# Revisiting The Regime Problem hypothesis: 25 years later

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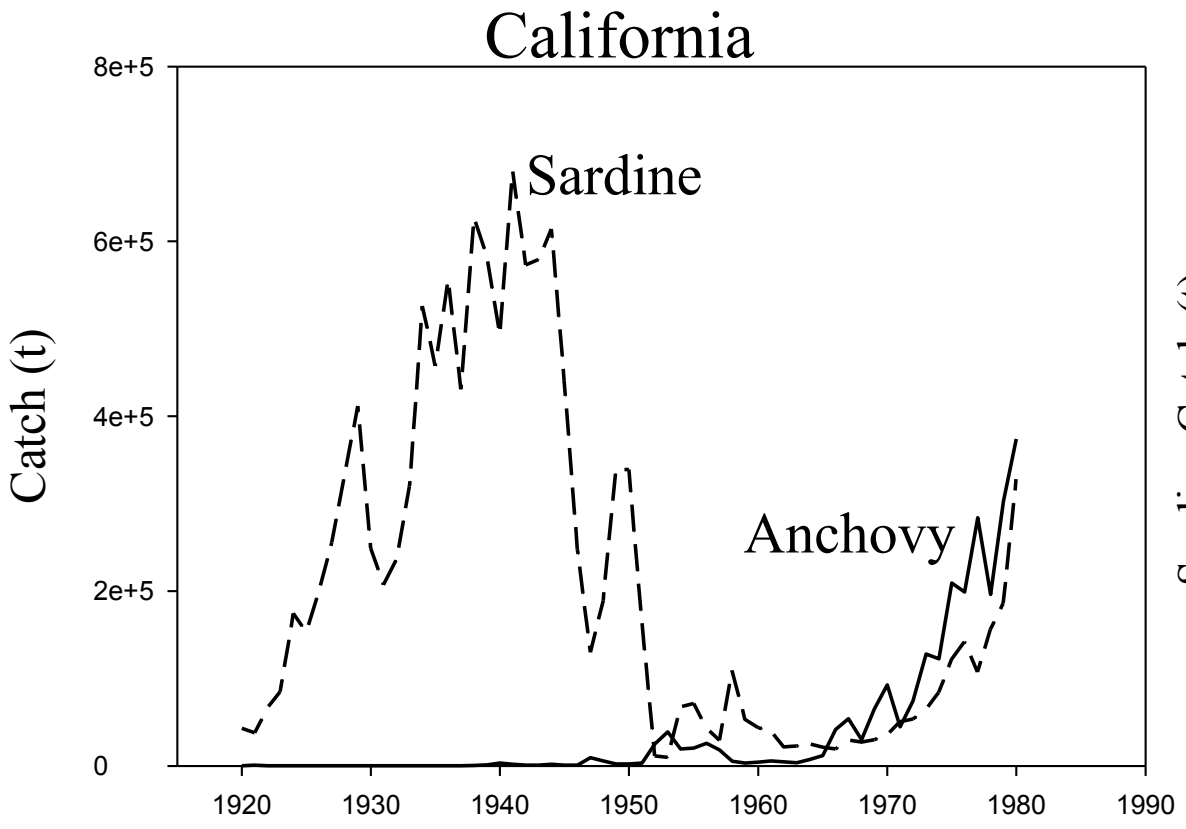
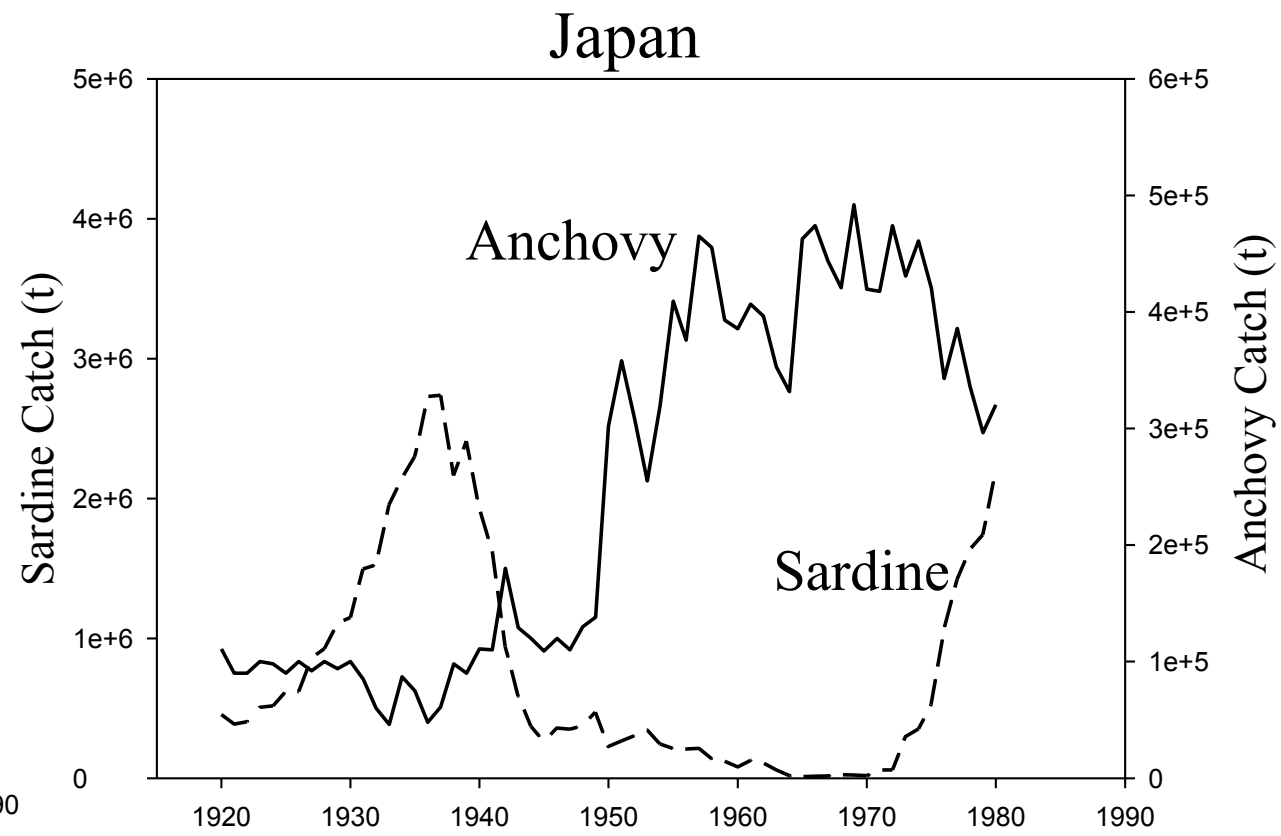
# "The Regime Problem"

