What drives tuna captures between XVI (1525) and XVIII (1756) centuries in southern Europe?

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- In 1756, the Duke of Medina Sidonia, D. Pedro Alcántara Guzman, concerned by the strong decrease of tuna catches in his almadrabas, requested to the monk Martín Sarmiento the reasons of this economic disater.
- In 1757, the monk Martín Sarmiento sent a letter to the Duke of Medina Sidonia explaining that was mainly due to the overfishing and could be related to climatic variations (López-Capont, 1997).

Objective

- To test the effect of climatic factors on the decrease of tuna captures.

1. Statistical analysis of time series of the climatic events that occurred between years 1525 and 1756
2. Statistical analysis of the relationship between climate events and bluefin tuna catches of the Medina Sidonia Almadraba

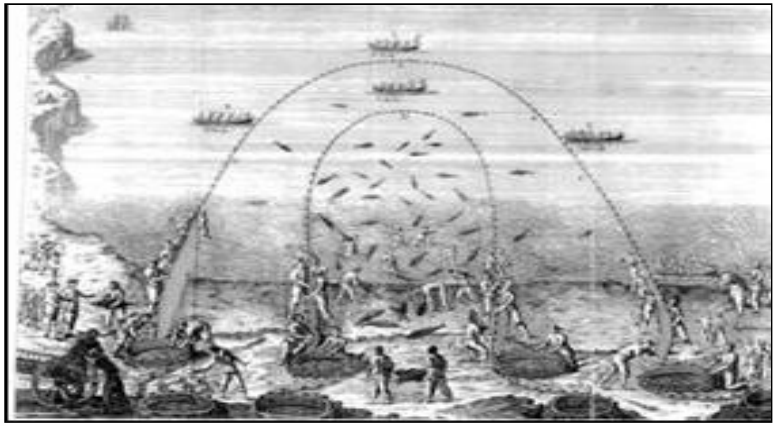
Time series data

- The historic **bluefin capture series** has been extracted from Lopéz-Capont (1997).

- Data **series on different climatic parameters** for years 1525 to 1756 encompasses :

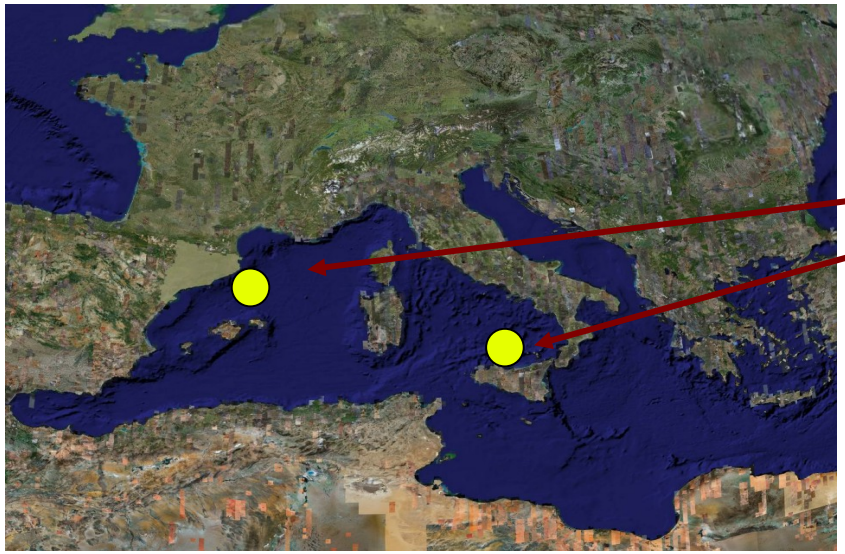
  - **Sea Surface Temperature (SST)**
  - **Temperature of the air**
  - **Greenhouse Gases (GHG)**

