Guidelines for depth data collection in rivers when applying interpolation techniques (kriging) for river restoration

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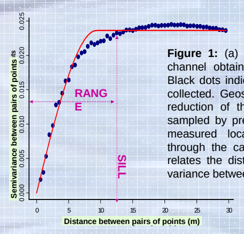
Statement of the problems:

River restoration projects require the implementation of monitoring programmes to assess the river quality before and after the implementation of the project. Biological, chemical and hydromorphological (i.e. depth, velocity and substrate) variables are monitored for this purpose. Field work is time and cost consuming and can be reduced with the application of geostatistical interpolation techniques.



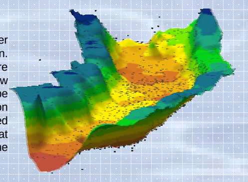


Figure 1: (a) Three dimensional diagram of a river channel obtained through geostatistical interpolation. Black dots indicate the locations where the data were collected. Geostatistical interpolation techniques allow reduction of the number of points that need to be sampled by predicting the value of a variable at non measured locations. (b) Predictions are obtained through the calculation of the variogram, a plot that relates the distance between pairs of points and the variance between them.

This project aims to produce a set of guidelines for the collection of hydromorphological data when applying geostatistical interpolation techniques. Three main problems are identified when designing efficient & effective sampling strategies for hydromorphological parameters:

Spatial: where and how many points need to be collected? (Figure 2 & 3)

Scale: what is the length of the river that needs to be sampled?

Temporal: how often do we need to repeat the sampling procedure? (Figure 4)

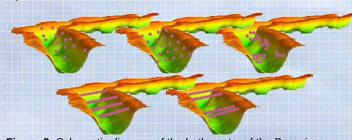


Figure 2: Schematic diagram of the bathymetry of the Bere river site. Different sampling strategies: random points, regular transects and regular grids have been compared to assess the accuracy when predicting depth, velocity and substrate at non measured locations.

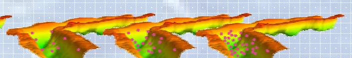


Figure 3: Schematic diagram of the bathymetry of the Bere river site. Different sampling densities have been compared to assess the accuracy when predicting depth, velocity and substrate at non measured locations.

Figure 4: the distance recommended to characterise the spatial variability of a site varies according to different authors.

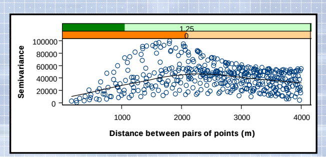
Figure 5: physical features of the river change when changes in discharge occur. It is necessary to identify the temporal variability of the site to design the monitoring programme.

Guidelines for hydromorphological data collection:

•Geostatistics proved to be a useful tool for the development of optimal sampling strategies.

THE SPATIAL PROBLEM

•It is recommended to apply grid sampling strategies when characterising the spatial pattern of depth rather than applying any type of transect sampling strategies.



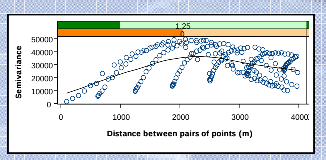


Figure 6: Results obtained with regular or stratified transects (right) have been proved to be highly sensitive to the number of points sampled, as well as to the location of these transects. Grid sampling strategies (left) provide better results when characterising the depth spatial pattern. Differences between both variograms are clear (note the scale of the y axis and the distribution of the points). Regular grids provide a variogram that is more similar to that obtained with an intensive original data set from which the sampling strategies were derived.

•The use of random grids is preferred to the use of stratified and regular grids since (i) results obtained for random grids do not significantly differ from those obtained with regular grids and (ii) random sampling strategies (i.e. random walk) are less time consuming sampling strategies.

•During the data collection procedure it is necessary to invest special effort in characterising the deepest areas of the river site to be sampled since this could have an effect on the variogram calculation.

•Sampling density needs to be selected according to the objective for which the data is being collected (Figure 6). A set of tables relating the accuracy obtained in the predictions when applying a specific sampling density are being developed.

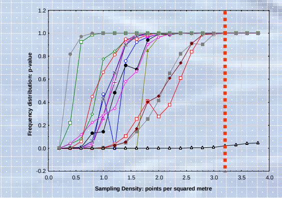
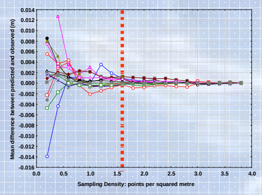
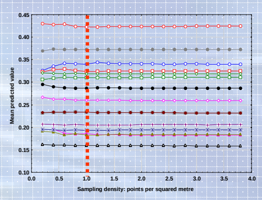


Figure 7: Results obtained when comparing 20 different sampling densities for some of the indicators analysed. The vertical red lines indicates the recommended sampling density for each objective. Note that this value is different according to the indicator that is being characterised.





•The variogram is a tool that can be used to understand the spatial pattern of a variable under study. Its calculation needs to be accompanied by a sensitivity analysis that considers the variogram model selected, the number of pairs of points, the lag distance selected the maximum distance used, the azimuth tolerance and the azimuth direction. Otherwise, variogram results could be misleading.

•The higher the hydromorphological uniformity and continuity of the river site, the lower the sampling density that needs to be applied.

THE SCALE PROBLEM

•The distance sampled needs to be longer (from two to three times longer) than the maximum distance that we want to consider for the analysis of the spatial structure.

•Results suggests that repetitions of the depth spatial pattern might not correspond to a fixed sampling distance and this needs to be defined according to the characteristics of each river site. Repetition in the characteristics of river depth have been encountered at distances equal to 500 m, 350 m and 150 m (Figure 8) for the rivers Brazos and Sulphur.

Point number	Cycle	Wavelength	Distance
1	0.05714	17.50	350.0
2	0.1285	7.78	155.5
3	0.2285	4.37	87.5
4	0.3285	3.04	60.8

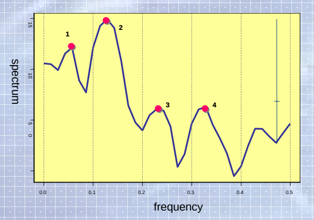


Figure 8:The scale problem has been analysed with a combination of spectral and geostatistical analysis. The periodogram (right) is the final output. Each peak on the periodogram represents a repetition of the characteristics of depth spatial pattern. The table transforms the periodogram information into distance at which the pattern is repeated.

THE TEMPORAL PROBLEM

•The variogram cloud (Figure 9) is able to detect differences between the spatial structure of the bed channel and the spatial structure of the river banks. This suggests that the variogram cloud could be used as a tool (i) to describe the hydromorphological characteristics (depth) of the channel and (ii) to detect the temporal changes in the hydromorphological characteristics of the river

Figure 9:The variogram cloud represents the distance between pairs of points and the variance of all these pairs of points. The image shows three variogram clouds: one calculated for data collected in the wet channel (pink), data collectedoin the river banks (green) and all the collected data (blue). Note that the variogram cloud is able to identify the relation between the banks and the river bed. This could be useful to quantify the physical changes achieved with restoration projects.