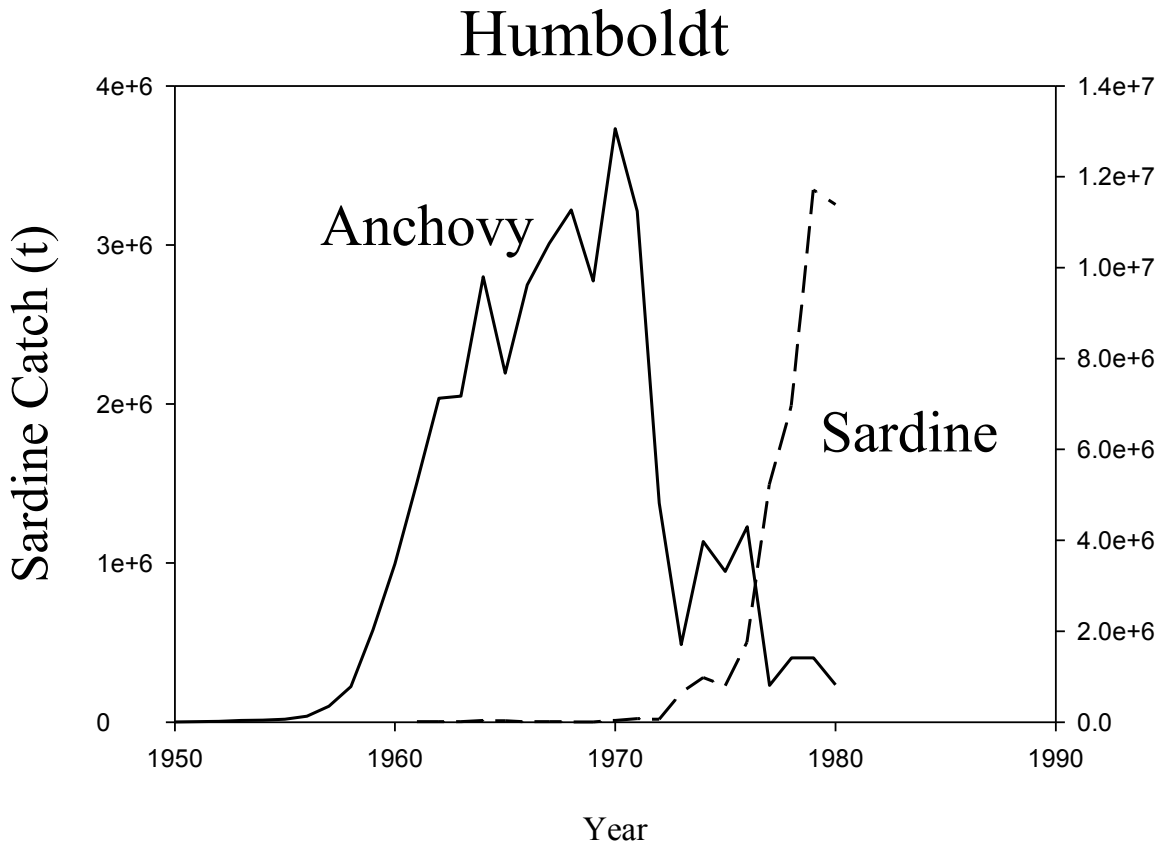
This hypothesis suggests that there is an alternation in the abundance of sardines and anchovies in the major fishing regions of the world, and that periods of high and low abundance are synchronous between different systems (Japan, California, and Humboldt).

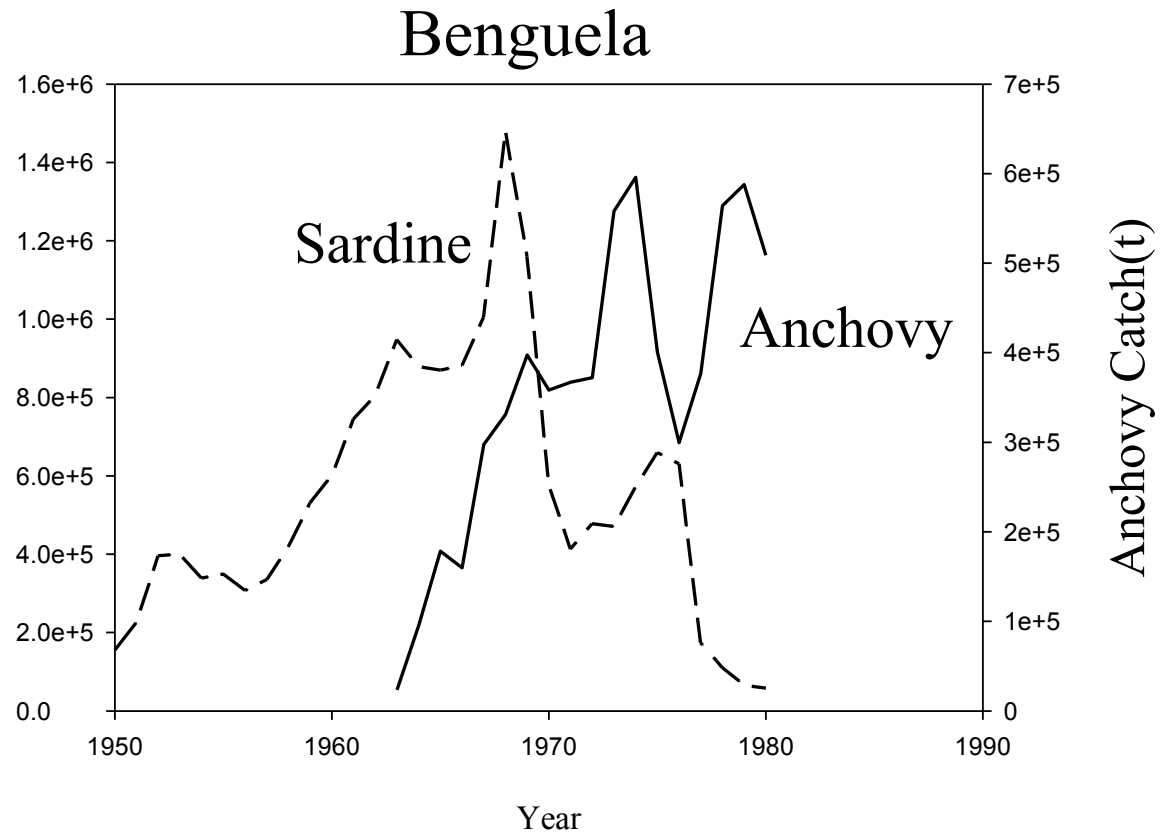



Kawasaki 1983, Lluch-Belda *et al*., 1989, 1992, Schwartzlose *et al*., 1999.

For Sardines in Benguela their cycle is out of phase compared with other sardine populations.
Sardines tend to be abundant during high temperature global regimes, while anchovies are abundant during low temperature global regimes.