- **Social-economics** events : epidemics and wars



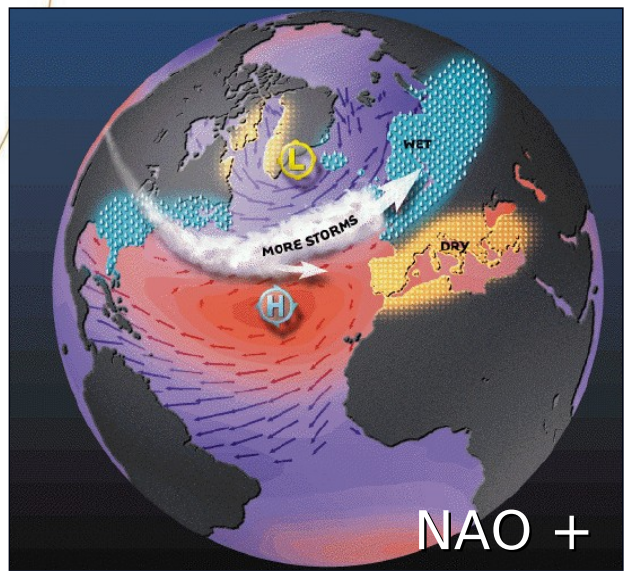
- The “almadraba” (tuna traps) have been used to catch migrating tunas, particularly bluefin, in South Spain since the Phoenician times, without significant changes in location or way of fishing.
- The bluefin tuna were seen from a tower The Duke’s when these are entering the Mediterranean in their reproductive route (April – mid June).
- The “almadraba” needed about 300 people.

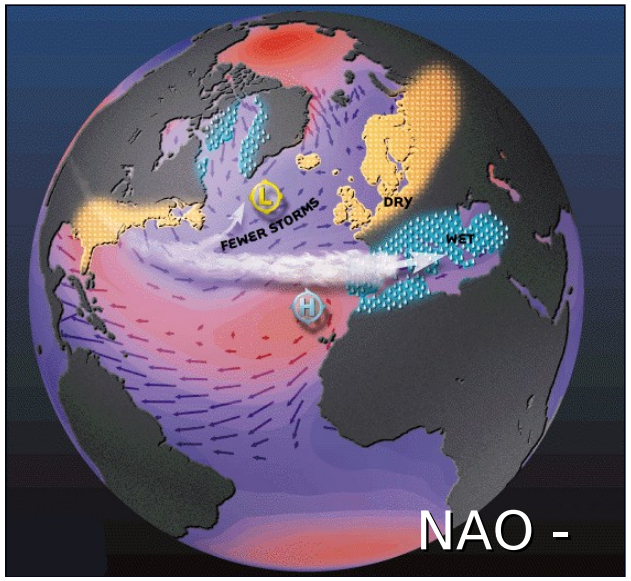
Spawning migration



• In the Eastern Atlantic, the bluefin tuna lays eggs in the Mediterranean, in general from end of May to July.

• The main concentrations of larvae are located around the Balearic Islands, the Tirrenean Sea and the Central Mediterranean, when the temperature of the sea surface is 24-25,5 ºC (Rooker et al., 2003).

