Three decades of bivalve fishing surveys along the south coast of Portugal: a spatial-temporal analysis of the striped venus clam (*Chamelea gallina*)

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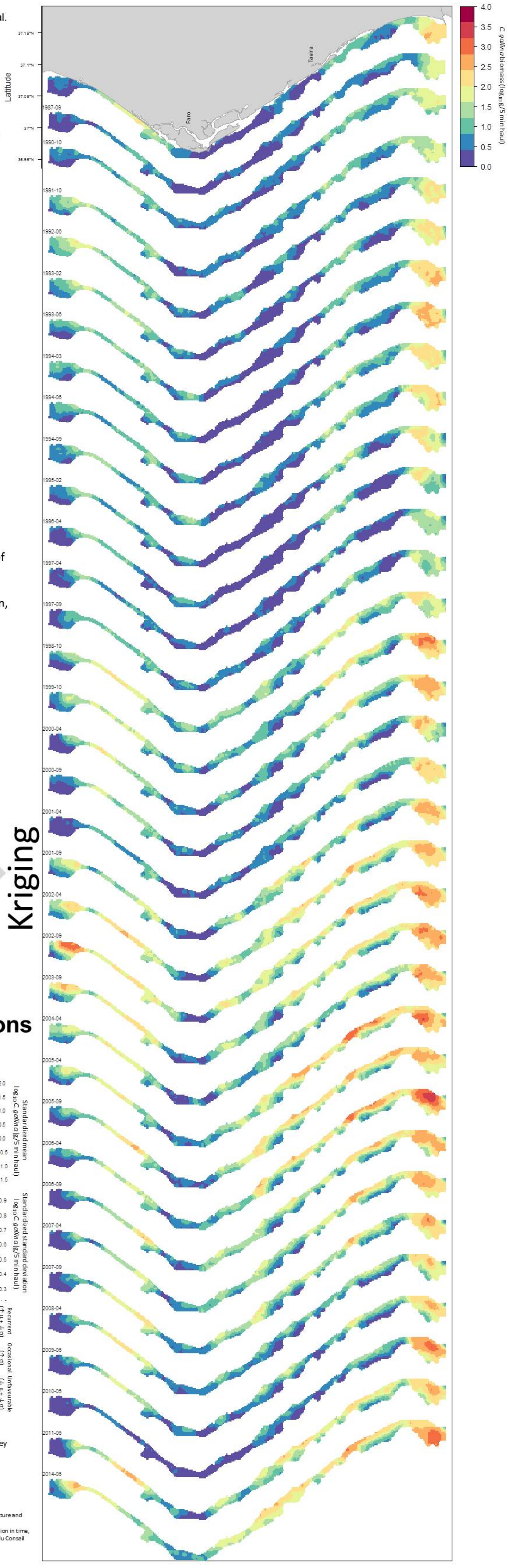
Abstract

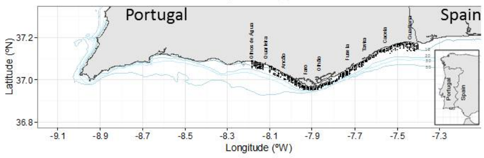
Most marine species are known to be aggregated in spatial patches. Those patches vary through time, both in biomass and location, as a response to a set of drivers. Thus, to understand the ecological, environmental and anthropological drivers of species biomass, long-term spatial analyses of species dynamics are essential. In particular, target species of small-scale fisheries are further influenced by governance and market drivers, with a significant impact on their dynamics, which in turn have considerable economic and social impacts. In the Algarve coast (southern Portugal) an important small-scale fishery targeting four commercial bivalve species takes place on sandy bottoms. In the current work, almost three decades (1986-2014) of data on the biomass of the striped venus clam (*Chamelea gallina*) were analysed using spatial-temporal geostatistical methods. The study area comprises 119 km^2 of coast, distributed between -8.1º to -7.4ºW longitude and 36.95º to 37.17ºN latitude, and from 3 to 15 m depth. Species biomass was modelled in function of space and time using a spatial-temporal variogram. The model was then used to produce interpolations over the study area and period using spatial-temporal kriging. The striped venus clam (*C. gallina*) showed a simple sum metric covariance spatial-temporal model, explaining 53% of the covariance. The model showed that this bivalve species is aggregated in 2.9 km spatial patches, whose location and dimension varied throughout the sampling period.

Spatial-temporal kriging prediction maps were used to extract the main summarizing statistical features, such as the mean, maximum and variance, for all time-series stacked, thus determining the prevailing favourable areas for this species and corresponding spatial patterns of variation through time. The main spatial-temporal patterns of variation were further explored using Empirical Orthogonal Function analysis (EOF), which is a particular type of principal component analysis that decomposes the spatial-temporal variability in the time series into principal spatial orthogonal components. This analysis allows identifying the main types of spatial distribution and temporal evolution of a given variable.

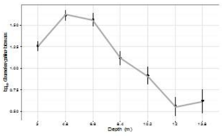
The stock estimates produced and the corresponding spatial distribution will be used in the framework of the European research project SAFI (http://www.safiservices.eu/; REA Grant Agreement 607155), that aims to develop indicators between species and aspects of their environment to support fisheries operations and help in management decisions, thus contributing for the sustainable exploitation of the living marine resources by using satellite-derived information.



