Modelling the effect of environmental and anthropogenic factors on the abundance of early life-history stages of the European sardine in the Guadalquivir estuary

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INTRODUCTION

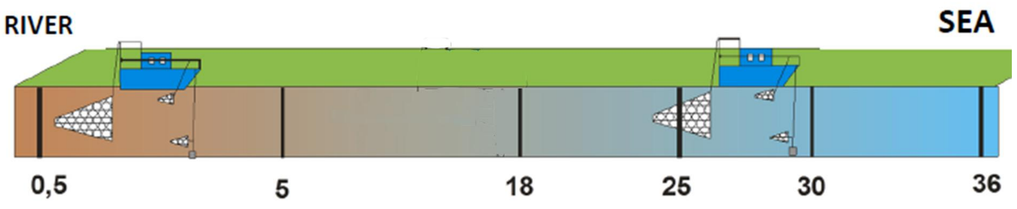
The Guadalquivir estuary (SW Spain) is tidally-dominated and well-mixed system with a longitudinal salinity gradient. It supports an important biodiversity and functions as a nursery area for many marine species (e.g. sardine and anchovy) in the Gulf of Cadiz (GoC). The estuarine zone acting as nursery grounds corresponds to the last 32 km of the mainstream. The effects of the environmental and anthropogenic forcing are essential to understand its functioning in relation to the GoC fisheries. The drivers of sardine recruitment and particularly the interactive effects of environmental (temperature, salinity, turbidity and winds) and anthropogenic (freshwater discharges) factors are largely unknown. We modelled these effects on the abundance of sardine larvae and juveniles in the Guadalquivir estuary.

STUDY AREA AND METHODS

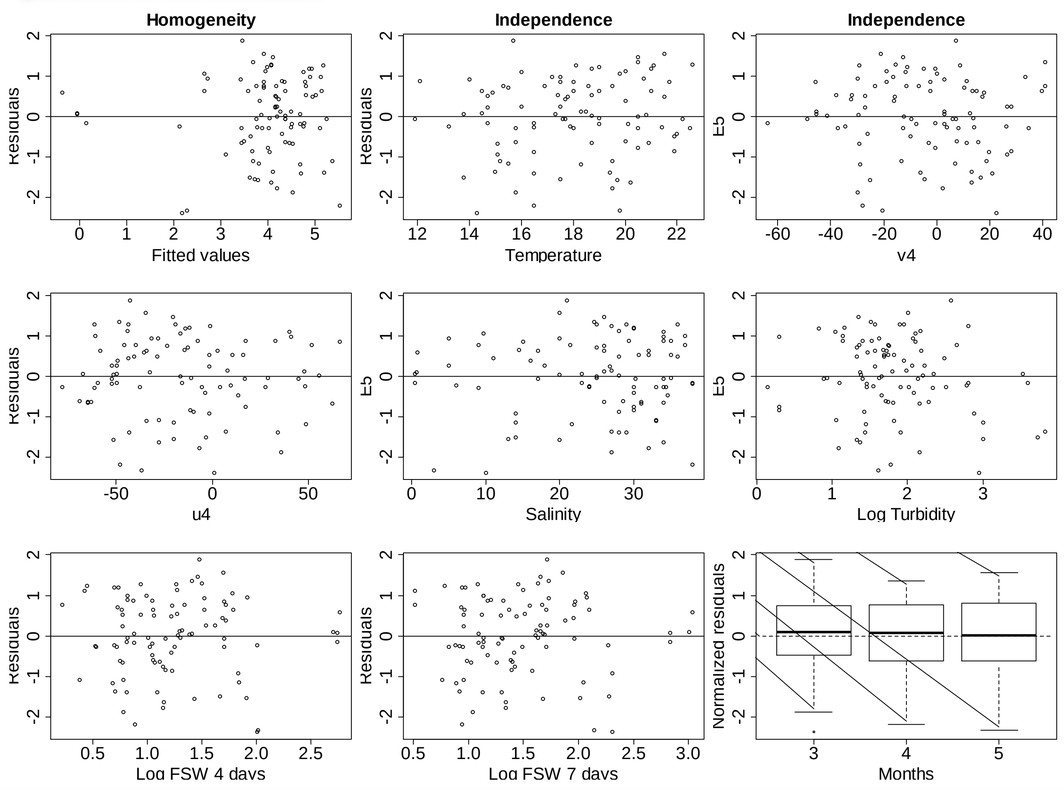
A long-term (18 yr) monitoring program has been carried out from May 1997 to December 2015 in two stations situated along the last 32 km of the Guadalquivir estuary (Tarfia and Bonanza, see map) from the river mouth. In this study, we used the months of the high recruitment period of sardine (Spring) at the latter station as it samples well the marine water masses advected into the estuary, especially during the ebb tide. Our dataset includes sardine larvae and juveniles, temperature, salinity, turbidity, freshwater discharges (FSW) from the dam to the estuary (hm3 day−1) accumulated during four days (V4), one week (V7), 2 weeks (V15) and one month (V30) before each sampling date; local rainfall accumulated during four days (P4), one week (P7), 2 weeks (P15), one month (P30) before each sampling date, the nominal variables Year and Months, and the wind regimen (the components northern-southern v4 and eastern-western u4). We used time series-analysis (GAMMs) to test the environmental and anthropogenic effects.