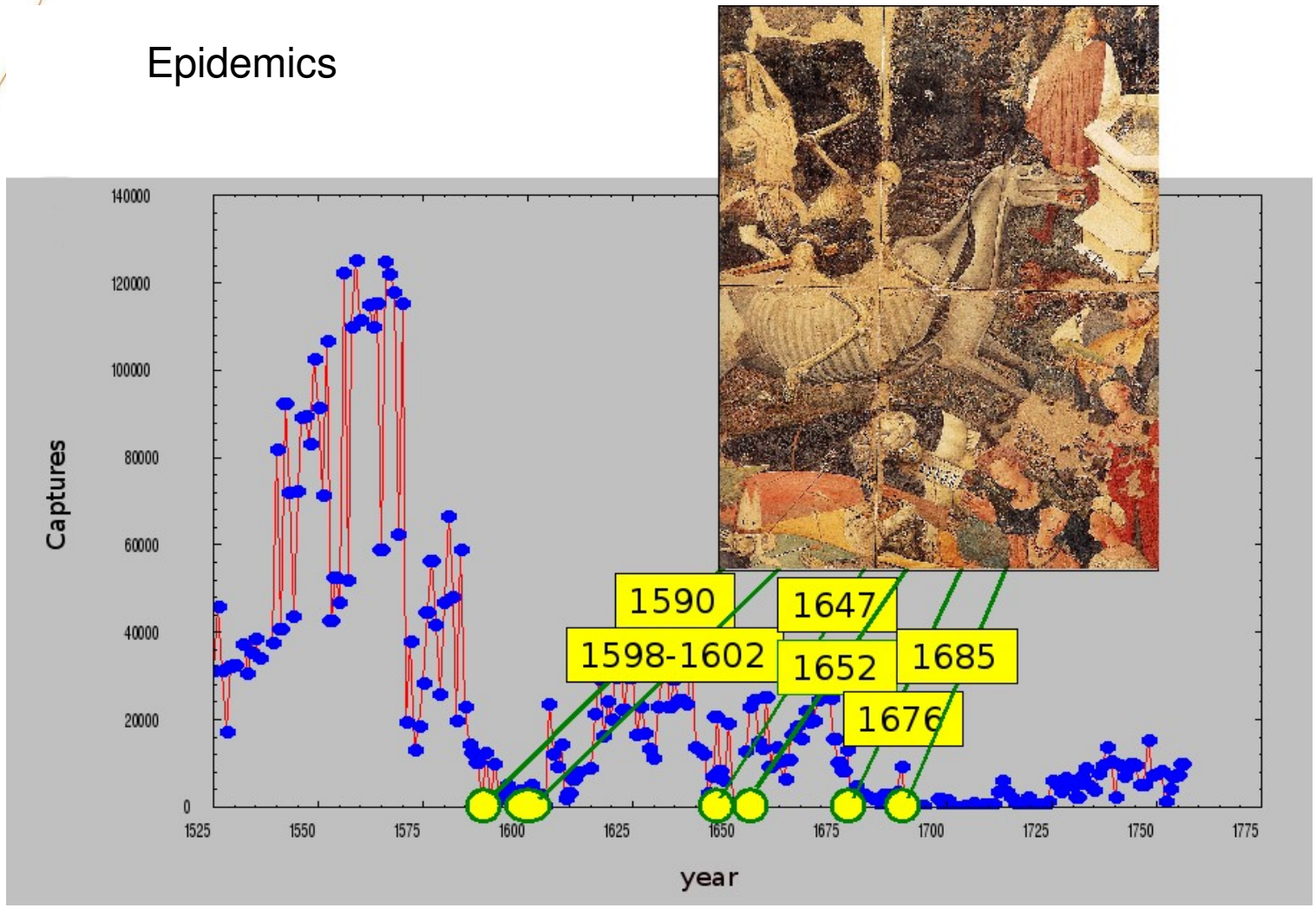




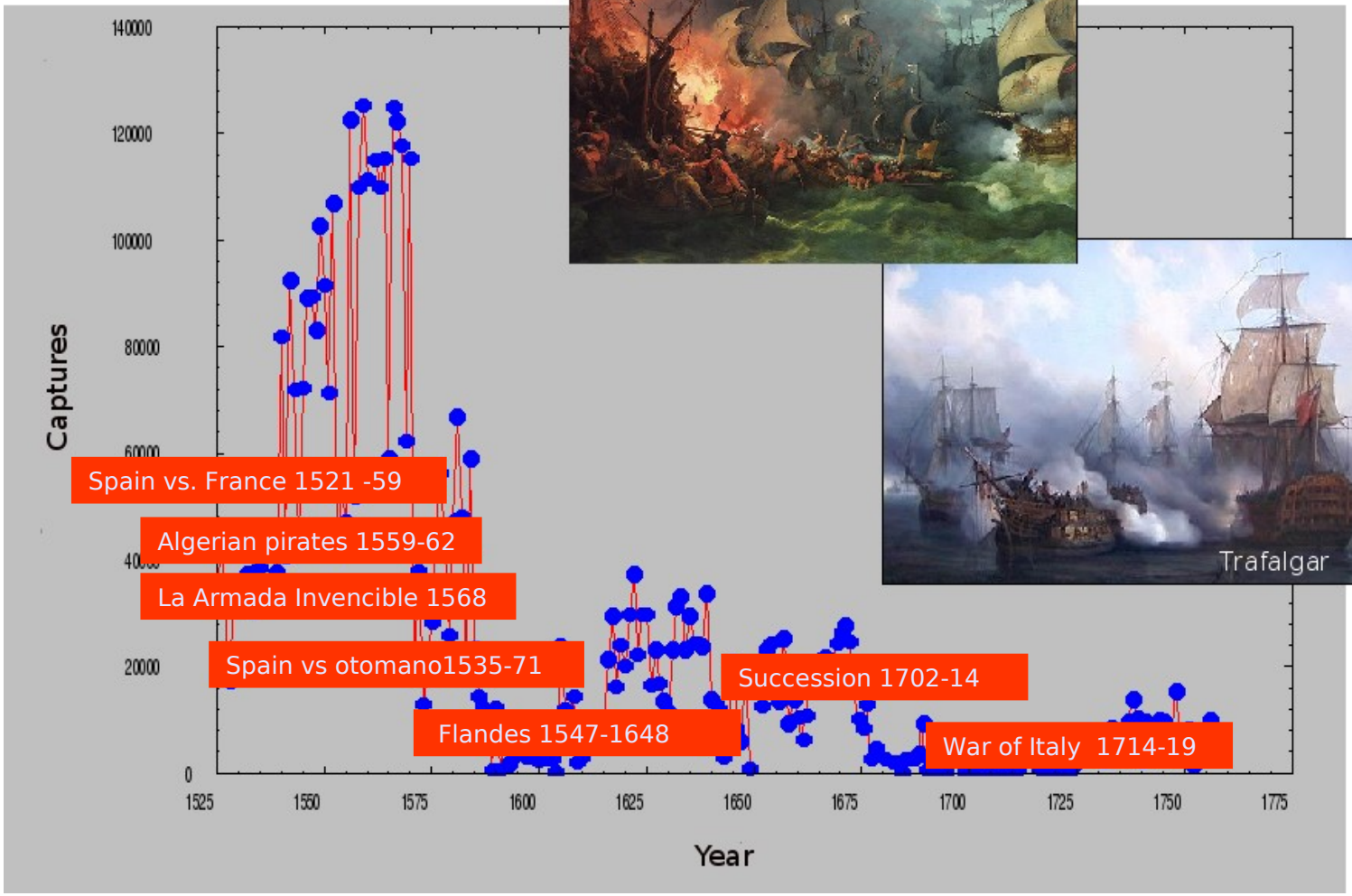
- The environmental conditions found by tunas during their migration in oceanic waters may have a significant influence in both their local abundance and behaviour (Korsmeyer & Dewar, 2001).

- For example, the relationship between the winter NAO index and bluefin tuna captures is positive (Santiago, 1998), although negative for albacore.
- The NAO explained
    - 38% of bluefin tuna recuitment var.