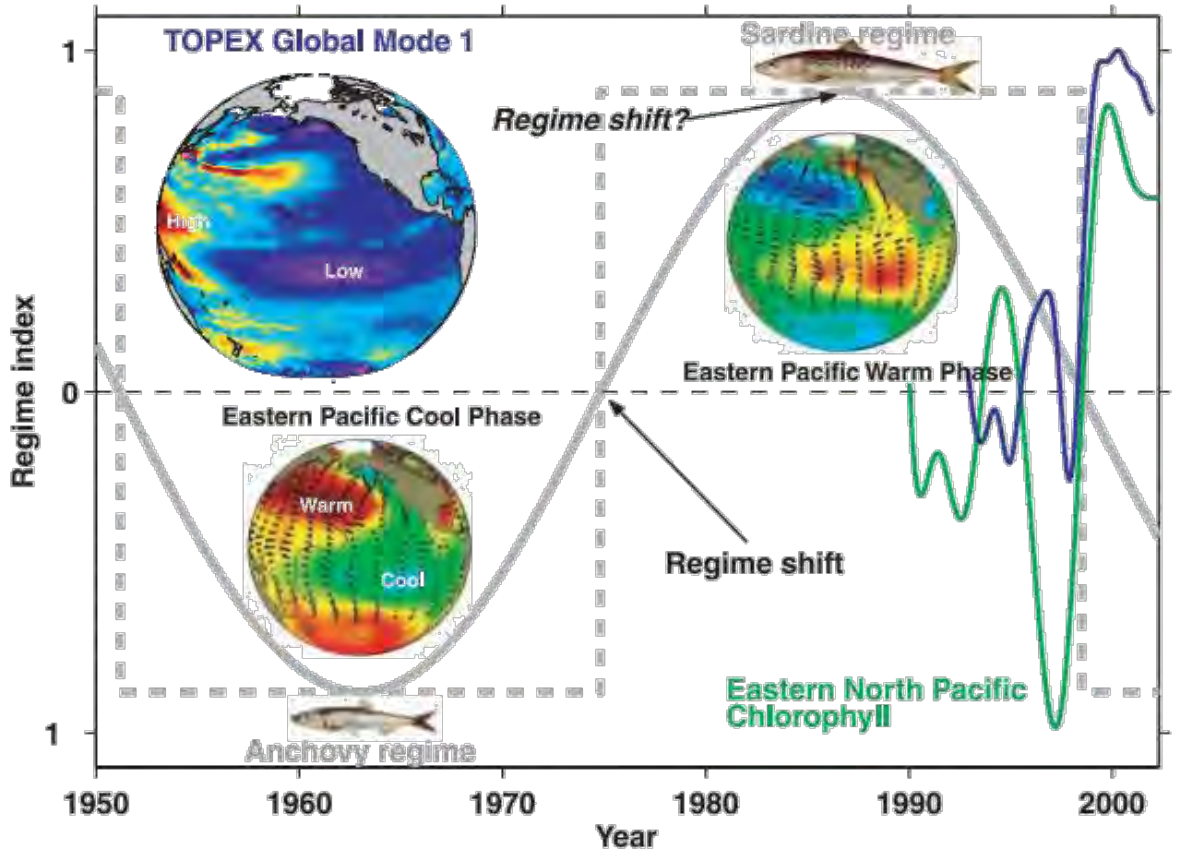



Lluch-Belda *et al*., 1989, 1992

# Anchovy and Sardine Regime

The sardine and anchovy fluctuations are associated with large-scale changes in ocean temperatures for periods of ~25 years, warmer-than average temperatures in the Pacific are associated with sardine abundance (Sardine regime) and cooler periods with increases in anchovies catches (Anchovy regime).




Chavez et al., 2003

# Objectives

- Evaluate if after 25 years since the hypothesis was proposed, the synchrony (periods) and symmetry (between sardine and anchovy) of the four systems (California, Humboldt, Japan and Benguela) is still occurring.

- Explore the occurrence of a multidecadal regime signal using the catch data from different regions to those considered originally in the hypothesis

# Methods

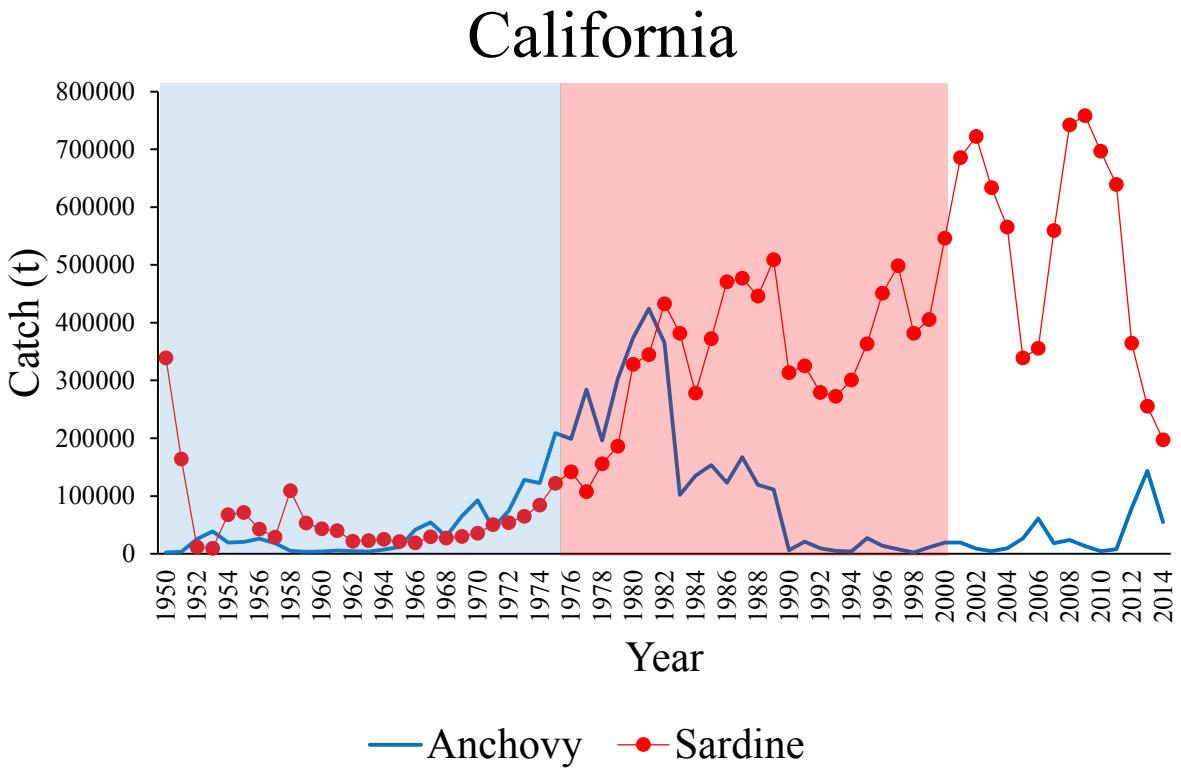
Use of historical time series of sardine and anchovy catches for the 4 systems, analysis of trends to identify synchronies and fluctuations of sardines and anchovies.

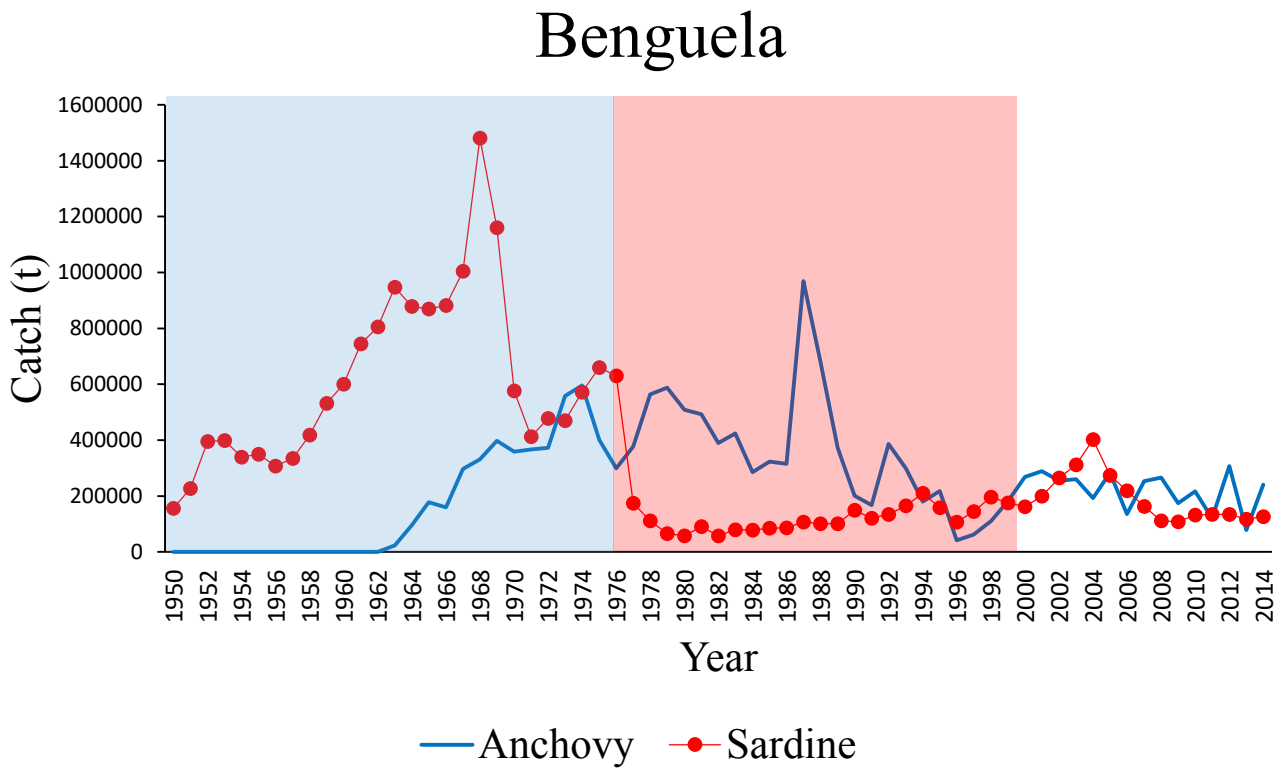
Principal Components Analysis for clupeid (sardine) and engraulid (anchovy) including Black and Mediterranean Sea, Indian Ocean, and South Atlantic, to identify patterns.

