

Reconstructing the Dynamics of Small Pelagics in the Adriatic Sea over more than a Century (1902-2014)

D. Panzeri^{1,2}, T. Fortibuoni^{1,3}, P. Carpi⁴, A. Santojanni², C. Solidoro^{1,5} and S. Libralato¹

Catch data regarding fisheries that have been subjected to relatively small modifications over time can represent an important source of information in the framework of marine historical ecology. The *lampara* purse seine (fig. b) in the Gulf of Trieste (Northern Adriatic Sea, Mediterranean, fig. a) is a traditional exploitation activity carried out since almost a century for targeting two small pelagic migratory species, European anchovy and sardine (*Engraulis encrasicolus* and *Sardina pilchardus*). Despite technological improvements (that can be considered in model construction), the fishing system (fig. c), the fishing area and the market demand for these resources have remained locally almost the same over time. Quantitative and anecdotal historical information on landings, fishing capacity and environmental variables from 1902 to 2014 was collected from books, research reports, logbooks, fish market statistics and thesis works. **The aims of this work were to analyze the long term landings dataset of anchovy and sardine for the Trieste fish market (the main fish market of the area) using statistical decomposition of monthly time series, and to develop an integrated model for estimating the incoming biomass of the species in the Gulf of Trieste.**

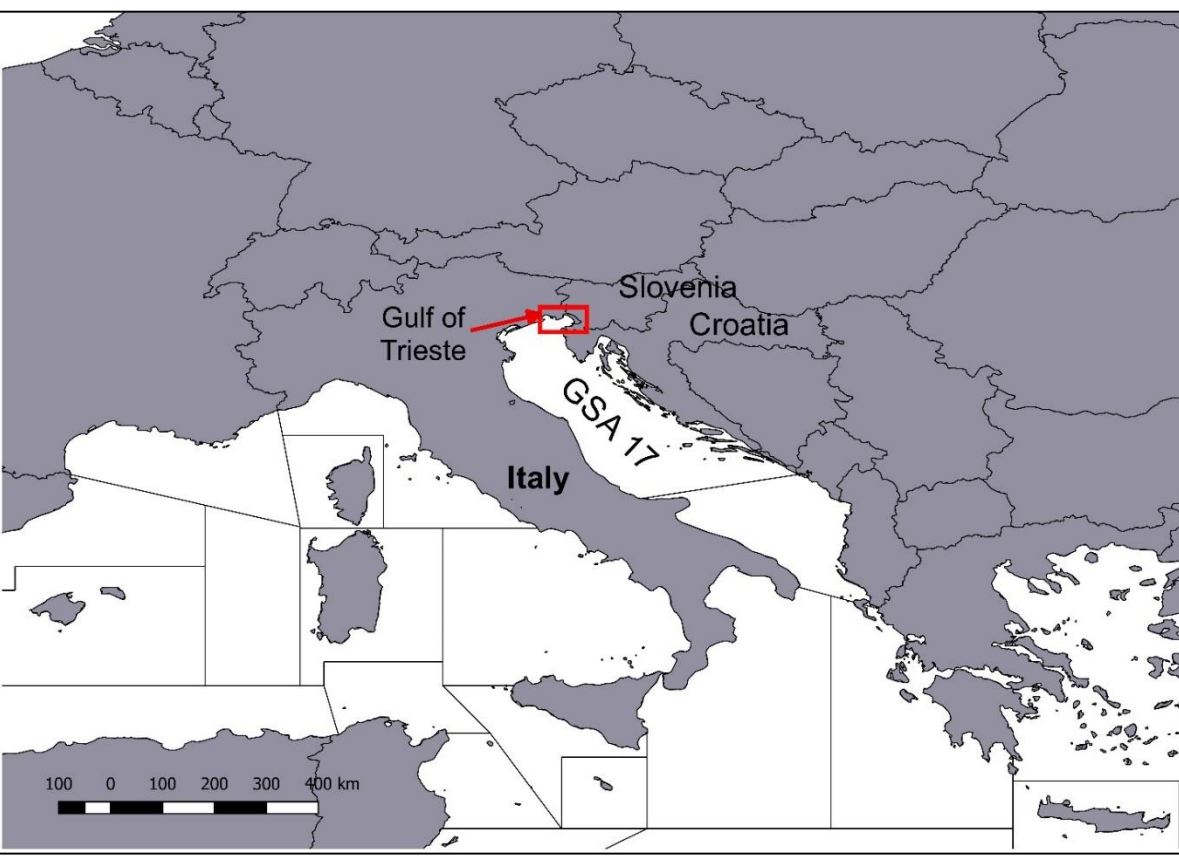


Fig. a: Area of study Gulf of Trieste (Northern Adriatic Sea, Mediterranean)

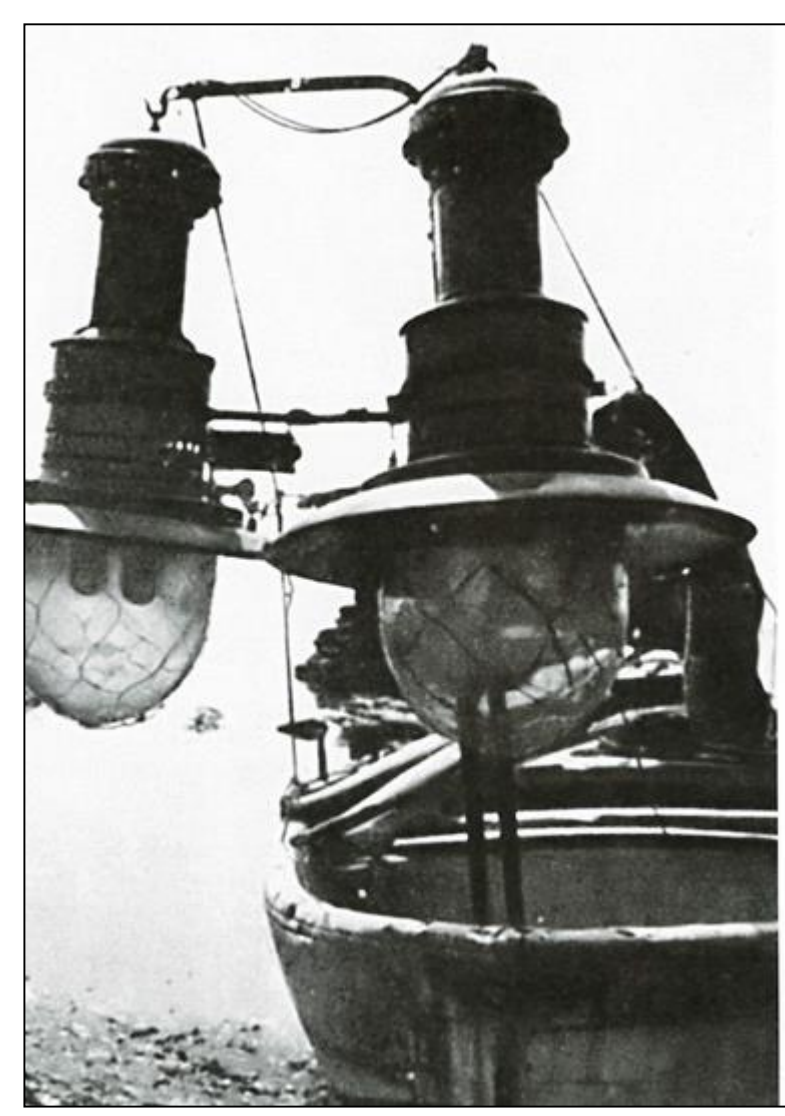


Fig. b. Old lampara.

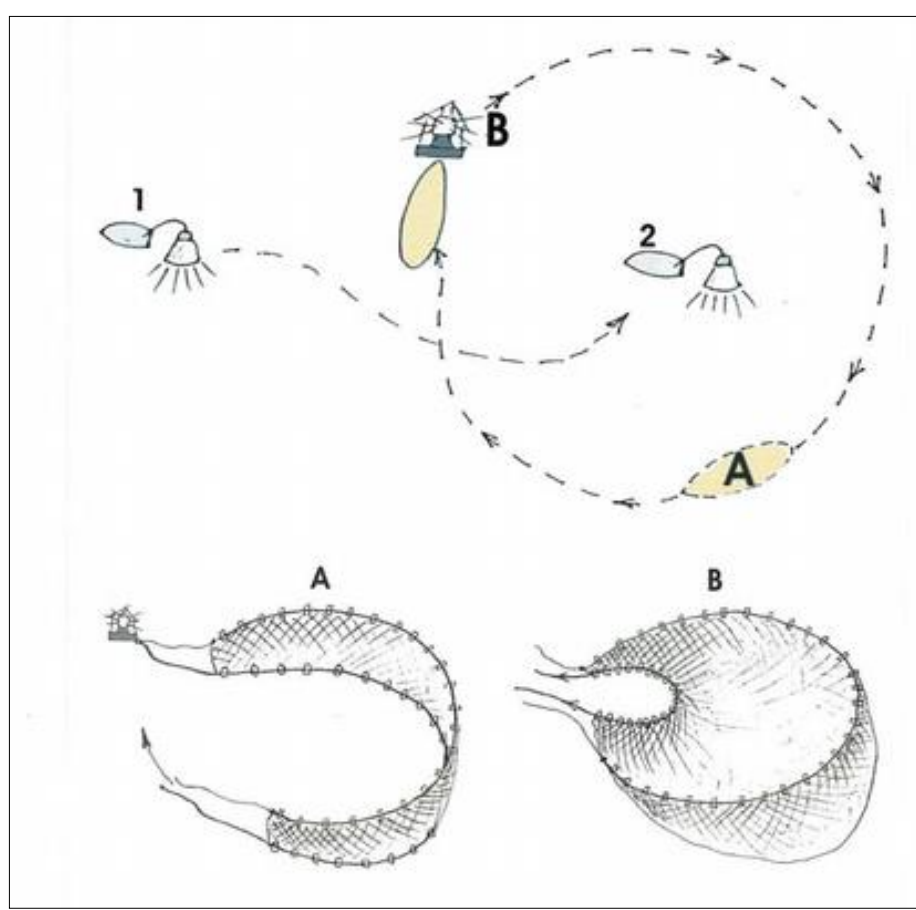


Fig. c. purse seine fishing system. Above: A&B main boat with light. Below: fishing operation

Materials

- Landings** time series for the Trieste fish market from 1902 to 2014 (sources: D'Ancona, 1926; 1949, Italian National Institute of Statistics-ISTAT, Trieste fish market, Fortibuoni, 2010)
- Length frequency distributions** of sardine and anchovy landings from 1975 to 1995 (source: ISMAR-CNR)
- Wind intensity** time series from 1902 to 2014 (source: ISMAR-CNR)
- Fishing capacity** (sources: ISTAT, EU Fleet Register, Cingolani *et al.*, 1996)

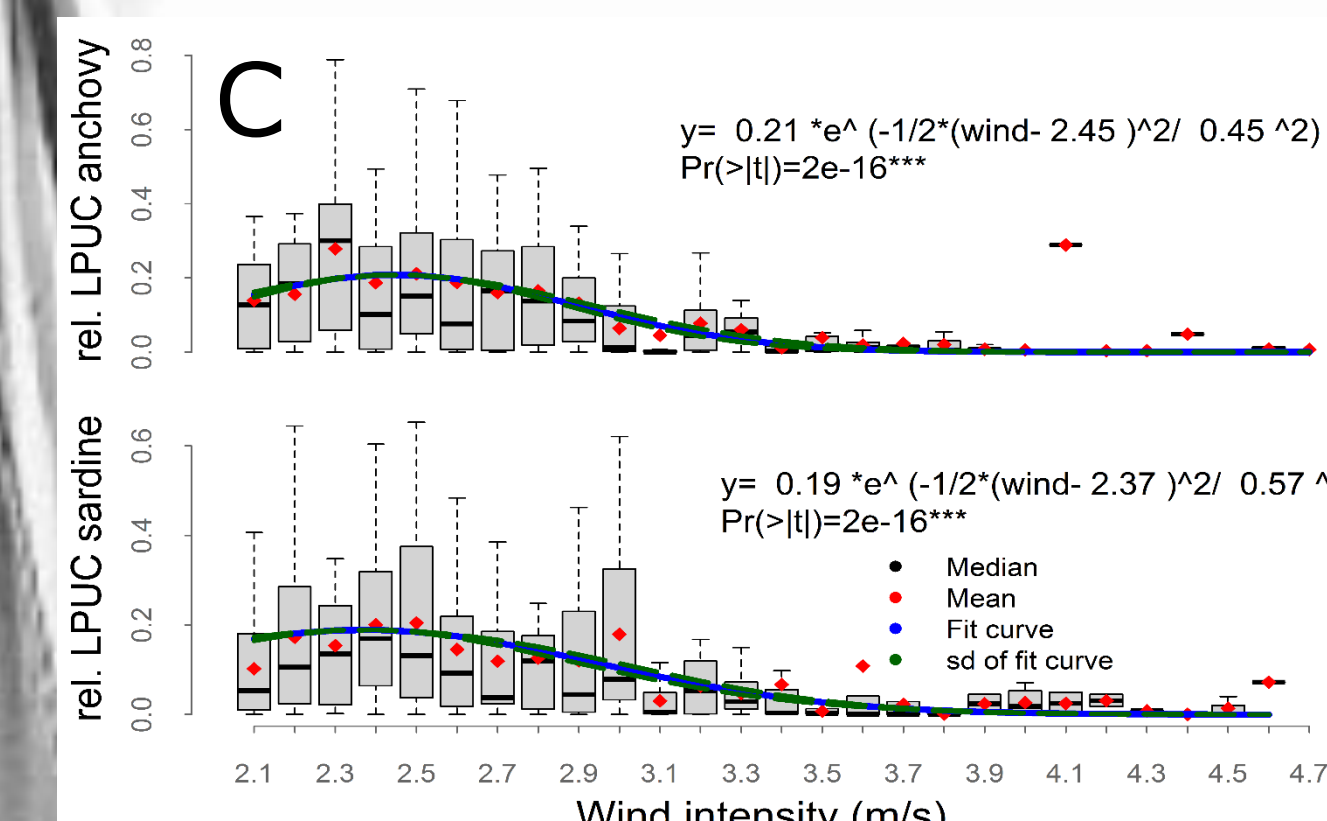
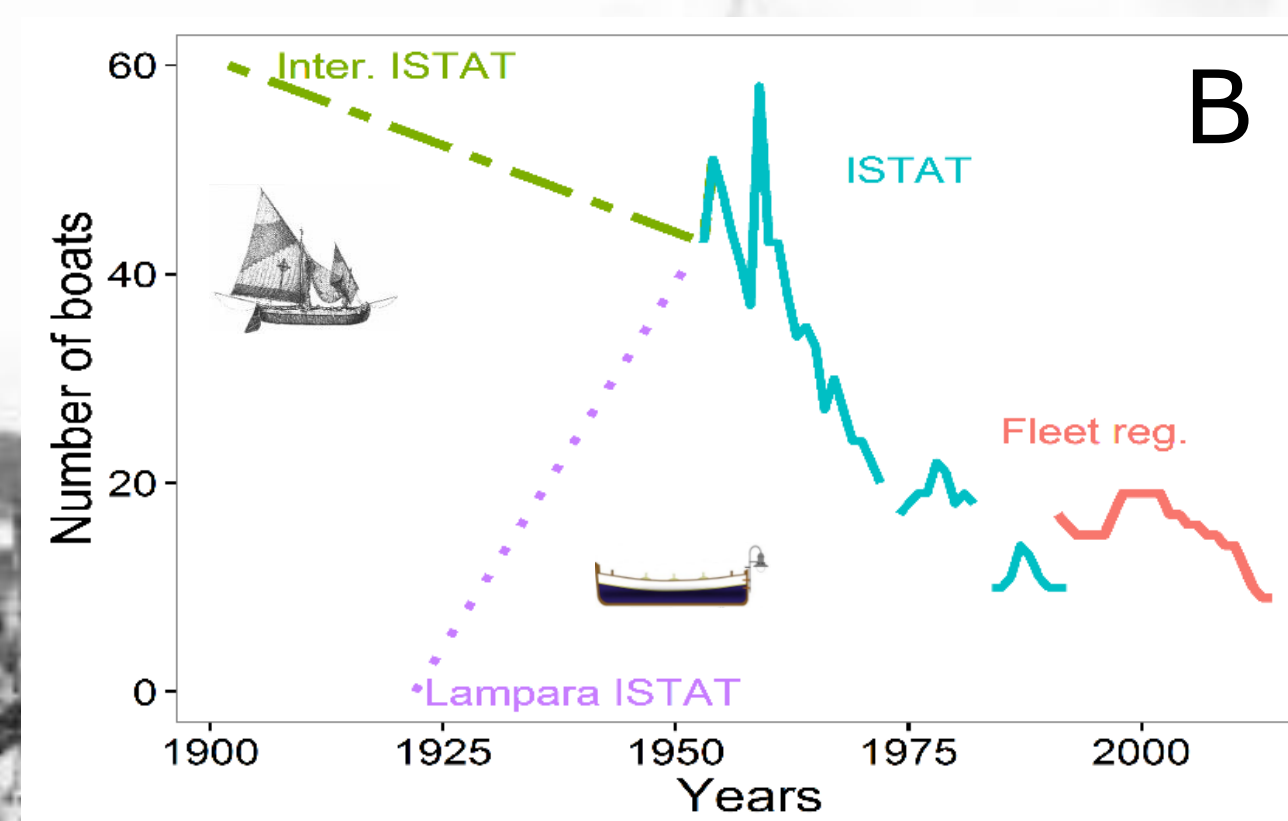
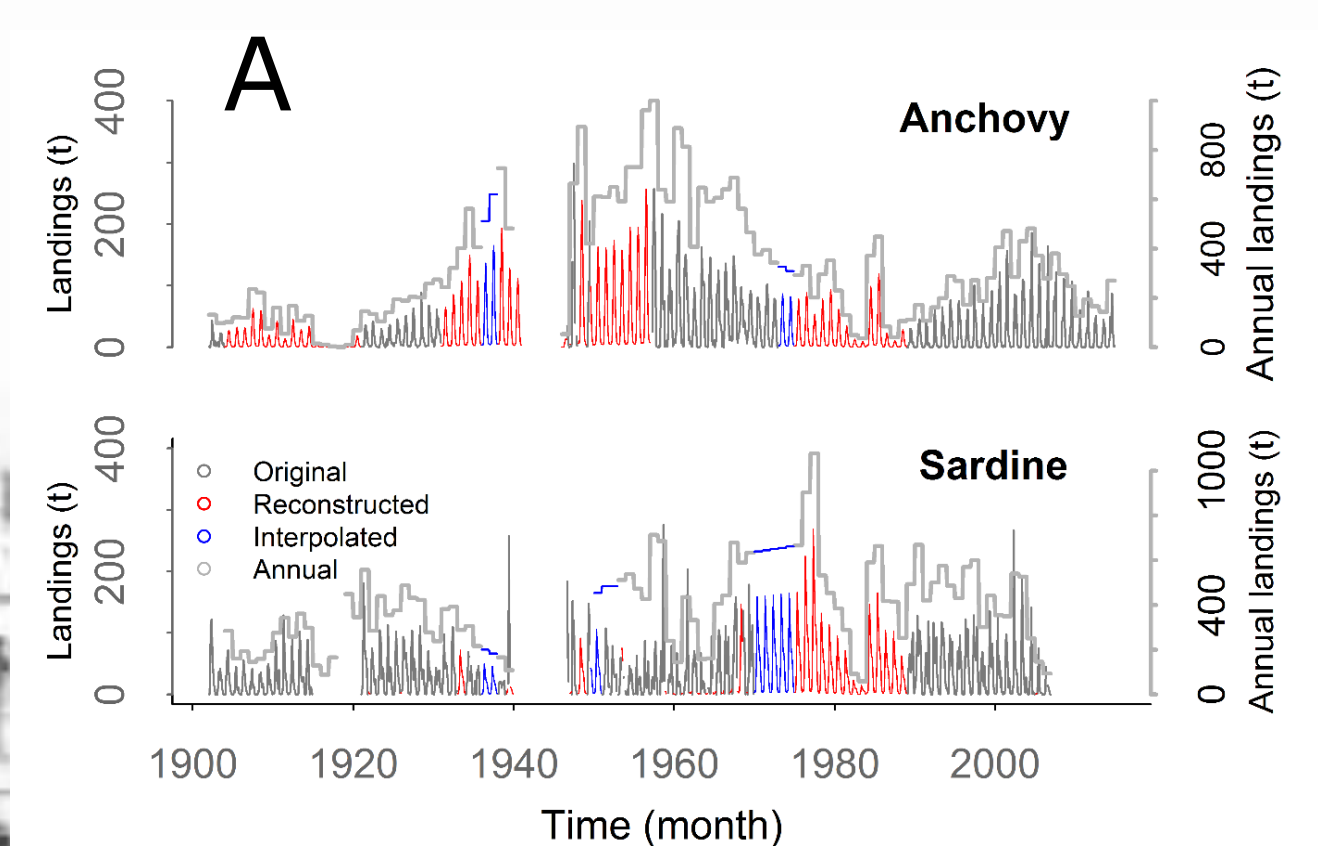
Methods