    - 64% of albacore recruitment var.

Epidemics



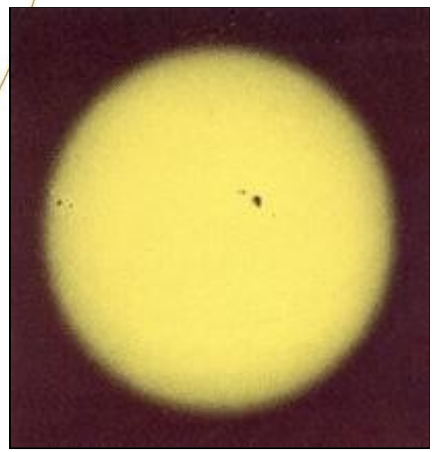
Wars



• Some of the changes in the climate during this period are documented in the literature, especially in relation to the cooling that affected Western Europe between 1640 and 1715, called the "**Little Ice Age**".

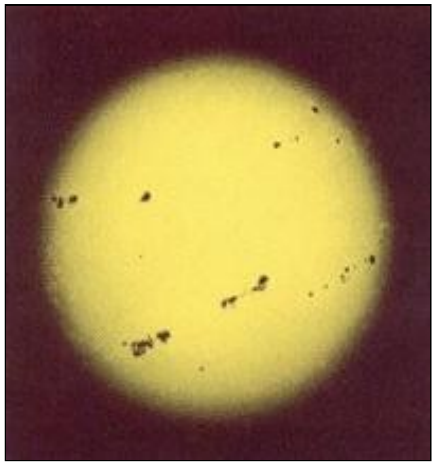
• During this cold period, rivers and lakes, that were normally ice-free, froze down and the snow cover did not melt all year around, even at low latitudes.