Use of Rodionov (2005) method to detect regime changes and search for coincidences among all series during the 1950-2014 period.

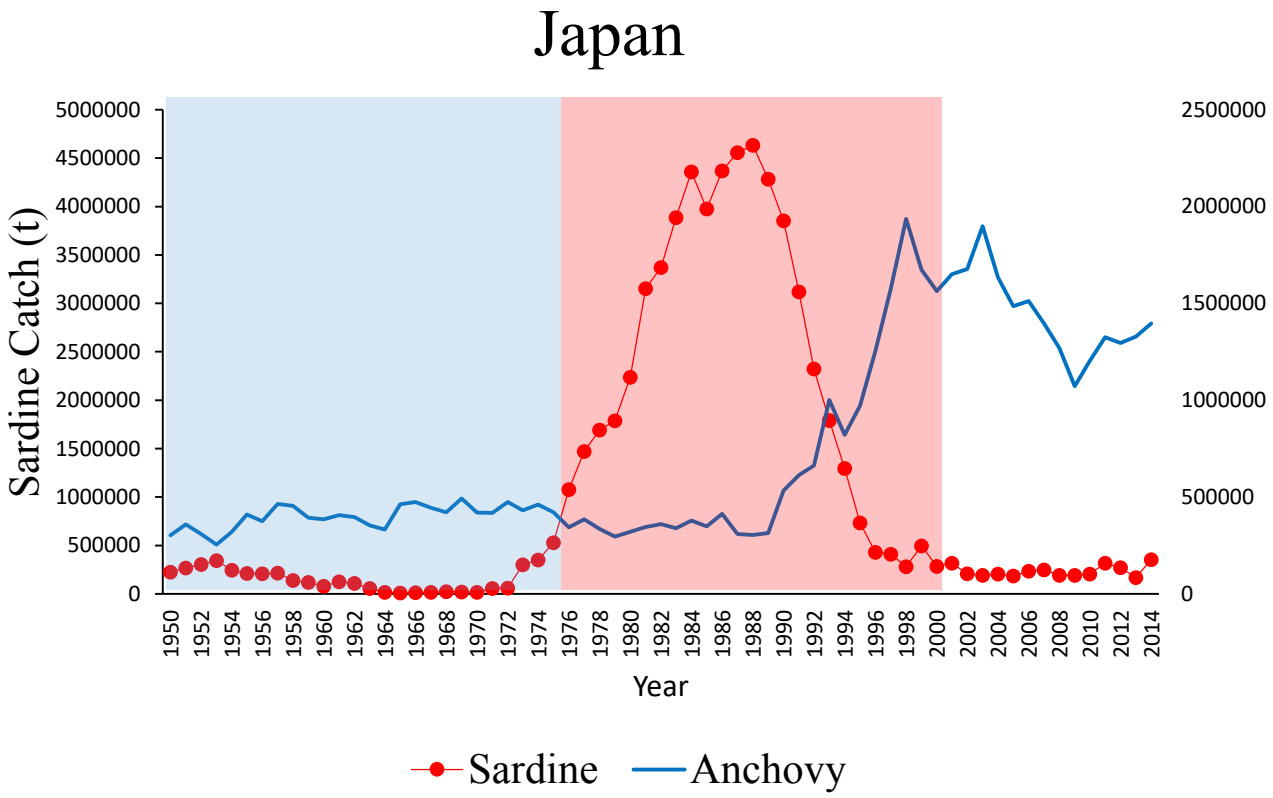
# Updated time series of sardine and anchovy to 2014

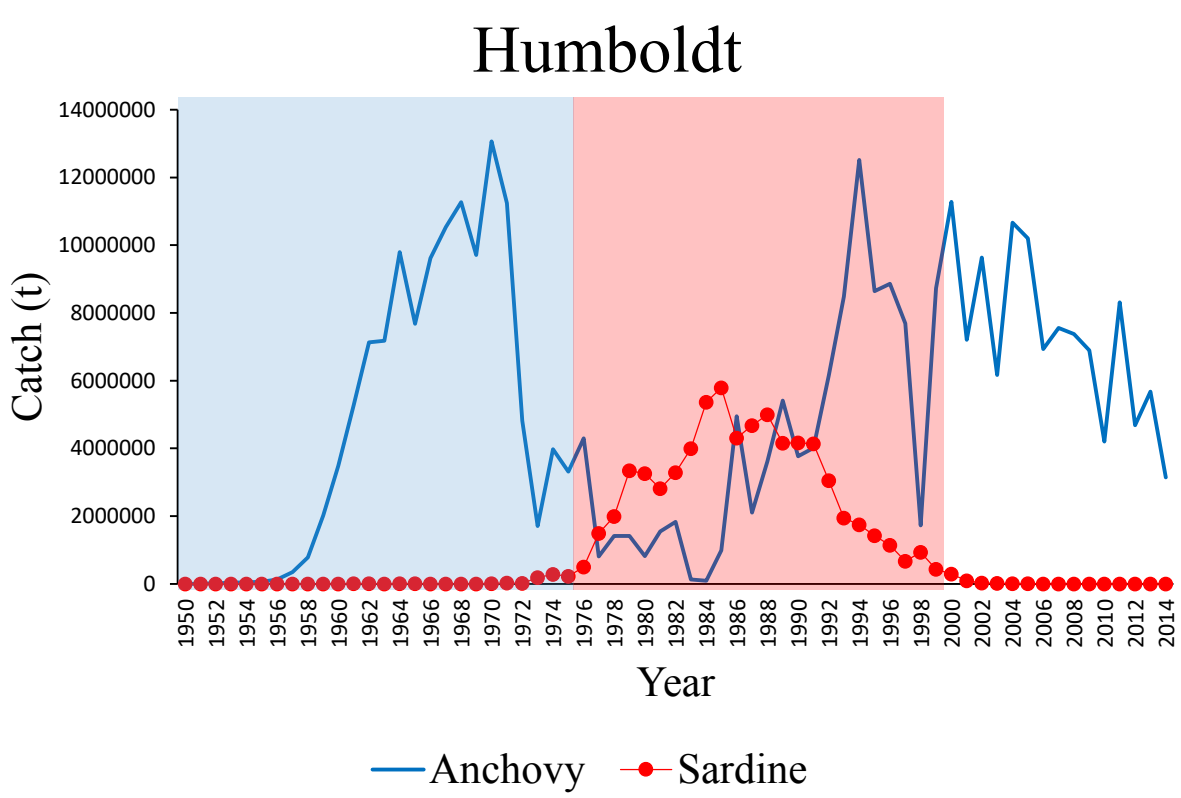
Catches from the four systems reveal that in California the sardine abundance does not fluctuate synchronously, and in Benguela the alternation pattern is no longer evident.