Location & sampling



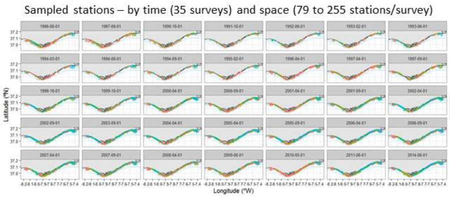
Chamelea gallina (striped venus clam)



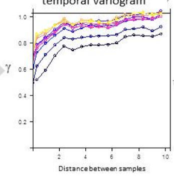
- **Temporal coverage**: 1986-2014 (28 years)
- **Bathymetry**: 3-15m
- **Substrate**: Sandy bottoms – fine-sand/gravel
- **Area covered**: Olhos d' Água to the river Guadiana
- **Aim**: IPMA's regular monitoring fishing surveys for estimation of the status of the stocks of commercial bivalves
- **Sampling stations**: 92 transects perpendicular to the coast, crossed at crossed at eight bathymetric levels: 3 m, 4.8 m, 6.6 m, 8.4 m, 10.2 m, 12 m, 13.8 m and 15.6 m.
- **Sampling methods**: bivalve dredge towed for 5 minutes at a constant speed of 1.5 knots, sweeping an area of 144m^2

Spatial-temporal analyses

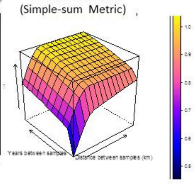
Sampled stations – by time (35 surveys) and space (79 to 255 stations/survey)



Sample spatial-temporal variogram



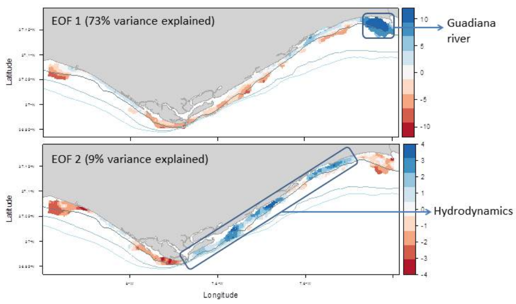
Spatial-temporal variogram model (Simple-sum Metric)



Kriging

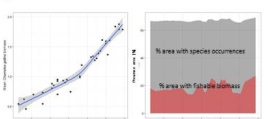
Examples of results that can be achieved with the kriging predictions

Mechanisms - Empirical Orthogonal Function (EOF)



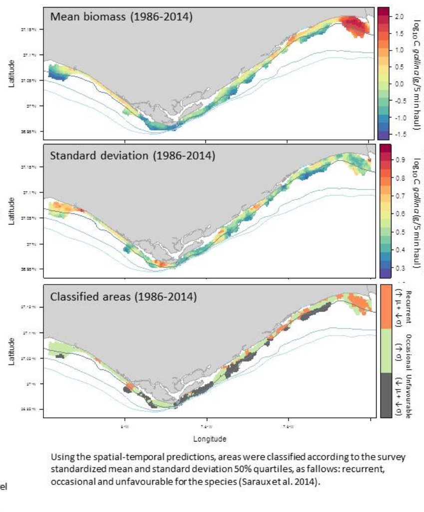
EOF analysis, is a particular type of principal component analysis (PCA) applied to a series of gridded maps, which allows to decompose the space–time (residual) variability in the time-series into principal spatial modes and their amplitudes. The two spatial components explain 82% of the variance, showing that *Chamelea gallina* has two main patterns of distribution along the study area.

Spatial indices for fisheries monitoring



Presence area (PA, i.e. the percentage area occupied by the species) can be estimated either using the samples or using indicator kriging approach, that provides probability maps. Similarly, the percentage of the area where the species occurred at commercial level (>100g/5min haul) can be estimated in a probabilistic manner, which can then be used for fisheries monitoring (Woillez et al. 2007).

Distribution and areas classification



Using the spatial-temporal predictions, areas were classified according to the survey standardized mean and standard deviation 50% quartiles, as fallows: recurrent, occasional and unfavourable for the species (Saraux et al. 2014).

SAFI is a FP7 project funded by the European Commission in the frame of the Seventh Framework Programme (grant agreement n°607155). The views and opinions expressed in this publication are the sole responsibility of the authors and do not necessarily reflect the views of the European Commission.

References:

Saraux, C., J.-M. Fromentin, J.-L. Bigot, J.-H. Bourdeix, M. Morfin, D. Roos, E. Van Beveren, and N. Bez. 2014. Spatial Structure and Distribution of Small Pelagic Fish in the Northwestern Mediterranean Sea. PLoS ONE **9:e111211.**

Woillez, M., J.-C. Poulard, J. Rivoirard, P. Petitgas, and N. Bez. 2007. Indices for capturing spatial patterns and their evolution in time, with application to European hake (Merluccius merluccius) in the Bay of Biscay. ICES Journal of Marine Science: Journal du Conseil **64:537-550.**

All analyses were performed using R-project, in particular packages gstat, spacetime, Rgeostats and rasterVis.