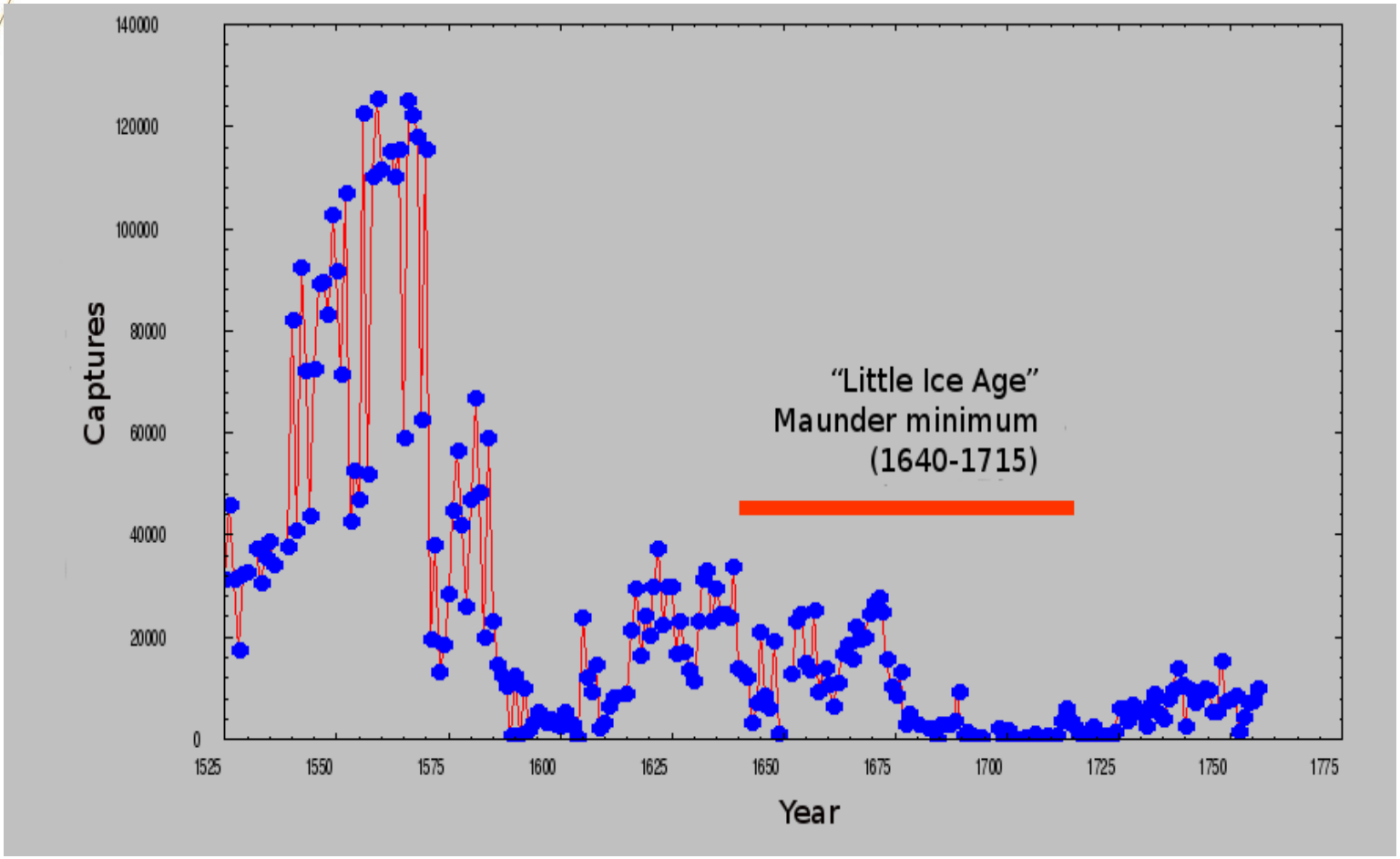
• In the middle of the 18th century, temperatures dropped so low that both the Baltic Sea and the Thames River froze regularly.