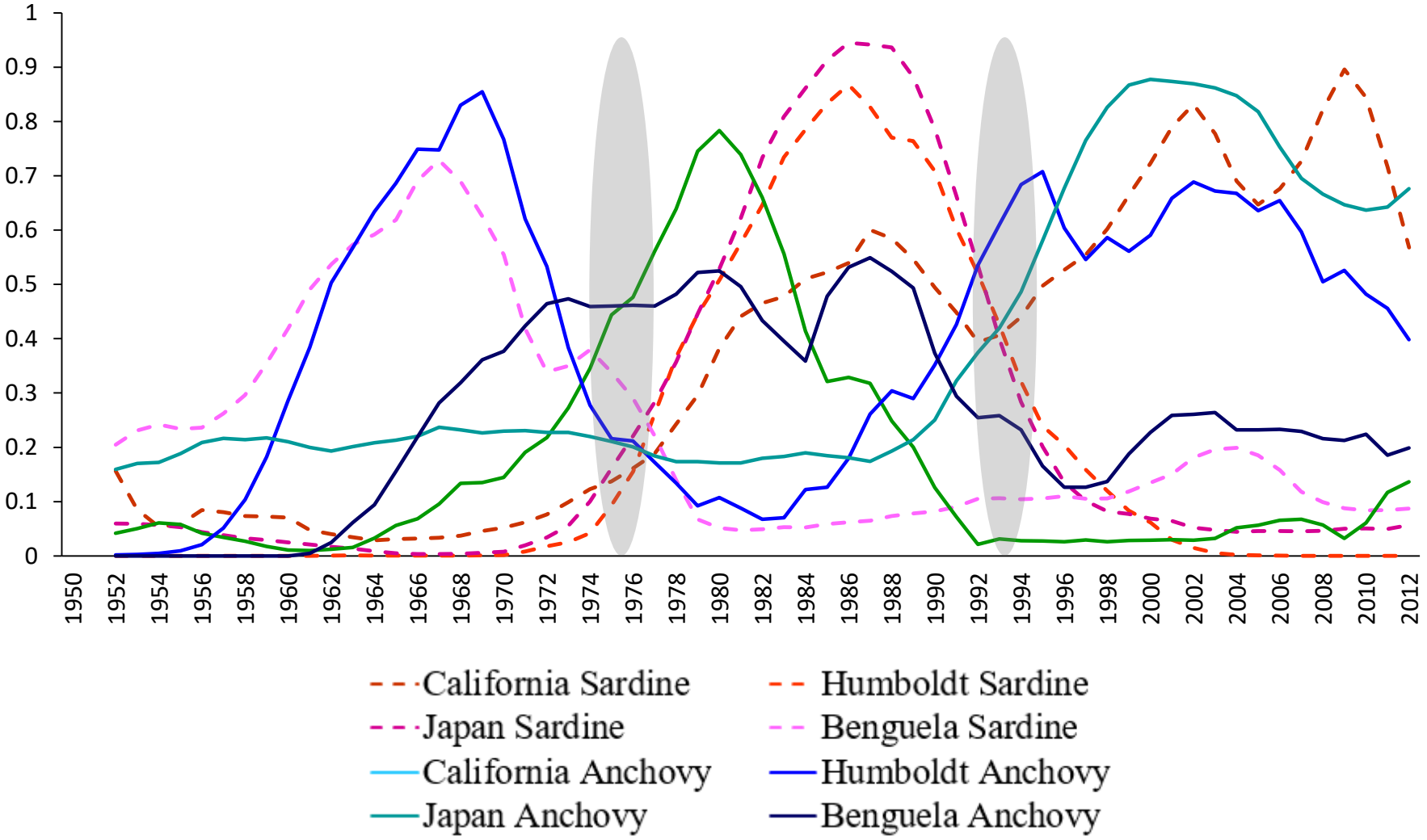



Only the systems of Japan and Humboldt are still responding as predicted by the Regime hypothesis.

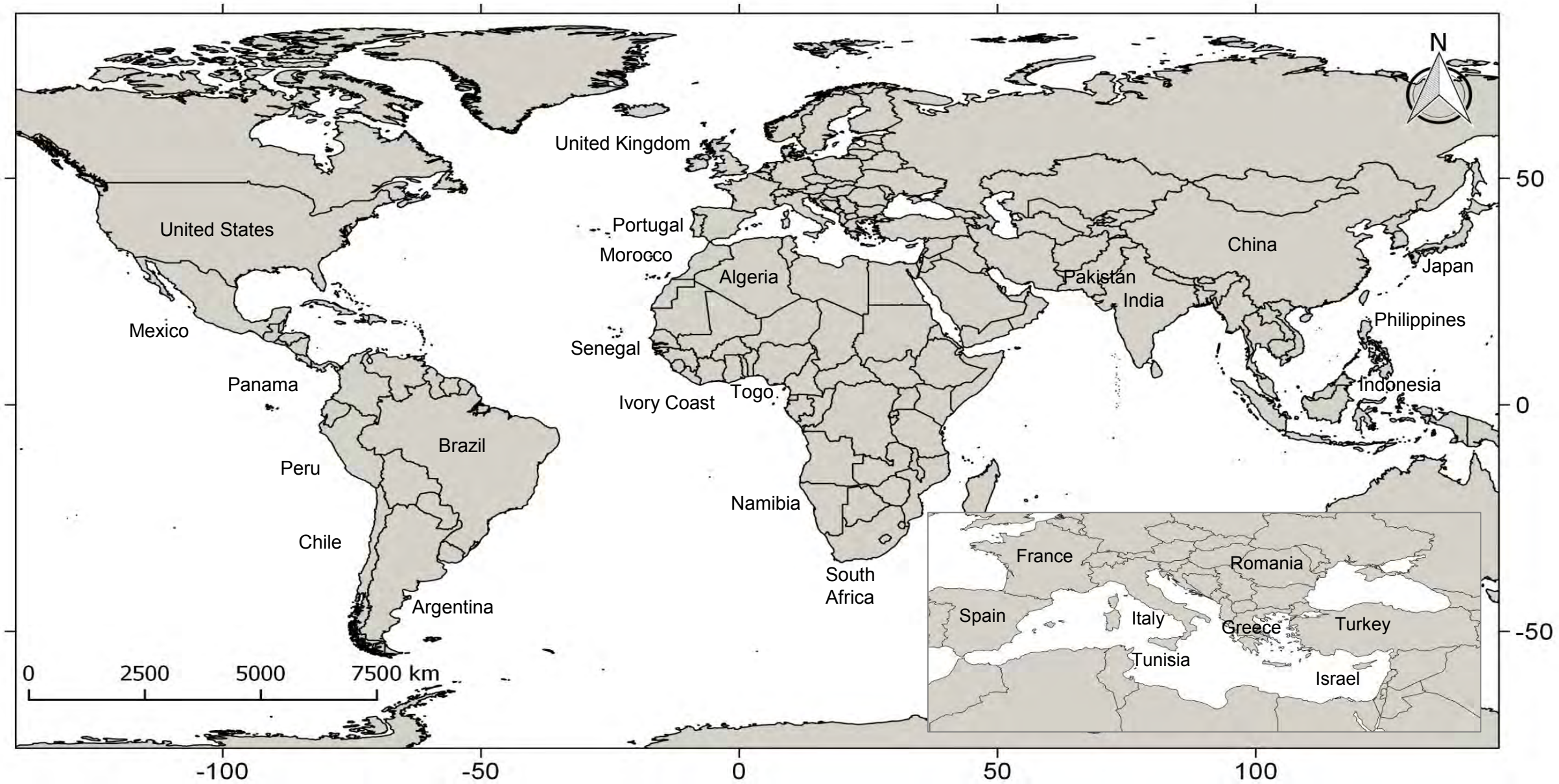


When considering all series (California, Humboldt, Japan and Benguela), three periods are evident, before the mid 1970s, from there to the early 1990s and onwards. There are important differences between the three periods (not cyclical).