- Analysis of landings time series with classical methods (additive, mixed, multiplicative) to extract seasonality
- Missing landings monthly data reconstructed from annual data (based on seasonality)
- Integrated mathematical model for reconstructing the incoming biomass of anchovy and sardine in the Gulf of Trieste
- Comparison of our model (from 1975 to 2014) and state-space assessment (SAM) estimated for the Adriatic basin by the General Fisheries Commission for the Mediterranean (GFCM)

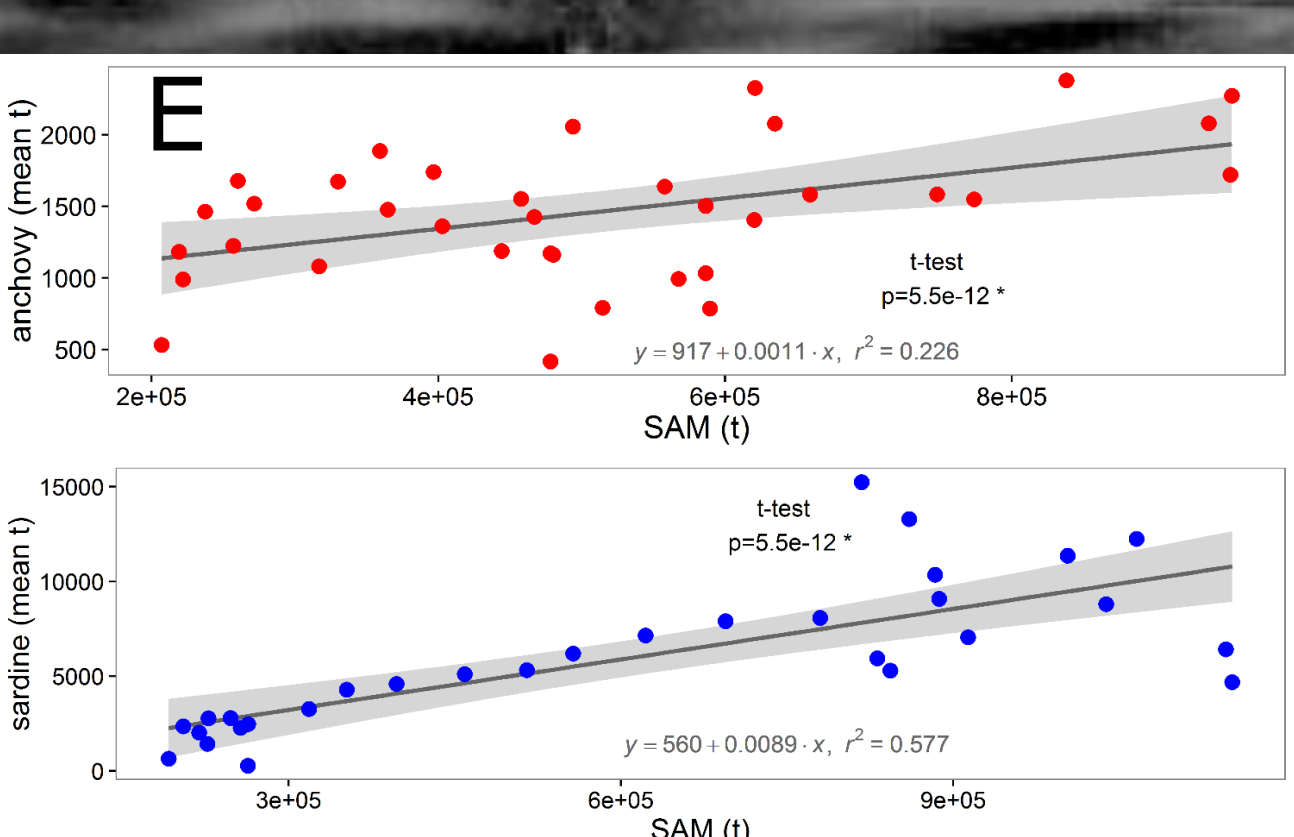
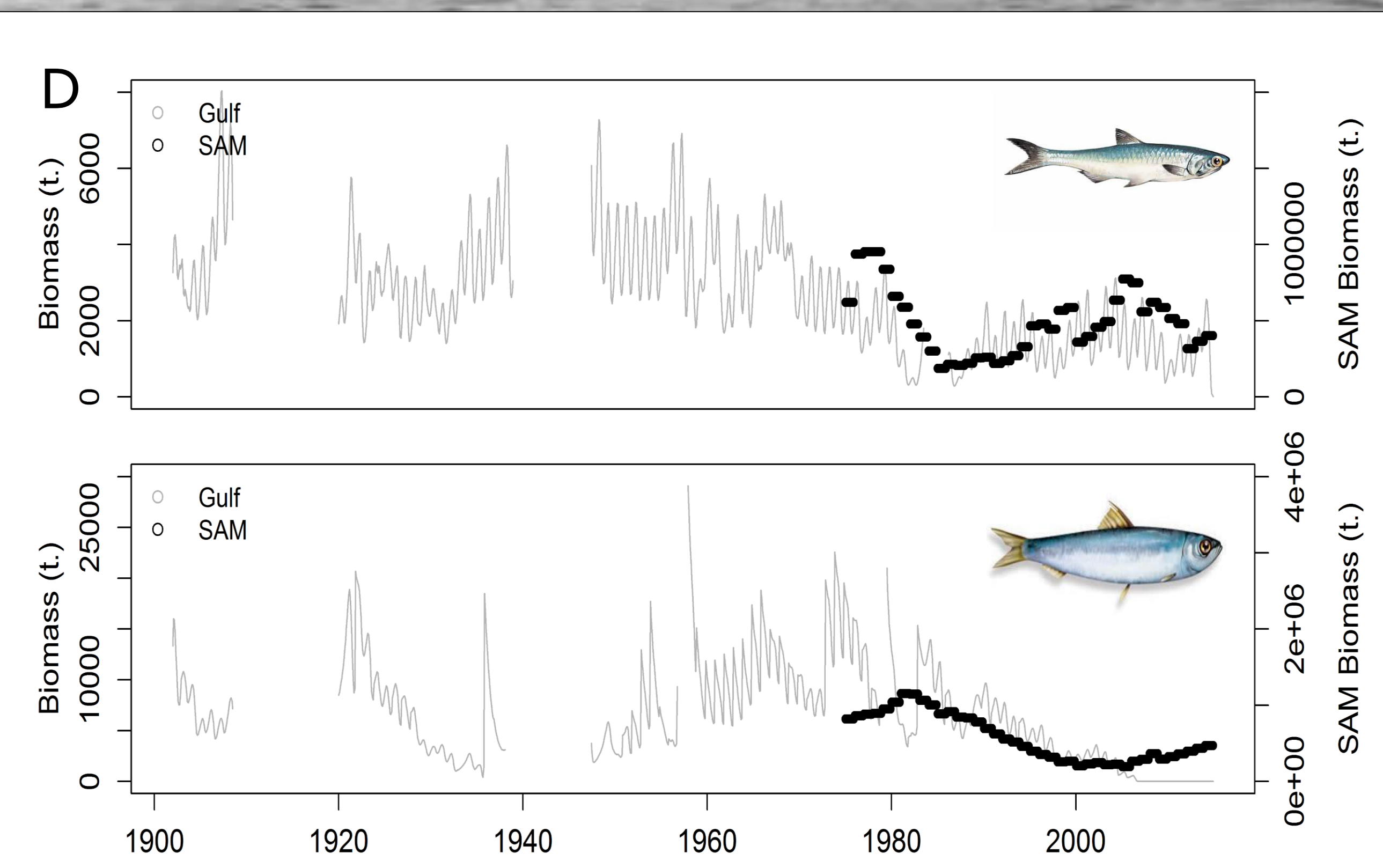
Symbol	Description	Value used
a	Allometric coefficient	A: 0.004 S: 0.006
b	Allometric coefficient	A: 3 S: 3.077
L_{inf}	Max length	A: 19.4 S: 20.5
K	Growth coefficient	A: 0.57 S: 0.46
L_s	Length at class size s	From 4 to 22
s	Class size	From 4 to 22
m	Month	From Gen. to Dec.
y	Year	From 1902 to 2014
N	Number of individuals	-
q	Catchability	A: 0.0136 S: 0.0183
F	Fishing mortality	S: 0.37
M	Natural mortality	A: 0.6 S: 0.5