- Theses changes have a clear relation with **solar radiation** during the **Maunder minimum**; this implied a period of low temperatures in Western Europe and over the whole world (Lean, 2000)

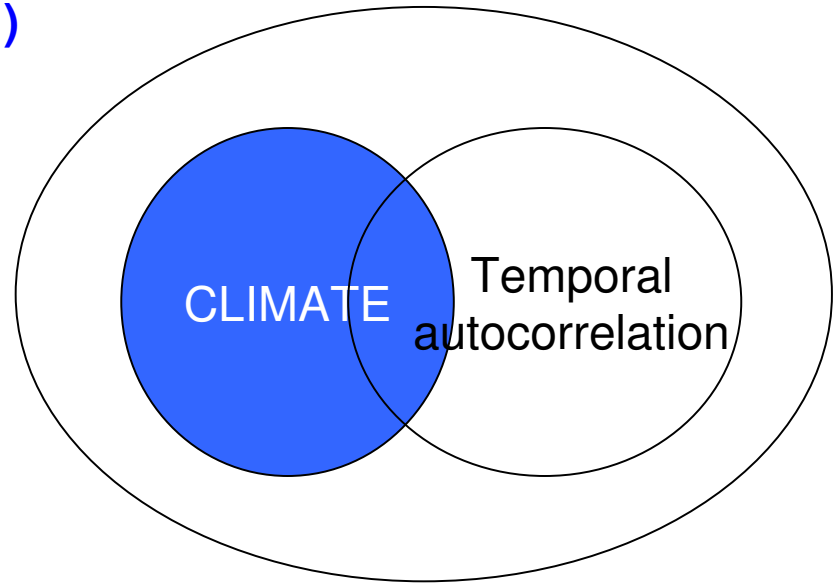
- Comparison of the Sun-related data sets with various reconstructions of terrestrial Northern Hemisphere mean surface temperatures reveals consistently **positive correlation coefficients with the number of sunspots** and negative correlation coefficients with the cosmic rays (Usoskin et al., 2005).





Statistical Analysis

- Time series analysis: Crosscorrelation
- Relationship analysis:
  - GLM model. Explanatory variables:
    - **(a) Sea surface temperature (SST) (Zorita, 2005)**
    - **(b) Air temperature (Zorita, 2005)**
    - **(c) Greenhouse gas (GHG)**
  - Variation partitioning



Results

Highest cross-correlation coefficient between tuna captures and climatic variables:

