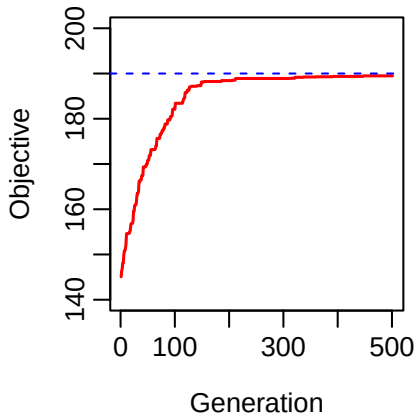
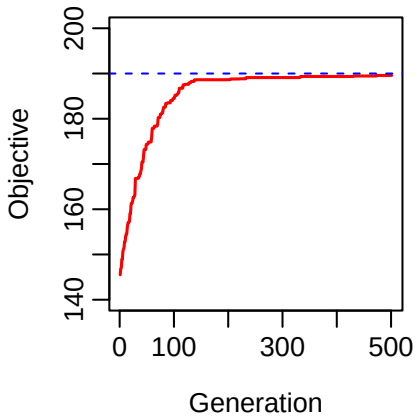
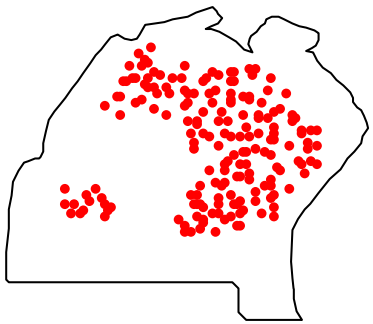
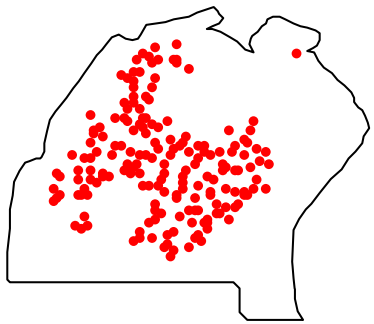
Algorithmic optimisation - three examples

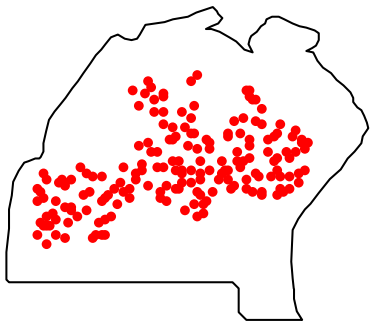












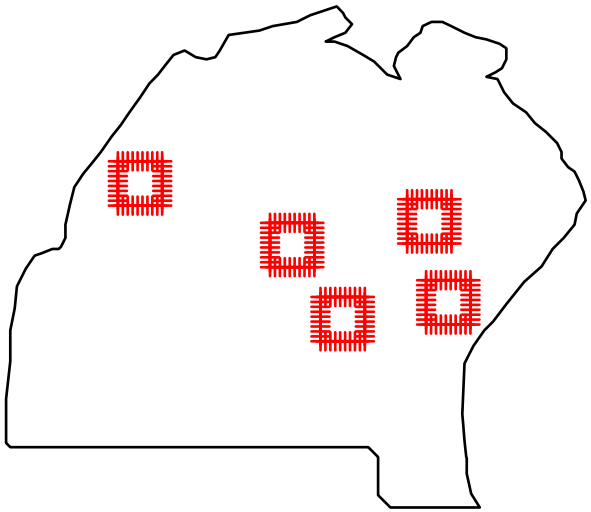
varying random seed, similar objective value

Evaluate algorithmic optimisation by simulation

Methods –

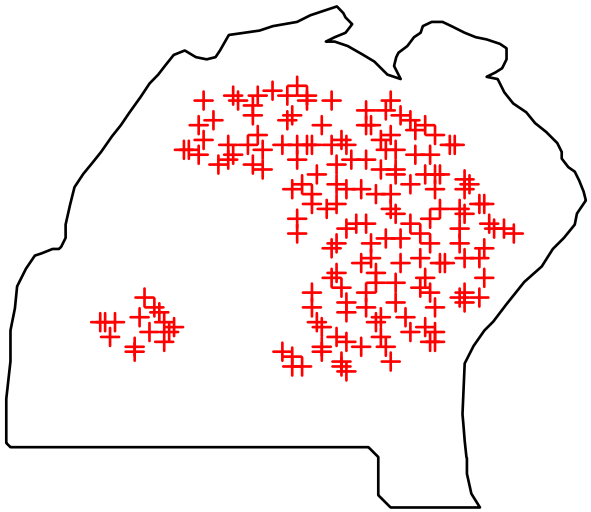
- parameter values based loosely on possum study
- uniform random (Poisson) activity centres
- report
  - accuracy: relative RMSE($\hat{D}$)
  - coverage of 95% confidence intervals for $\hat{D}$