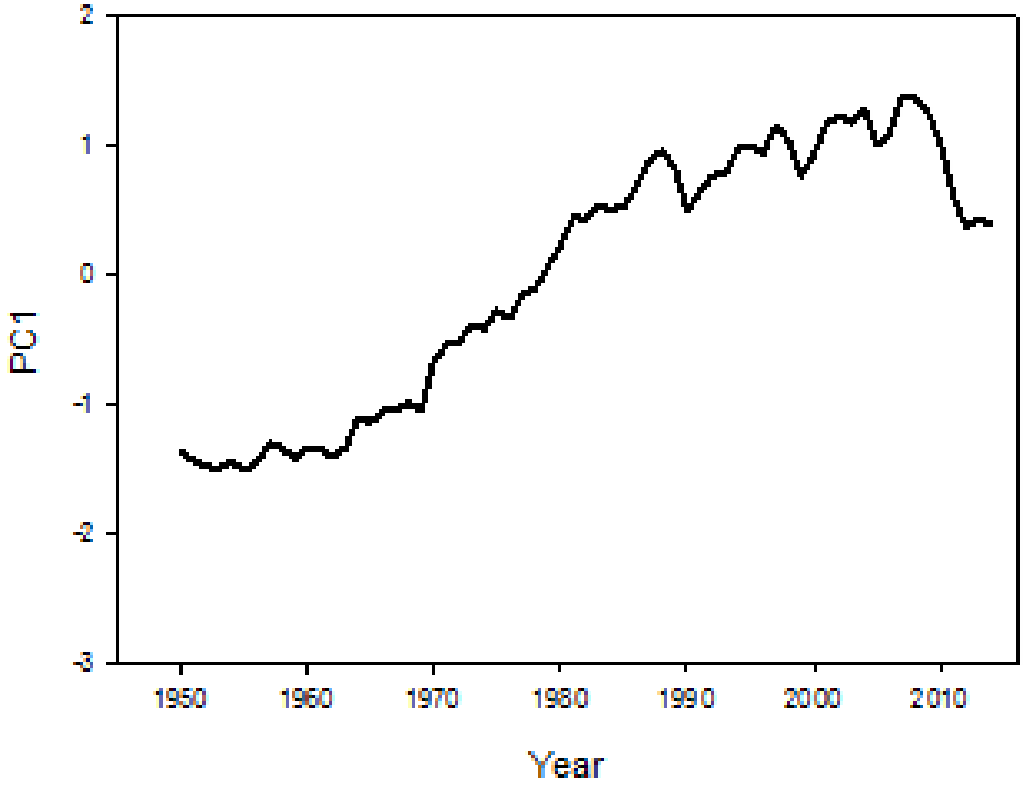


Countries included in the analysis considering the catches of small pelagics using the statistical database for fisheries by FAO (Time period 1950 - 2014).



# Principal component analysis (PCA) for all clupeid and engraulid species

Time series (1950-2014) of the principal components analysis. The PC1 shows an increasing trend while the PC2 is characterized by a marked multidecadal signal. These two main components accounted for 45% and 20% of the total variance.



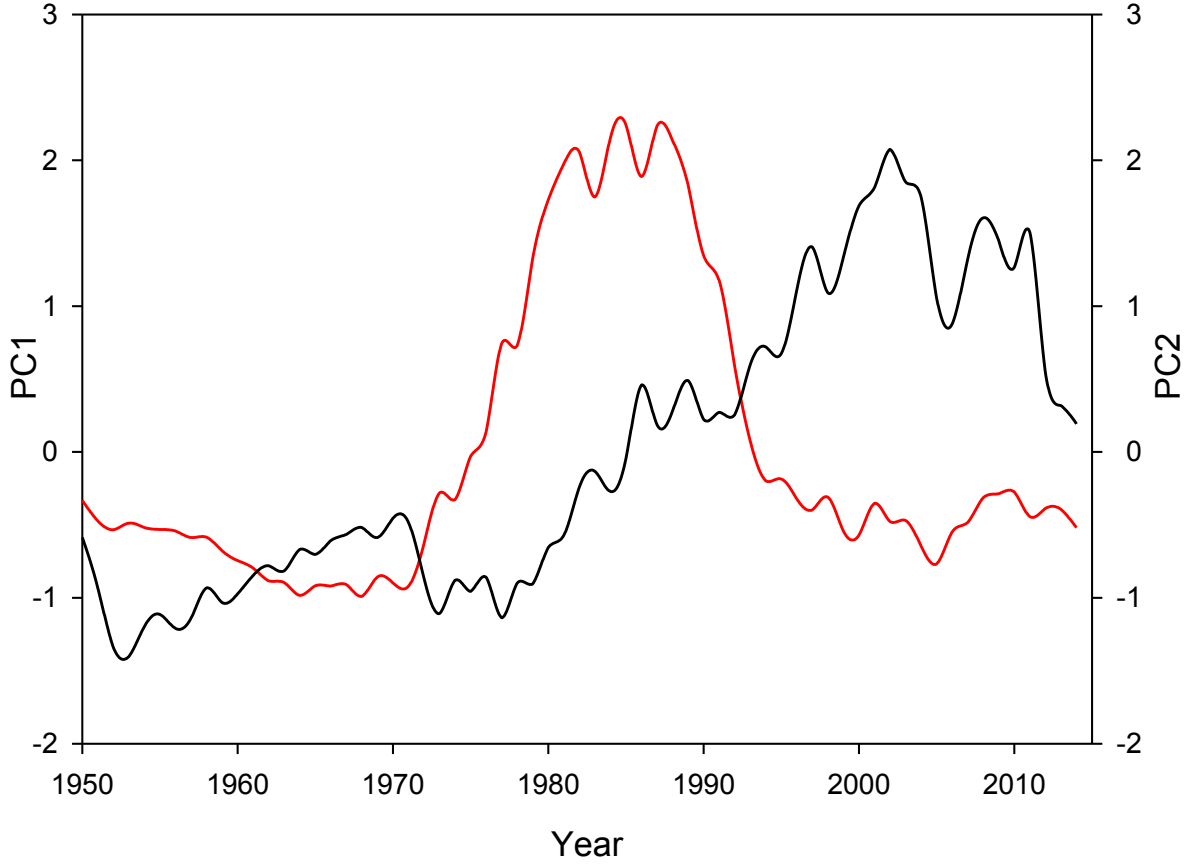

*Sardinella aurita, Sardina pilchardus, Engraulis encrasicolus, Sardinella aurita, Sardinella gibbossa, Sardinella lemuru and Sardinops caeruleus.*

