1 Introduction

Bottom trawl surveys (BTS) have been carried out for a long time mostly following spatial stratified random designs (e.g. Fogerty, 1985; ICES, 2004b). The survey design usually relies on previous knowledge of the target species spatial distribution and population structure and on statistical analysis of preliminary data (e.g. Ault et al., 1999; Hata and Berkson, 2004) or simulation procedures (e.g. Schnute and Haigh, 2003; ICES, 2005b). These results are combined with operational issues (trawlable grounds, vessel availability, etc) to define a protocol for the BTS.

The survey sampling design is often reviewed across the years with the aim of improving the estimates of abundance. The most common changes in survey designs are related with stratification (e.g. Smith and Gavaris, 1993; Folmer and Pennington, 2000), tow duration (e.g. Cerviño and Saborido-Rey, 2006; Wieland and Storr-Paulsen, 2006) and technical issues such as gear changes (e.g. Zimmermann et al., 2003; Cooper et al., 2004).

Most surveys use sampling statistics (Cochran, 1960; ICES, 2004b) to estimate abundance. However these methods rely on the independence among observations, wich is seldom guaranteed due to operational constraints like trawlable grounds, commercial vessels operating on the area or bad sea conditions, that jeopardize the designs' randomness.

On the other hand, fish populations have an explicit spatial behavior interacting with each other looking for food, reproductive conditions, protection, etc; clearly introducing spatial dependency on the observations . Our main interest is about modeling abundance and make use of models to extract the most of the data available. In this line of though we adopted the geostatistical framework. Geostatistics explicitly take into account spatial patterns of the variable of interest, by adopting a model that contains a function to explain how the covariance between locations behaves with distance (see e.g. Cressie, 1993; Chiles and Delfiner, 1999; Rivoirard et al., 2000; ICES, 2004b).

Geostatistics are a model-based technique with two main advantages in what concerns inference about fish abundance: (i) robustness to odd observations, in particular with small data sets; and (ii) flexibility, allowing the estimation of variance for systematic sampling designs, or to compute statistics for which analytical expressions are not available using simulation. The major problems with model-based methods is model mis-specification and over parametrization. We relied on our experience with bottom trawls surveys (ICES, 2002, 2003, 2004a, 2005a, 2006; Sousa et al., 2005; Mendes et al., in press) to provide contextual information to support adoption of a particular class of models. With regards to overparameterization we used a two step approach to compute the covariance function parameters. To make inference about the model parameters we chose to use maximum likelihood techniques (Diggle et al., 1998).

The geostatistical framework introduces an higher level of complexity on the data analysis, but also provides a richer set of results to interpret.

Muller (2001) and Zimmerman (2006) showed that to estimate a global mean of a spatial process a regular design is better then a random design, although the latter would be better for estimation of the correlation parameters.

The main objective of the present work was to propose a set of geostatistical tools to analyze and assess BTS designs. An application of these methods was performed using data collected by a Portuguese BTS carried out in 2001 that executed four different sampling designs , three proposed by Jardim and Ribeiro Jr. (2006, submitted) in a simulation study and the design in use at the moment.

2 Material

Portuguese bottom trawl surveys (ptBTS) have been carried out on the Portuguese continental waters since June 1979 on board the R/V Noruega, twice a year, during Summer and Autumn. The main objectives of these surveys are: