Identifying ecosystem patterns from time series of anchovy (Engraulis ringens) and sardine (Sardinops Sagax) landings in northern Chile

1st Francisco Plaza
Unidad de Auditoría y Control
Instituto de Fomento Pesquero
Valparaiso, Chile
francisco.plaza.vega@ifop.cl

2nd Rodrigo Salas
Escuela de Ingeniería Biomédica
Universidad de Valparaíso
Valparaiso, Chile
rodrigo.salas@uv.cl

3rd Eleuterio Yáñez
Escuela de Ciencias del Mar
Pontificia Universidad Católica de Valparaíso
Valparaíso, Chile
eleuterio.yanez@pucv.cl

***Abstract*—This work presents a Knowledge Discovery from Data (KDD) approach in time series pattern identification for anchovy and sardine monthly fishery-biological data in northern Chile. Time series, multivariate analysis and data mining techniques, along with technical literature review for results validation are implemented. This approach, achieved an integration between variables, identifying relevant patterns, associated with fisheries abundance fluctuations and strong association with environmental changes such as El Niño and long-term cold-warm regimes between them, establishing predominant time-periods. The latter, establishes groundwork for studying underlying functional relationships that could reduce gaps in the national fisheries research and management policies.**

***Index Terms*—Anchovy, Sardine, Ecosystem, Patterns, Data Mining, Time Series, Knowledge Discovery from Data**

I. Introduction

The Chile-Peru Current System (CHPCS) is a very productive marine system due to nutrient transport by large-scale horizontal advection and persistent coastal upwelling. In Chile the average annual landing in the last 30 years is 4.8 million tons and the pelagic resources of the northern zone (18°21'S-24°S) represent 40% ([2]). In this area the fishery is successively based on anchovy (*Engraulis ringens*) and sardine (*Sardinops sagax*), with notable changes associated with fishing effort and fluctuations in the environment ([3]).

Ocean-climate changes alter marine ecosystems at various scales, in fact, [3] propose an integrative conceptual model of the main local to large-scale phenomena involved in northern Chile. On the intra-seasonal scale, coastal trapped waves are mainly responsible for most of the variability of sea surface temperature and currents on the continental shelf and slope of the CHPCS. On the interannual scale, changes in atmospheric and oceanographic conditions are mainly associated with the El Niño Southern Oscillation (ENSO) phenomenon. Interdecadal long-term regime shifts (warm or cold), would influence the reorganization of marine communities and trophodynamic relationships, inducing changes in dominant species. Thus, the link between the variation of anchovy abundance and environmental changes at different spatio-temporal scales opens the possibility for predicting fluctuations in landings in the short, medium, and long term, one of the main objectives of fisheries management ([4]; [5]). Therefore, the main objective for this work is to identify patterns of interaction between those variables in northern Chile.

II. Materials and methods

A. Data

The study analyzes monthly data considering local and global environmental variables and fishing variables from 1963-2011 in northern Chile (18°21'S-24°S and from the coast until 73°O). This area is where industrial purse seine fleet operates in northern Chile. Table I summarize all considered variables.

TABLE I
Summary of analyzed variables

Type	*Variable*	*Desctiption*
Local	SST	Sea Surface Temperature from Antofagasta coastal oceanographic station
	TI	Turbulence Index from Antofagasta coastal oceanographic station
	MSL	Mean Sea Level from Antofagasta coastal oceanographic station
Global	MEI	Multivariate ENSO Index
	PDO	Pacific Decadal Oscillation index
	N12	Climatic Index in the Niño12 area
	N34	Climatic Index in the Niño34 area
	SOI	Southern Oscillation Index
	CTI	Cold Tongue Index
Fisheries	VANC	% days per month of anchovy fishing prohibition (fisheries ban)
	VSAR	% days per month of sardine fishing prohibition (fisheries ban)
	LANC	Anchovy landings in northern Chile
	LSAR	Sardine landings in northern Chile

B. General procedure

For this study, a similar approach to [6] is considered, involving as a first step an inspection of the multivariate time series, using signal decomposition (trend, seasonality and noise), then Principal Components Analysis is performed to reduce dimensionality and to discover preliminary patterns (which are contrasted with field literature). Finally, as a third step these patterns are grouped, using k-means clustering, in order to obtain different ecosystem periods, which allows to identify changing trends (increases or decreases) of anchovy and sardine landings, associated to environmental conditions. Integrated graphical representations are then implemented to show discovered patterns.

III. Results and discussion

Figure 1 shows the additive decomposition performed on the 4 PCs, showing the trend, seasonality and irregular component.

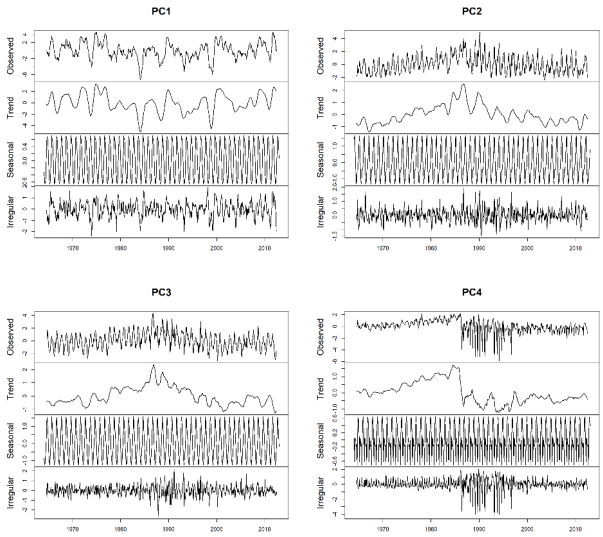

Fig. 1. Decomposition of the selected PCA components.

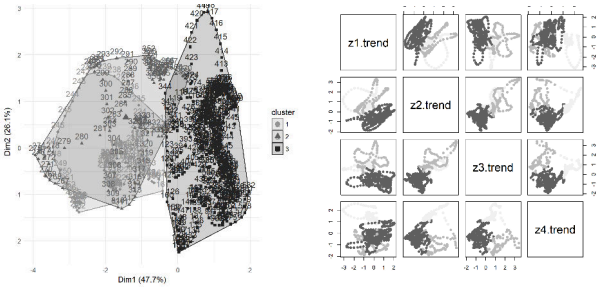

Fig. 2. Clustering performance and results. Representation of clusters centroids (left), classification of the principal components (right).

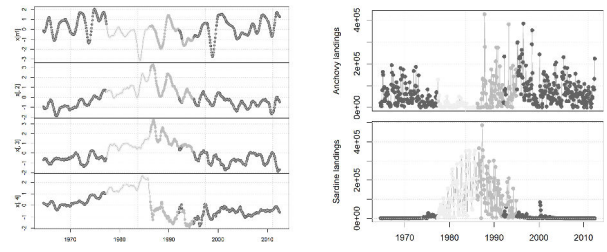

Fig. 3. Cluster classification applied to data. Cluster classification of PCA selected components (left), Cluster classification of anchovy and sardine landings time series (LANC and LSAR)(right).

In order to address the problem, a series of research questions were established to guide the analysis. To summarize the results obtained in this study, the answer for each research question is presented as follows:

1) *what is the relationship between the time series between sardine and anchovy?*. Results show an alternance between anchovy and sardine time series. The latter can be observed in both the time series of each fishery and in the results obtained from the clustering process (Fig. 3, having an anchovy period, then a transition period, followed by a sardine period, and finally an anchovy period, respectively.
2) *what is the relationship between environmental variables and the anchovy-sardine?*. As discussed before, the first 4 components from the PCA have higher correlation with environmental variables. Also, the clustering process identified 3 clusters which can be related to environmental long-term cold-warm-cold periods(Fig. 2). Furthermore, those long-term periods are related with anchovy and sardine landings presence or absence. The underlying processes that describe functional relationships between particular environmental variables and anchovy and sardine behavior are still being discussed among the scientific community. However, this study proposes a more integrated scope, considering the ecosystem as a whole.
3) *Are there any procedures that allow to identify patterns?*. A process of mixing three well-known techniques (time series decomposition, principal components analysis and clustering) was successfully implemented in order to identify ecosystemic patterns.
4) *Are there identifiable patterns in the time series of anchovy, sardine, and environmental variables?*. Four clear periods could be identified, from 1963-1977, 1977-1986, 1986-1995 and 1995-2011, having an anchovy period, then a transition period, followed by a sardine period, and finally an anchovy period, respectively (Fig. 3).

Acknowledgment

This paper is presented as an overview of the work done by [1].

References

References

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