Results

- Landings missing data were reconstructed
- Fishing capacity was reconstructed
- Wind function was calculated to estimate fishing effort from landings per unit of capacity (LPUC) and wind intensity (m/s)
- Incoming biomass of anchovy (above) and sardine (below) in the Gulf of Trieste was estimated
- The correlation between biomass estimate (model SAM) for the Northern and Central Adriatic Sea and the Gulf of Trieste (our model) for the years 1975-2014 was analyzed



$$B_t = \sum_{s=1}^{s_{max}} \sum_{\delta=0}^{\Delta t_s} a \cdot \left(L_{\infty} - \frac{L_{\infty} - L_s}{e^{-k}} \right)^b \cdot \frac{f_{s,t+\delta} \cdot C_{t+\delta}}{\sum_s f_{s,t+\delta} \cdot (aL_s^b)} \cdot \frac{1}{q \cdot T C_{t+\delta} \cdot E_{t+\delta} \cdot f(v_{t+\delta}) \cdot S_l} \cdot e^{M \cdot (t+\delta)}$$



Discussion

The *lampara* fishery in the Gulf of Trieste represents some kind of “non-standard sampling” of pelagic resources, since it has not substantially changed in the last century in terms of fishing grounds. Fishermen still «wait» the resources, rather than «following» them in order to guarantee a constant supply to local markets.

We combined historical research methods and population modeling to estimate the biomass of European anchovy and sardine in the Gulf of Trieste between 1902 and 2014 (Fig. E). Wide long term fluctuations of species biomass were observed, and current biomass levels are dramatically lower than at the beginning of the 20th century. From 1902 to 1910 anchovy biomass was on average 4500 tons, twice than the actual biomass (period 2000-2014), while sardine biomass was 9000 tons, three times as much than nowadays (period 2000-2006).

Since species stocks seasonally migrate from the south Adriatic to the Gulf of Trieste, we compared their biomass estimated for the whole Adriatic Sea with the ones estimated for the Gulf, and we found a good agreement (Fig. D). This may allow to extend our long term reconstruction of the biomass of the species to the whole Adriatic Sea, and ultimately correlate species dynamics with environmental and anthropogenic drivers, possibly supporting future management actions.