*Sardinops melanostictus*, *Sardinops sagax* and *Engraulis mordax*

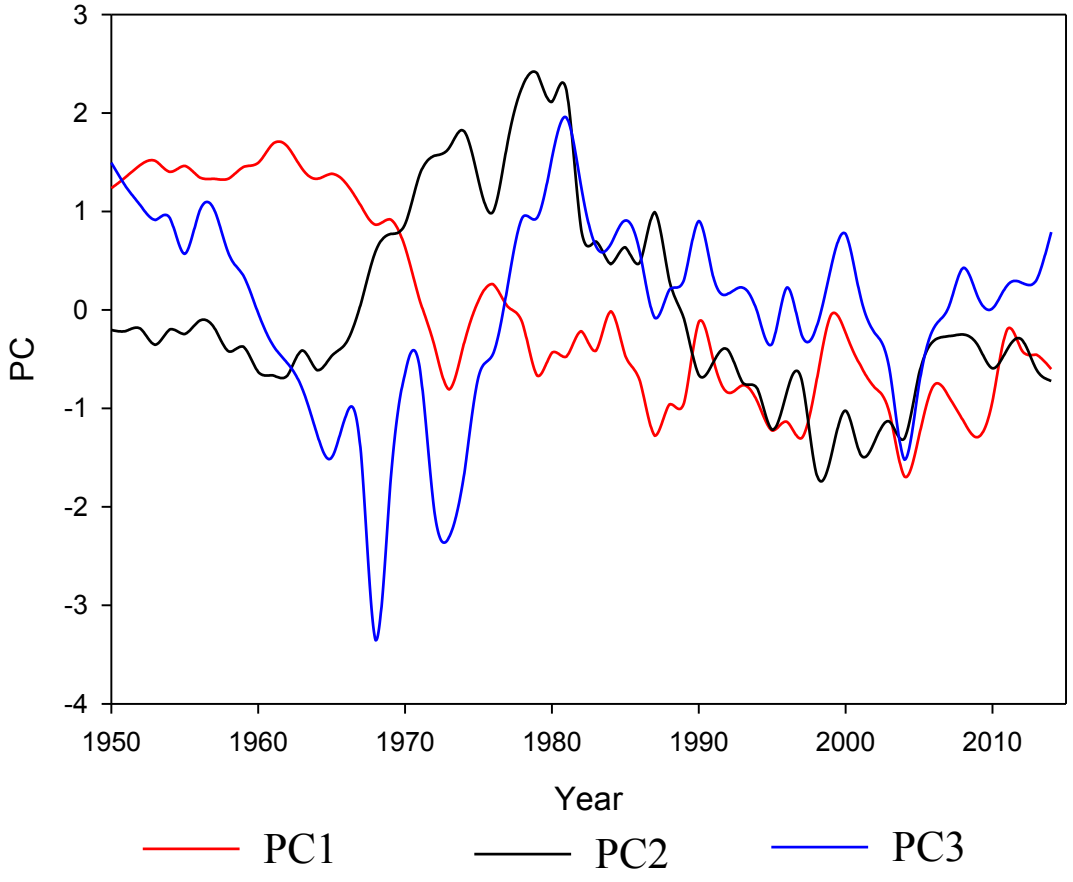
# Principal component analysis (PCA) by fishing areas

For the Pacific the PC1 is represented by the sardine (Japan, Humboldt) and the California anchovy, PC2 is represented only by sardine (California). These two main components account for 47% and 29% of the observed variance.