Original



RMSE 10.8%
COV 93.2%

GA optimized



RMSE 7.7%
COV 94.4%

2-D Poisson activity centres. 500 replicates

Algorithmic optimisation, in summary

- Objective, hands-off (for a given objective function)
- Some gain in precision
- 'GAoptim' in R package secrdesign $\geq$ 2.7.0 (Dec 2022)

but...

Algorithmic optimisation, in summary

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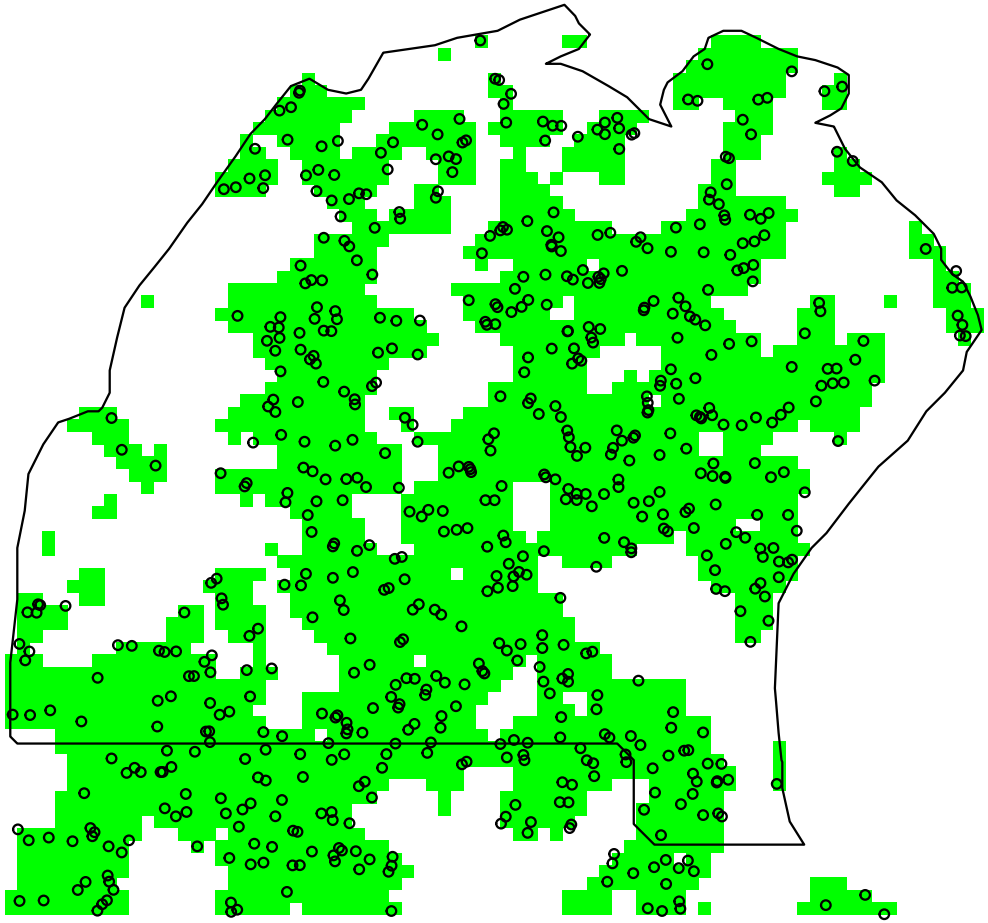
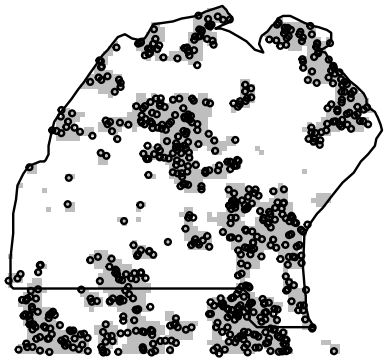
Sampling is representative *by accident, if at all*

What if distribution unknown, and not uniform?