Guadalquivir estuary (SW Spain)

At each sampling site, during 24 h, four passive hauls were taken, during the first two hours of diurnal/nocturnal flood and ebb tides, from a boat anchored on the East bank of the Guadalquivir and using three 10-m long nets (mesh size: 1 mm; net opening: 2.5 m width and 3 m depth).

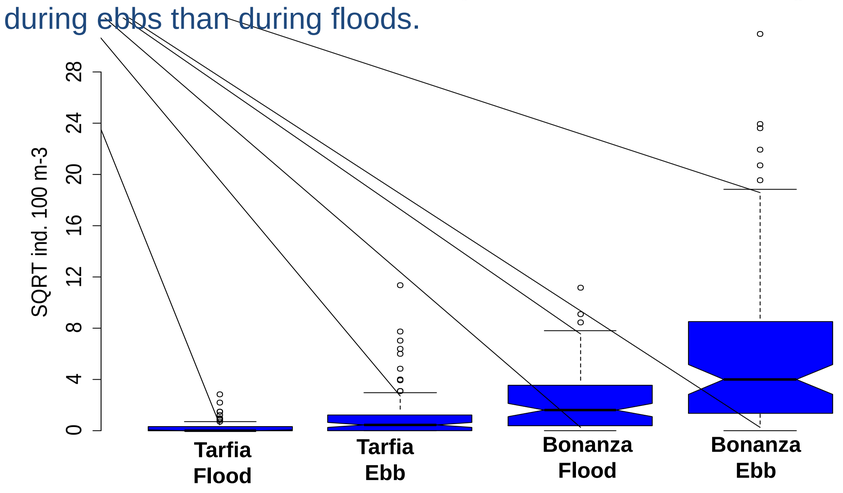


Model Validation: we extract the normalised residuals and were plotted against fitted values and all covariates in the model. Panels indicate that there are no clear patterns in the residuals