## Pacific Ocean

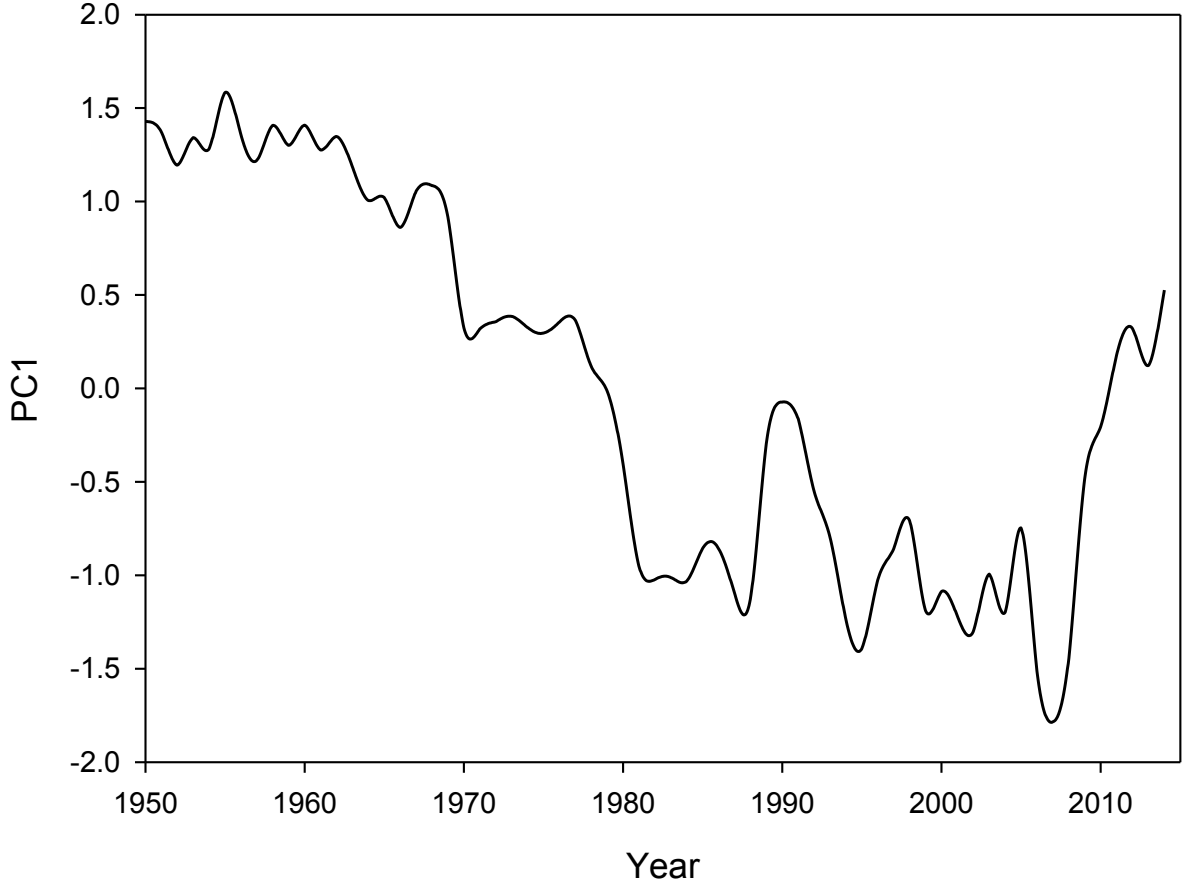



## Atlantic Ocean

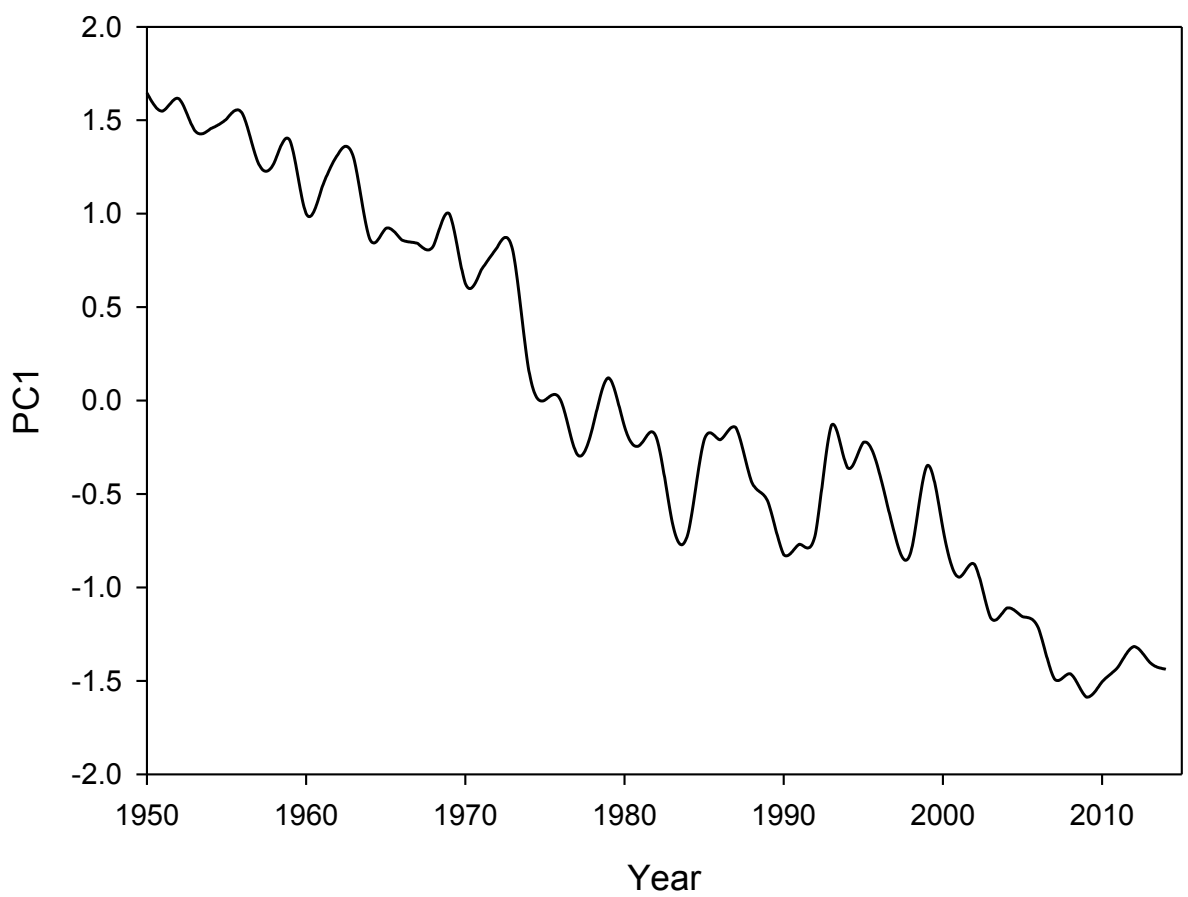


PC1 for the Black and Mediterranean Seas accounted for 76% of the variance, showing that both sardines and anchovies are showing interdecadal variations in the analyzed period, whereas the analysis for the Indian Ocean pelagics shows a decreasing trend.

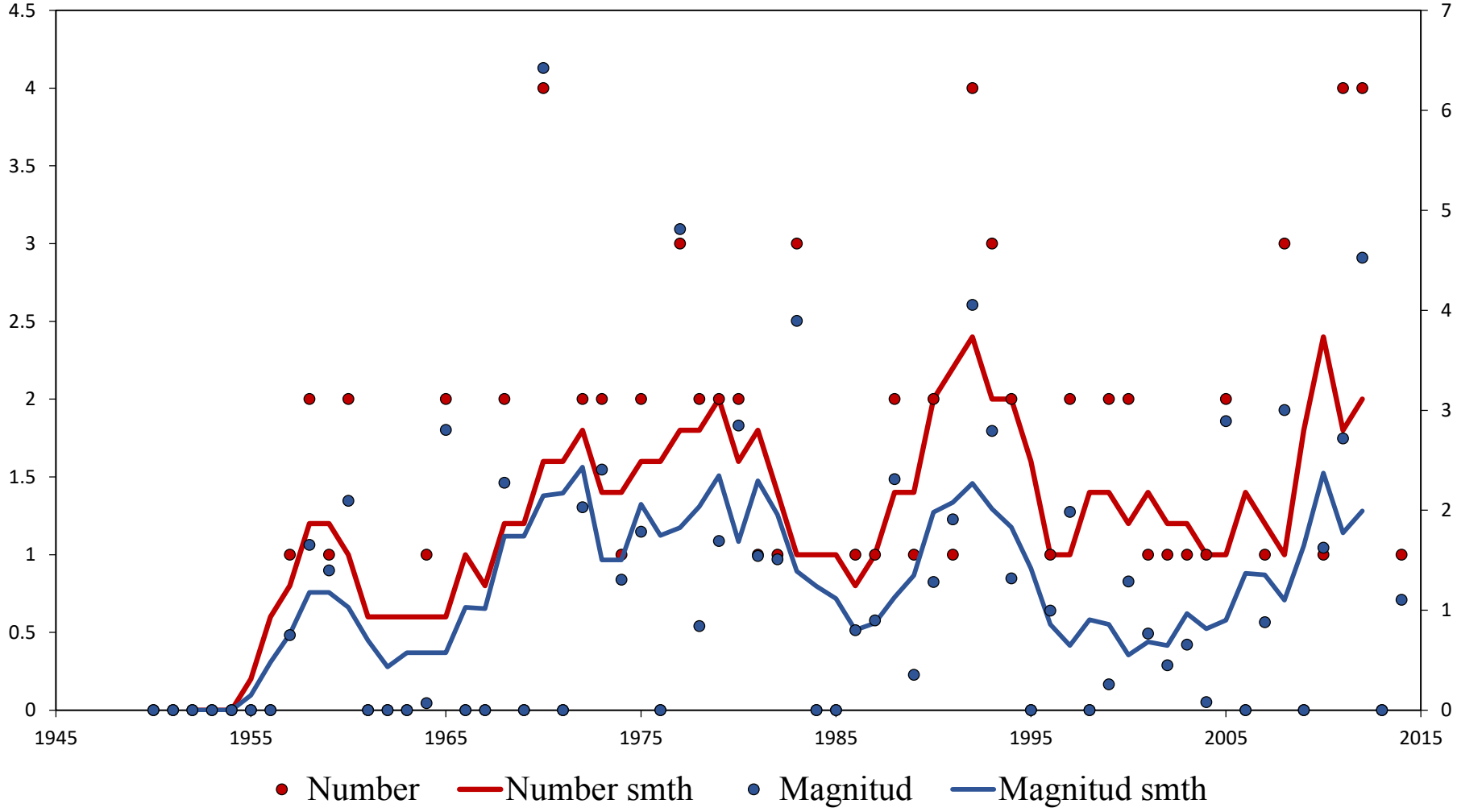
## Black Sea and Mediterranean Sea




## Indian Ocean



Regime shift detection integrated by number of fisheries changes the same year (number) and the summed shift intensity (magnitude) suggest roughly two periods (1970s and early 1990s) of major change, although the number of years with at least one changing is larger than the number of years without any change.



# Conclusions

- The revision of “The Regime Problem” hypothesis with data for the last 6 decades showed that it is only occurring in the Humboldt and Japan systems.

- The California system does not have synchronously fluctuations and in Benguela system the alternation between species is not evident.

- The inclusion of time series from other systems showed that most pelagics exhibit fluctuations, however there was not synchrony between systems nor alternation between species of clupeids and engraulids for the analyzed 1950-2014 period.

- Small pelagics time series have changed in time, apparently at the interdecadal scale, but dates of change can not be generalized for all the systems.

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