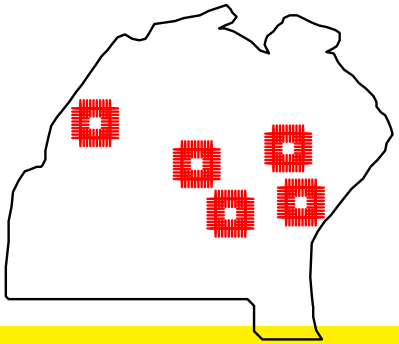
e.g., 50% random habitat



Unmodelled heterogeneity x unrepresentative sampling

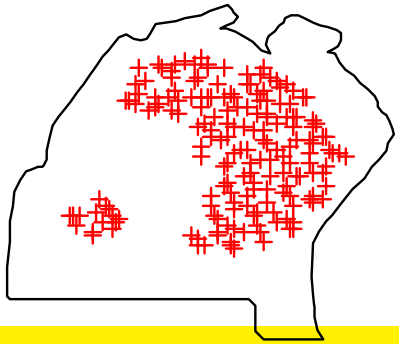


2−D Poisson, 50% habitat



RMSE 22.8%

COV 65%



RMSE 17%

COV 65.2%

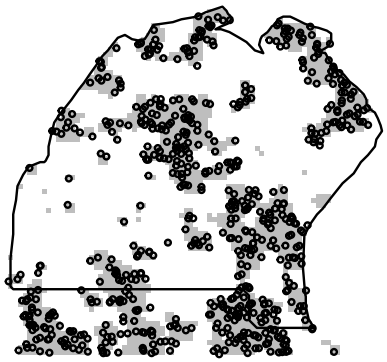
!

Representative sampling *by design*

Many options. I compare –

1. Simple random sample of detector locations
2. Clusters at centroids of compact spatial strata
   - 'spatial coverage sample' Walvoort et al. (2010)
3. Lacework
   - R package 'secr'

Comparing representative designs



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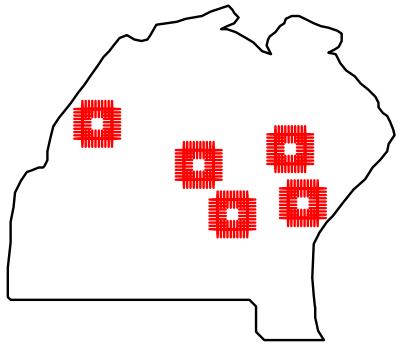

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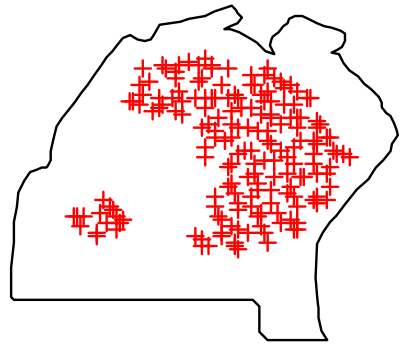

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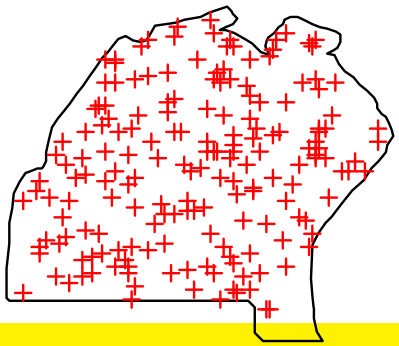
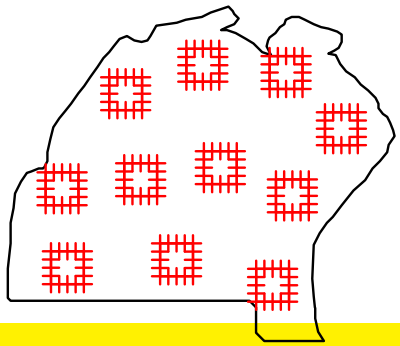


