Review of Laroche '*Efficient sampling designs to assess biodiversity spatial autocorrelation: should we go fractal?*'

This manuscript explores the ability of different sampling designs to estimate levels of spatial autocorrelation for a given sampling effort (number of sample points). Designs are categorised into two groups – regular grids where proportions of the points have been moved to random locations, and fractals (patterns that are self-similar across a range of spatial scales). The methods are split into two 'problems': Problem 1 explores whether sampling schemes can be recover the spatial autocorrelation value of a single variable. Problem 2 adds in one of two environmental covariates – a linear and a u-shaped gradient. Browsing rev 1 on bioRxiv, I think the inclusion of an environmental covariate was a new addition, and given the results I think this was a good decision.

There is a lot to commend the paper. The methods for defining the hybrid and fractal schemes is great and provides a really nice framework for future studies to follow. I also really like the pareto-front method of examining the trade-offs between estimating μ and a_s.

I have 3 high-level comments, and a few general comments, mainly related to the studies generalisability to real-world scenarios: 1) The idea of sampling for more than one variable/species is not considered and barely discussed; 2) The practicalities of implementing a mostly random design is also not considered; and 3) the environmental co-variates are too similar and don't necessarily reflect the scales most biologists sample at.

They may seem quite a lot, and the manuscript is already of considerable length, but they put the study in to the practical space that is more applicable to what field biologists need to consider when designing their projects. But before those, 2 points:

- Although it took a good 6-8 hours to run it on my computer, I can confirm that I get the same results figures when running the code. However, I found the code made available to the reviewers almost uninterpretable as it is completely unformatted, multiple objects defined on single lines, little to no annotations etc. So I am unable to review whether the code is doing what is described in the manuscript.

- I won't review the appropriateness of the mathematical approach to resolving the theoretical autocorrelations (such as the section from lines 221-284 and in the SI), as it is beyond my expertise, so I will focus on other aspects of the paper.

Sampling for more than one variable/species is not investigated

The last sentence of the abstract states "The interest of designs with a clear hierarchical structure like fractals may stand out more clearly when studying biological patterns with contrasted spatial structures across scales". This is a really important point, as in the vast majority of cases researchers will be simultaneously sampling multiple variables that have differing spatial autocorrelation structures (eg topographic wetness index vs annual precipitation) or multiple species where body size/dispersal ability/home range sizes can differ by orders of magnitude (eg wrens vs eagles, or a whole saproxylic beetle community in the author's own example). However, at the moment it is only tagged on to the very final paragraph of the conclusion!

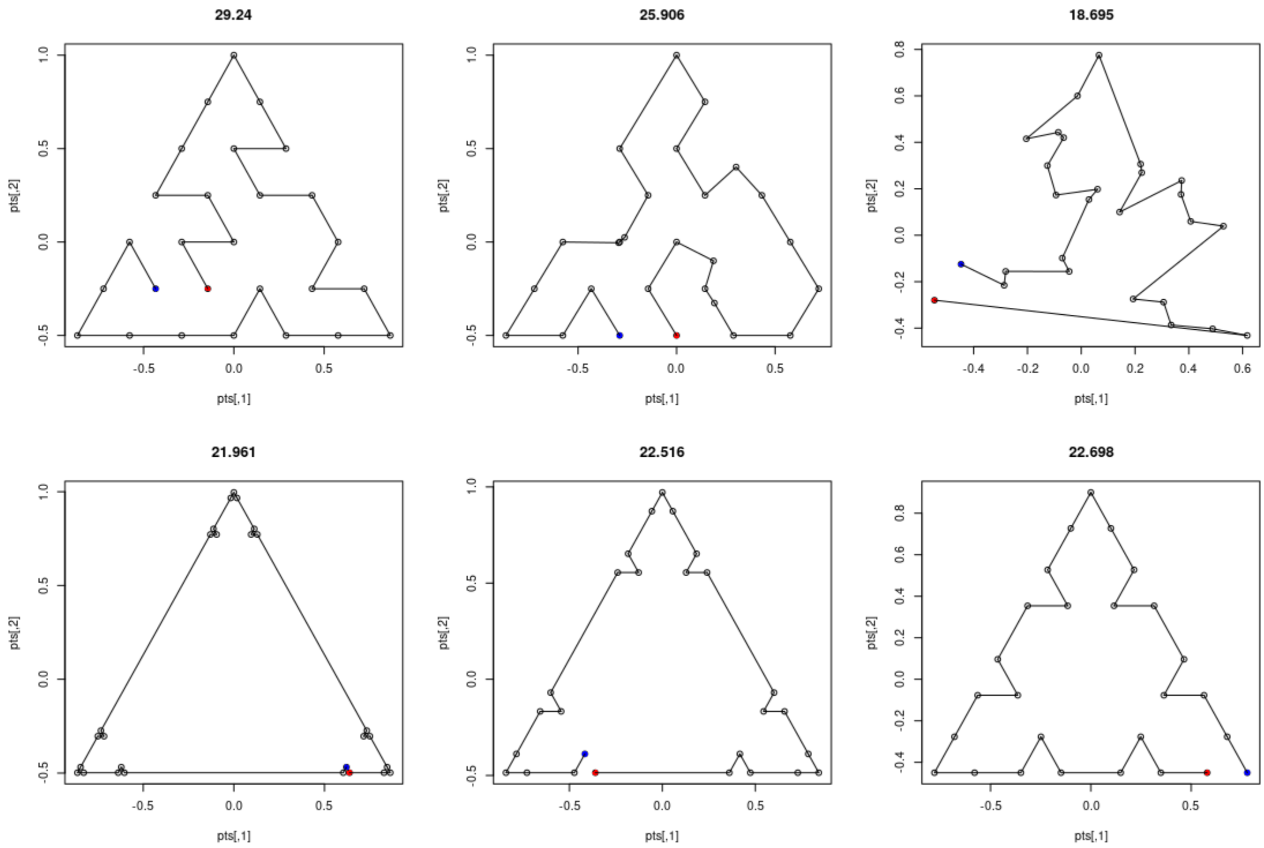
The importance of the fractal design (or other cluster patterns) is that it can investigate a range of spatial scales simultaneously – a good example is the SAFE project in Borneo which has implemented the fractal design (see https://www.safeproject.net/info/design and its hundreds of outputs on thousands of different species, functions and processes). All are sampled under a unified network that means patterns and processes across different scales can be directly linked to each other in space, and that makes multi-taxa studies easier. See Ewers (2011) https://doi.org/10.1098/rstb.2011.0049 for the original description of the project, and also the Ecological Fractal Network (https://ecofracnetwork.github.io//) which has implemented the protocol across the northern hemisphere.