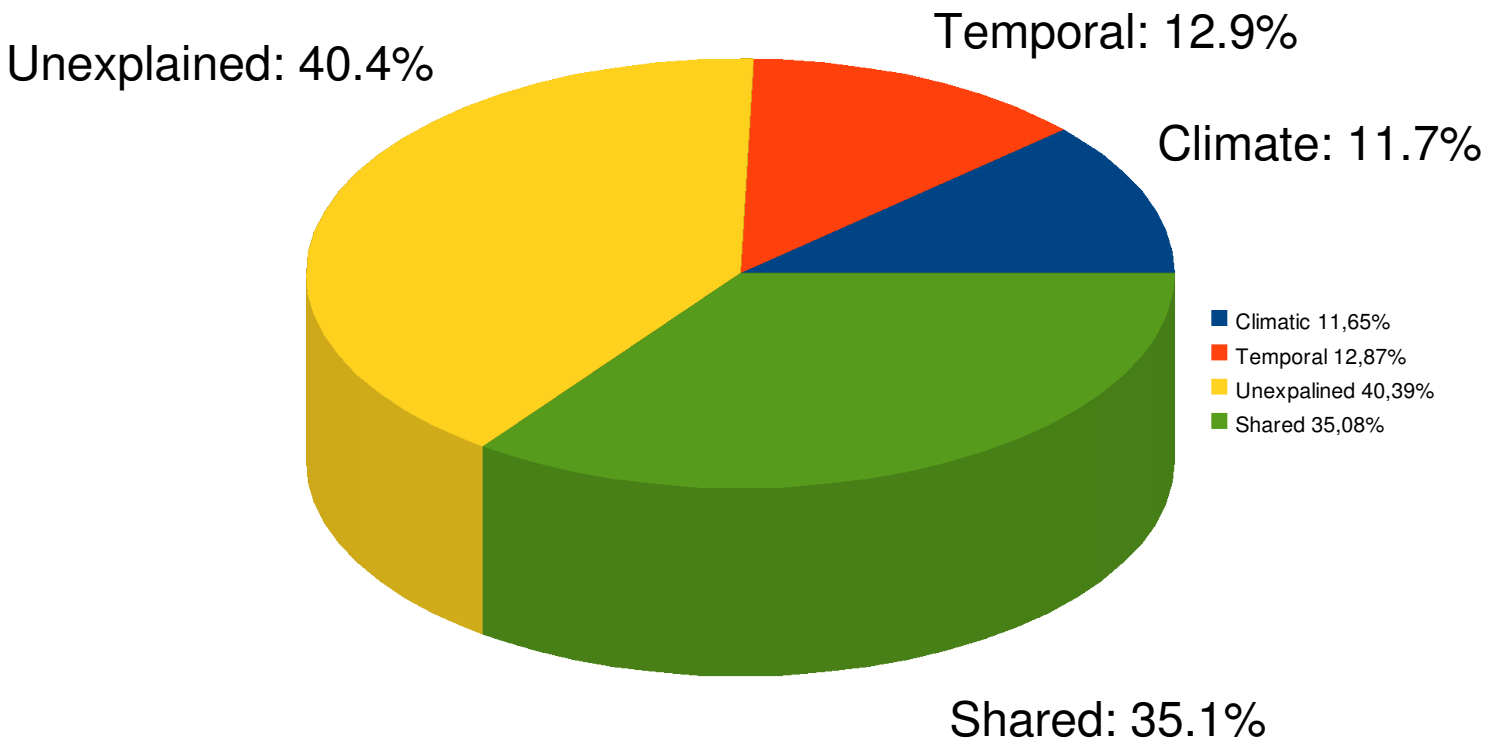
Climatic variables	*Cross-correlation coefficient*	*p-value*	*Stand. Error*	*Lag (years)*
Air temperature anomaly (Mann *et al.* (1998))	0.290	< 0.01	0.067	6
Air temperature anomaly (Mann *et al.* (1999))	0.356	< 0.01	0.068	6
Air temperature anomaly (Zorita *et al.* (2005))	0.238	< 0.01	0.069	7
Sea Surface Temperature (Zorita *et al.* (2005))	0.268	< 0.01	0.069	7

- The temperature affects captures with 6-7 years of lag, which coincides with the age of tunas when start to migrate

