Analysis of long-term changes in a Mediterranean marine ecosystem based on fishery landings

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Why

Long-term analyses are necessary for understanding the processes that brought the marine ecosystems as we see today, avoiding the so-called "shifting the baseline syndrome". In the Mediterranean Sea, structured and standardized monitoring programs of marine resources were set only in the last decades, so the analysis of changes in marine communities over longer time scale has to rely on other sources (e.g. landings).
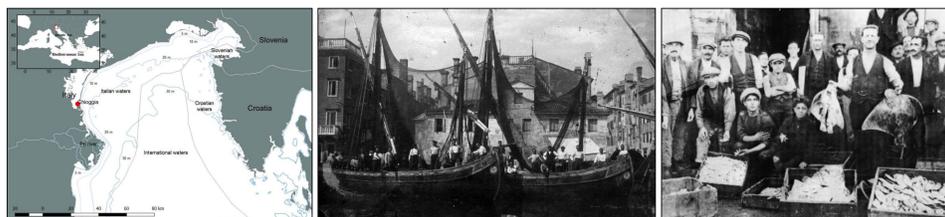
The Northern Adriatic Sea (Mediterranean); fishing boats in Chioggia (Italy) at the beginning of the 20° century; fish-sellers in Chioggia in the mid-1950s

How

We analyzed seven decades (1945–2014) of landings from the Chioggia's wholesale fish-market. Multivariate composition of landings was analyzed through chronological clustering. A suite of ecological indicators was applied to landings and compared with main ecosystem drivers (fishing capacity, Po river discharge, NAO, sea surface temperature) through the global BEST test. Indicators were further compared among periods identified through the chronological clustering (Table 1).

Table 1. Significant differences (Mann-Whitney U-test, p < 0.05) of total landings (Y), landings per unit of capacity (LPUC), and ecological indicators between successive periods. mTL = mean trophic level; MTC = mean temperature of the catch; PPR = primary production required to sustain the catches; LSI = large species indicator; E/T ratio = elasmobranchs-bony fish ratio; Q-90 = a variant on Kempton's Q index; P/D ratio = the ratio of small pelagic fish to demersal and benthic landings

	1945–1954	1955–1961	1962–1985	1986–1993	1994–2008	2009–2014
Y (t)	3520 (3293–4174)	▲		▼		
LPUC (t)	0.99 (0.95–1.06)					
mTL	3.65 (3.12–3.18)	▼	▲			
MTC	13.21 (12.42–13.55)	▼			▲	▼
PPR (10^{12}gCy^{-1})	0.08 (0.07–0.11)	▲		▼		▼
LSI	0.37 (0.35–0.41)	▼	▼			▼
E/T ratio	0.04 (0.03–0.06)	▼			▼	▼
Q-90	4.66 (4.48–4.96)				▲	▼
P/D ratio	0.94 (0.80–1.19)	▲	▼	▼	▲	▲

It is reported the median value and the interquartile range (in brackets) for the first period and significant positive (green) and negative (red) changes for successive periods.
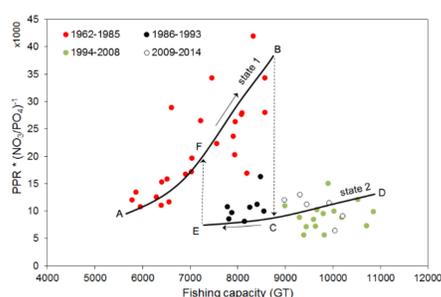

Dynamics of fisheries production under changes of fishing capacity and nutrient limitation from 1960 to 2014. PPR is scaled to N:P ratio to take into account changes in the nutrient limiting factor. Solid lines represent subjective indication of average main trajectories identifiable as two alternative states of the system (state 1: line A–B; state 2: C–D–E). The mid-1980s shift is coherent with a catastrophic shift between two alternative stable states (dashed arrow from B to C) and the presence of hysteretic behavior. For going back from the actual state (state 2, lower solid line) to a state prior to the catastrophic event of mid-1980s (state 1, upper solid line) it is necessary to considerably reduce fishing capacity (left dashed line E–F, placed subjectively).

Where

The Northern Adriatic Sea (NAS) is the shallowest (average depth of 33.5 m) and northern-most area of the Mediterranean Sea. It is characterized by strong riverine outflows (mainly from the Po river). Due to the presence of a wide flat trawlable platform coupled with the high productivity, the NAS is the Italian basin with the highest fishery pressure, and one of the most exploited areas in the Mediterranean Sea.

Chioggia (Italy) hosts the major fish market of the Adriatic Sea and the largest fishing fleet. Changes in landings can contribute to depict changes in the abundance of marine species in the basin.
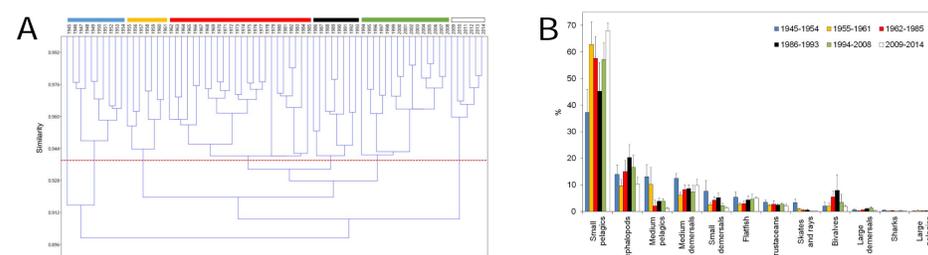
A. Chronological clustering (Bray-Curtis similarity, unweighted pair-group average) of the composition of landings. At a similarity of 0.94 seven clusters were identified (1945 was aggregated to the 1st cluster resulting in 6 periods with different community composition)

B. Percentage composition of the fish community in the periods identified through chronological clustering. The confidence interval (95%) is reported in the vertical bar

What

Most vulnerable species declined at the beginning of the industrialization of fishery in the mid-1950s (see LSI and E/B ratio decline, Table 1), probably because the exploitation rates were already not sustainable. Conversely, until the mid-1980s total landings increased, possibly as a consequence of the modernization of fishing fleets and of the growing cultural eutrophication. Later, the nutrient load delivered to the NAS decreased (mainly due to the ban of phosphorous from soap powders), thus leading to a combination of high exploitation and reduced productivity. Indeed, from our analysis resulted that phosphorous load (a proxy of primary production) and fishing capacity (a proxy of fishing effort) were the main drivers of change. It is likely that long-term effects of fishing drove significant changes in fish community structure in the NAS that were partially balanced by an increase in productivity in the period of high nutrient discharge. Once productivity declined, the food-web structure was already modified and probably the resilience of the system was unpaired. This evidence should be considered in fishery management, for instance by rescaling the fishing capacity according to the present status of environmental parameters (e.g. trophic conditions).