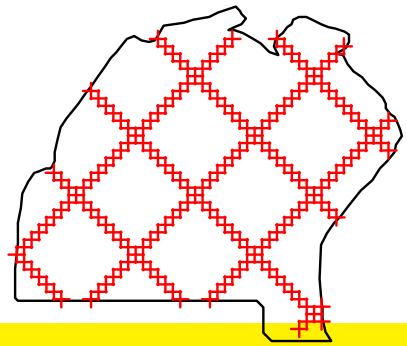
RMSE 10.9%

COV 86.6%



RMSE 11.5%

COV 86.4%



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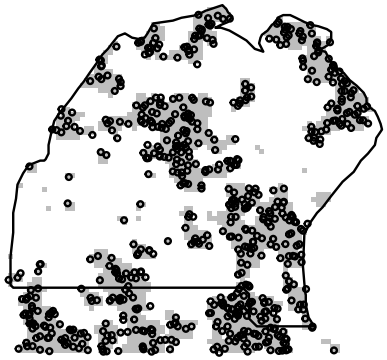
CI coverage adjusted for overdispersion, Fletcher's $\hat{c}$



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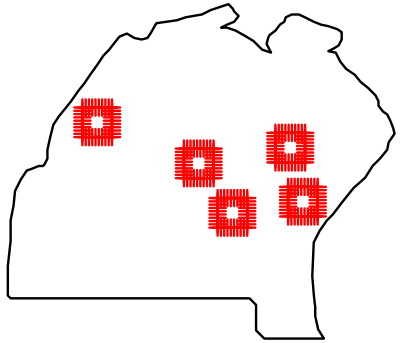
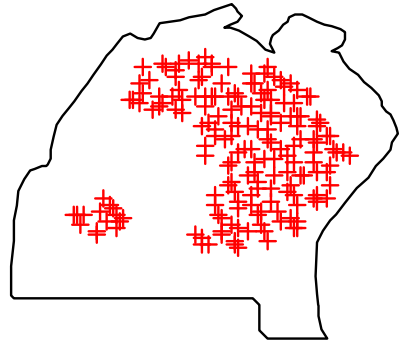


RMSE 22.8%

adj. COV 77%



RMSE 17%

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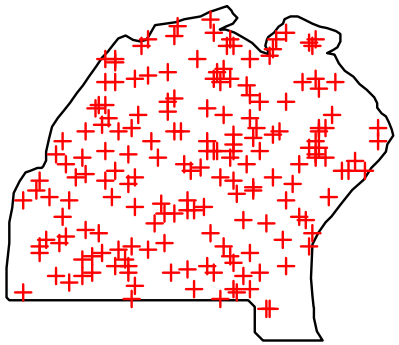

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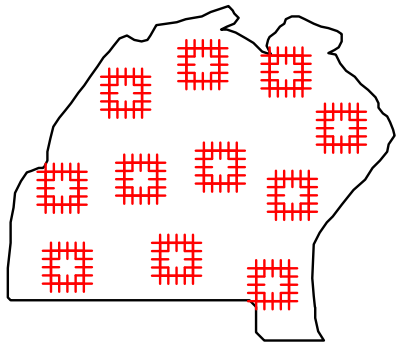

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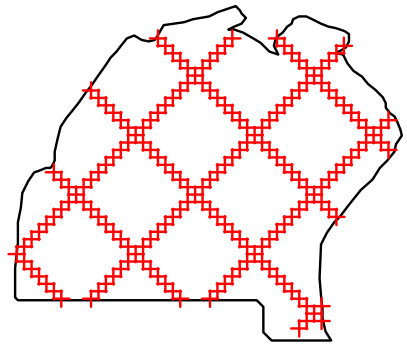

RMSE 11.2%

adj. COV 96%

Conclude

- Current ‘optimisation’ algorithms fail to deliver for large and potentially heterogeneous areas
- Spatially representative designs are robust to non-uniform distribution
- Spatial overdispersion should be taken seriously

References

Dupont, G., J. A. Royle, M. A. Nawaz, and C. Sutherland. 2021. Optimal sampling design for spatial capture–recapture. *Ecology* 102: e03262.

Durbach, I., D. Borchers, C. Sutherland, and K. Sharma. 2021. Fast, flexible alternatives to regular grid designs for spatial capture–recapture. *Methods in Ecology and Evolution* 12: 298–310.

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Walvoort, D. J. J., D. J. Brus, and J. J. de Gruijter, 2010. An R package for spatial-coverage sampling and random sampling from compact geographical strata by k-means. *Computers and Geosciences* 36: 1261–1267.