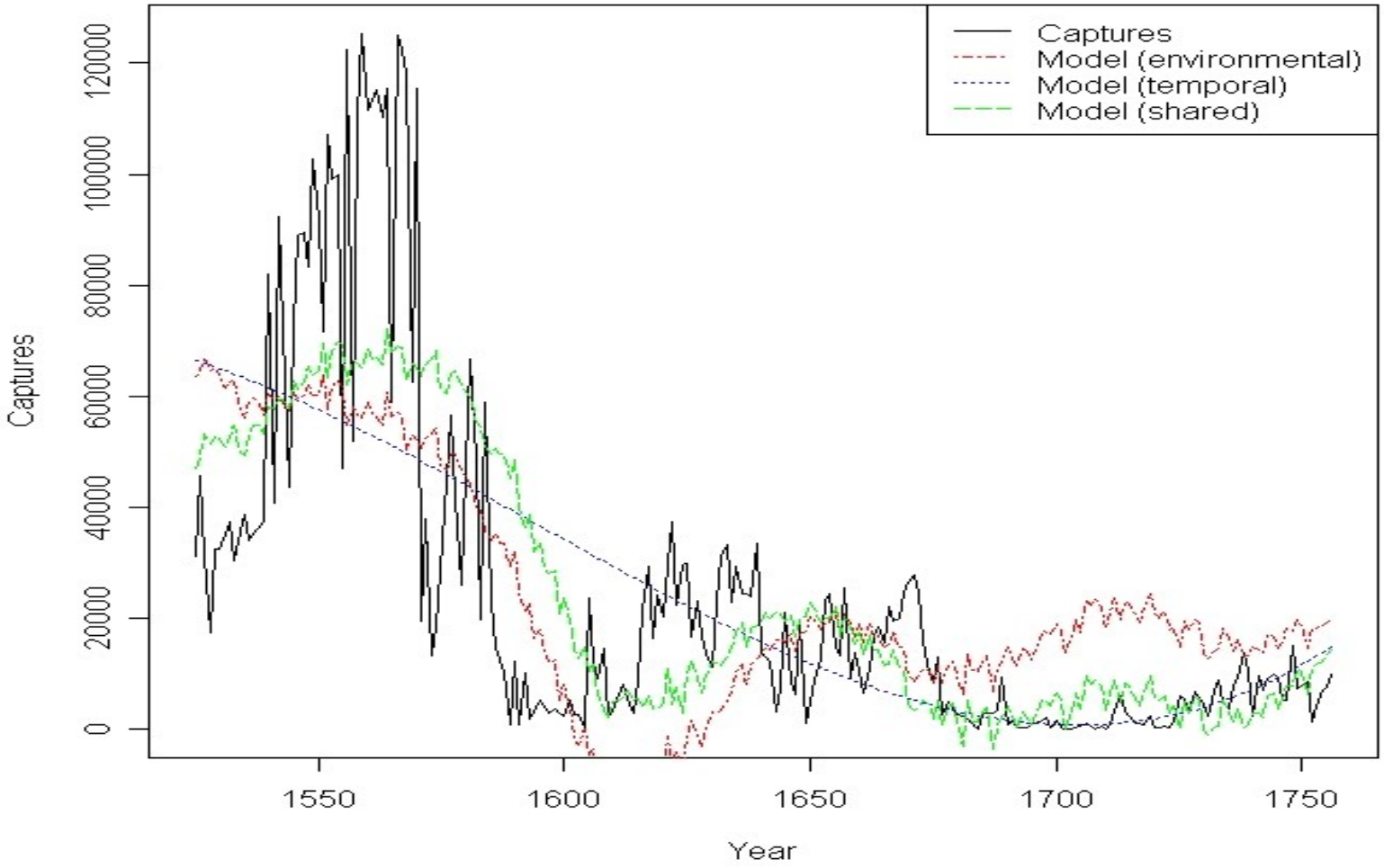
Variation partitioning of the captures series, using GLM model

	Terms	Selected Terms	p-value	Explained deviance (%)
Climatic	Greenhouse Gases	Greenhouse Gases	< 0.0001	11.65
	Sea Surface Temperature			
	Air temperature			
Temporal	T	T	0.0389	12.87
	T^2	T^2	0.0331	
	T^3	T^3	0.0284	
Shared				35.08
Unexplained				40.39

Variation partitioning of the captures series, using GLM model



GLM model of Tuna captures



Discussion and conclusions

- The results indicated that climate accounts for an 11.6% of the total variance of tuna captures, the temporal effects accounts for a 12.9% of the total variance, and a 35.1% of captures is accounted for by the joint effect of the two latter components
  - Our findings suggest that both environmental and population dynamic components played an important role in the Medina Sidonia almadraba
  - We can not disentangle, if all of the 35.1 % of the shared variance is due to an external forcing or to the recruitment feedback
- The presence of one cycle of 6-9 years revealed by the cross-correlation analysis suggest that:
  - the relationship between sea surface temperature and captures could be related with the lag between larvae hatching and the recruitment age at the moment of fishing
- During this period, various social events may have influenced the fishery, such as pestilence outbreaks and the Spanish War of Succession that reduced the fishermen population.
  - The extremely low capture in 1703-1704 could be a good example of this socio-political situation, probably due to the impact of the English-Dutch army military attacks to Cádiz and Gibraltar.

Acknowledgements

- We would like to dedicate this study to the memory of Prof. F. López Capont due to his works of compilation and publication of historic, highly valuable documents such as the letters of the monk Martín Sarmiento.

Thanks for your attention