It would be worth a more rigorous exploration in the discussion, if not it's own analysis (for example, you could look at a set of a_s values and examine which designs perform best across all of them, or which design has the 'least bad' worst-case).

Measures of efficiency

Another dimension that should also be discussed (or incorporated), is that the number of sampling points is only one measure of effort. Having implemented the fractal design myself in an Amazonian rainforest forest scenario (ie where trails have to be cut to reach each point) it is fairly similar to implementing a grid system, and getting around them efficiently is pretty straightforward as well. Any random points however, become quickly impractical as special trails have to be cut in random directions and distances to individual points, and not something I would ever recommend doing from a practical day-to-day viewpoint.

For example doing a simple travelling salesman solution to the examples given in figs 1 and 2 we can see that the fractal designs are much more efficient, apart from against truly random (not a surprise as that doesn't sample up to the edges). However, we can see how difficult it would be to implement something truly random in the field. An acknowledgement of this impracticality would be useful.



Appropriateness of the environmental variables

In terms of problem 2 and the effect of an environmental covariate, it is hard for me to assess how representative the scenarios are, because I struggle to visualise their effects on the response variable. However, with this caveat, my thoughts would be:

1) I really consider the two environmental variables as essentially the same – both are monotonic with a single peak in the landscape, only the ‘u-shaped’ variable the peak is centred on the centre of the study area, and the ‘gradient’ is centred on the edge. This scenario only really equates to either climate scales at continental extents, or variables at very small extents (tens of metres). I don’t think they really reflect the variables (soil, hydrology, vegetation etc) and extents most ecologists work with, which will be patchy within the landscape.

2) the U-shaped variable (fig. 3) is the absolute sub-optimal scenario for the fractal design, given that it is centred on the exact centre of the fractal design, where sampling effort is not present, and it is exactly radial, so that the points closest to the centre all have exactly the same information.

I would personally prefer to see variables which have multiple peaks within the study area. However, without seeing what the effect of the environmental variables has on variable of interest, it is hard for me to say whether it is worthwhile exploring a wider range of patchiness.

General comments

- Following on from the previous point, what would really help me would be some visualisation representations of the variable under different a_s values, and their interactions with the environmental variables in fig. 3. They key here is how ‘patchy’ they are in relation to d_{min} and I personally find it hard to do this when only presented with a_s values.

- As I mentioned, the pareto-front method of examining the trade-offs is excellent. Figs 5, 7 and 8 are a really nice way of visualising this. In fact, I would like to see them expanded – at the moment each only shows 1 value of a_s but it would easy to show, say, 5 values using 5 panels in a row for each figure.

- However, for figs 5, 7 and 8, please use a different colour scheme to separate the fractal and hybrid designs, as you have used blue and red for the small-large range values in other plots.

- Similarly, you could consider incorporating figs S1 and S3+4 into figs 4 and 6 respectively – I found myself flicking between the two repeatedly to the point where I ended up copying and pasting them together. Fig. 1 and 2 could be combined into a single figure if necessary to make the space.

- The Discussion and Conclusion are really long, almost 3000 words, and could do with some trimming (eg lines 496-511 could easily be lost).

- In general, there are quite a few wording issues throughout. I won’t find them all, but I noted down some at lines 56, 71, 163, 210, 317, 428, 486-9, 499, 517, 539. Perhaps worth getting a fresh pair of eyes to check it through.

- Try and keep consistent ordering throughout – in the text it is generally hybrid then fractal, but the figures are fractal then hybrid.

- Lines 221-244 – Should most of this not be in the Methods section? And potentially some of up to lines 284 as well?

Lines 70 – I think this should be fig. 2?

Line 74-77 – This paper didn’t really show that ‘fractal designs lead to estimating higher values of autocorrelation range than an intensive control design’ – rather that for a given sampling effort it could recover patterns on average more similar to the control than other designs.

Line 118 – please reference R, and any other key packages as a huge amount of work goes in to making them freely available for users.

Fig. 4 legend – I think it is ‘*red* shows the fraction of these designs that are eliminated when introducing the other type of design in the comparison’?

Fig. 5 legend and other places – I am not sure ‘browsing’ is the best wording. Perhaps ‘traversing’ or ‘tracking’?

Fig. 6 – I think the bottom right panel should be labelled as Hybrid rather than Fractal?

Line 615 – I strongly disagree that implementing designs with random points is easier than fractals (which are essentially a series of straight lines).