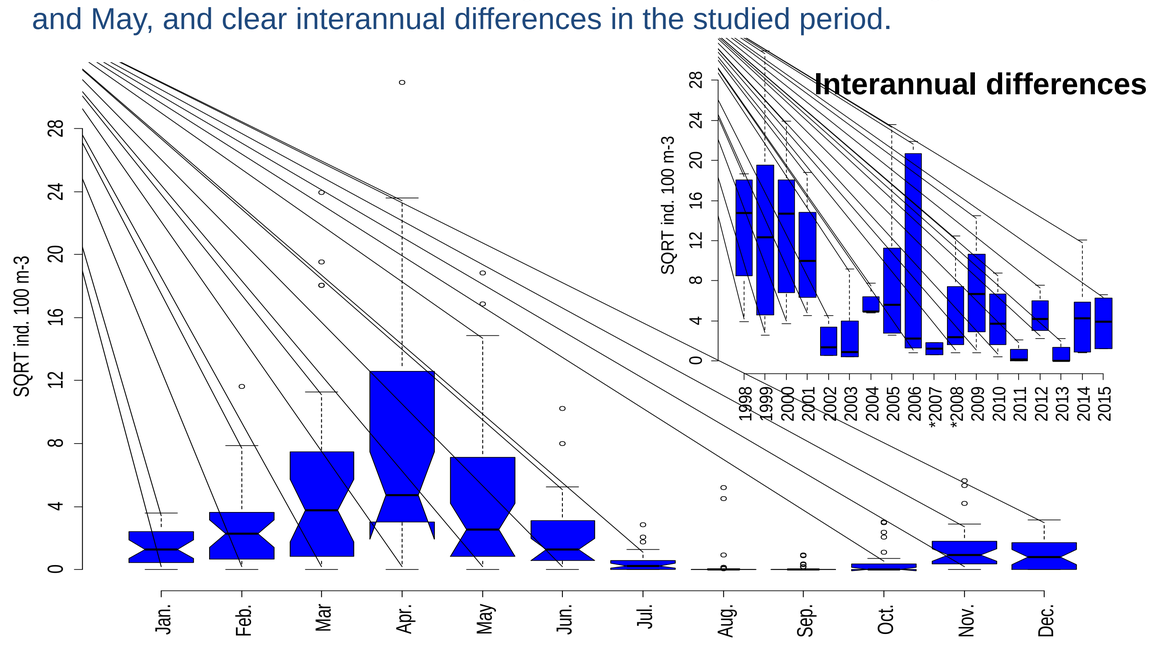


RESULTS AND DISCUSSION

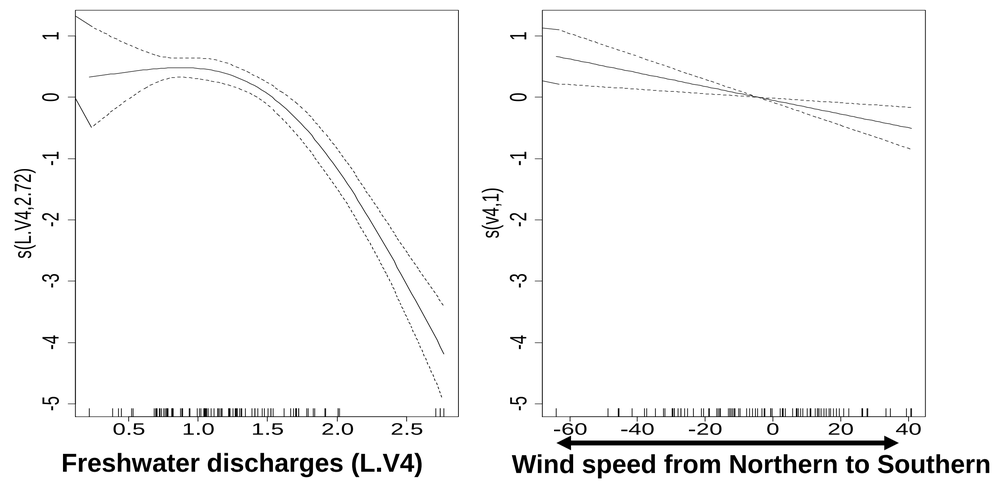
Clear spatial and tidal trends were observed at each month. Density decreased from the outer to inner stretch of the estuary and, at each sampling site, density was higher during ebbs than during floods.



The density of sardine juveniles in the outer stretch of the Guadalquivir estuary shows a seasonal pattern, with a high recruitment period in Spring between March and May, and clear interannual differences in the studied period.



The best selected model for the months of high recruitment (March to May) at the ebb tide in the latter station included the freshwater flow and the wind regimen (northern-southern component) as main drivers explaining their abundance. In addition, months and years were included in the selected model to remove temporal pattern in the residuals.



Freshwater input (L.V4) had a negative short-term effect on the abundance of juvenile sardines above a critical threshold. On top of this, the wind-speed variability in the northern-southern direction (v4) showed a clear linear effect: with strong northerly winds enhancing the sardine abundance in the Guadalquivir estuary. Differences between months and years in the sardine estuarine recruitment were significant.

Conclusions

The main recruitment of sardine occurs in spring when the estuarine salinity gradient is more variable due to FSW. Thus, water management has a clear influence on the nursery function of sardine in this estuary.

An scenario of bad conditions for the sardine estuarine recruitment occurs under accumulated FSW of more than 30 hm-3 and strong southerly winds at least in a short period of time (4 days).

These results contribute to the knowledge of the recruitment process of the European sardine and eventually to implementing an ecosystem approach to its fishery in the Gulf of Cadiz.