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Analysis of sardine *(Sardina pilchardus)* and anchovy *(Engraulis encrasicholus)* catches in the Spanish Mediterranean

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SUMMARY - The analysis of landings of two fishing categories, sardine and anchovy, is presented. Within each category there is a target species (*Sardina pilchardus* and *Engraulis encrasicholus,* respectively) providing the category name. Monthly landing data (in kg) corresponding to 54 years (1940-1993) have been used from 4 Spanish Mediterranean fishing areas (South Mediterranean, Levant, Tramuntana and Balear), whose geographical distributions are presented in Fig. 1. The contribution (%) of each area to the total Spanish Mediterranean landings, and the landing behaviour has been analysed in those areas by using the Spearman correlation by ranges coefficient. In the 4 Mediterranean regions, 62.4% of the total Spanish sardine landings, and 37.7% of the anchovy ones were achieved. The total average for the 4 areas was 2,987 kg/month for sardine and 1,271 kg/month for anchovy. The areas with a higher contribution on the total landings were the South Mediterranean and the Tramuntana for both species. In these regions, significant correlation coefficients with opposite sign were found. Finally, data were treated as time series by estimating the trend with the linear regression model and with the Box and Jenkins methodology, which presents the ARIMA models (Autorregresive Integrate Moving Average) to formulate the series evolution over time. A multiplicative seasonal-non seasonal model is proposed coherent for the evolution of the whole series in the considered period.

Key words: Anchovy, sardine, landings, time series, modelling.

RESUME - *"Analyse des débarquements de Sardine* (Sardina pilchardus) *et d'anchois* (Engraulis encrasicholus) *en Méditerranée espagnole". On présente l'analyse des débarquements de deux catégories halieutiques, sardine et anchois, où se trouvent les espèces plus nombreuses auxquelles elles doivent leur nom (*Sardina pilchardus *et* Engraulis encrasicholus, *respectivement). On a utilisé les données des débarquements mensuels (en kg) de 54 années (1940-1993) dans 4 régions halieutiques de la Méditerranée espagnole (Sudméditerranée, Levante, Tramuntana et Balear). La distribution géographique de ces régions est montrée à la Fig. 1. On a analysé la participation en pourcentage de chaque zone dans la totalité des débarquements de l'étendue totale, et le comportement des débarquements entre régions avec le coefficient de corrélation par rangs de Spearman. Les débarquements totaux des 4 régions considérées représentent 62,4% des débarquements totaux espagnols pour la sardine et 37,7% pour l'anchois. Les moyennes générales de ces régions furent de 2 987 kg/mois pour la sardine et 1 271 kg/mois pour l'anchois. Les régions avec la plus haute participation furent, pour la sardine comme pour l'anchois, Tramuntana et Sudméditerranée. Dans ces deux zones on a observé des coefficients de corrélation significatifs et de signe contraire. Finalement, les données ont été traitées comme des séries temporelles. La tendance a été calculée avec le modèle de régression linéaire et les séries avec la méthodologie de Box et Jenkins qui implante les modèles ARIMA (Autoregressive Integrate Moving Average) pour établir leur évolution dans le temps. On propose un modèle multiplicatif saisonnier-non-saisonnier cohérent pour l'évolution de l'ensemble des séries dans la période considérée.*

Mots-clés : *Anchois, sardine, débarquements, séries temporelles, modélisation.*

Introduction

Small pelagic species are qualitatively important for Spanish fisheries, even though they are not very relevant quantitatively, since they have high demand for human consumption and, furthermore, their fishery employs a considerable number of people. Within small pelagic fisheries, there are two predominant categories, *sardine* and *anchovy,* each of them with a target species which provides the category name (*Sardina pilchardus* and *Engraulis encrasicholus,* respectively).

As it is usual in this subject, their common name, sardine and anchovy, will be used despite each category includes other similar species. Both of them are distributed within the coast and the 200 m isobatha as maximum depth, and always away from the bottom. For these fisheries purse seine gears are mainly used and, also, pelagic trawl gears in very few cases (Oliver, 1983).

The study of pelagic fishes is so complex that only recording long data series is possible to confront it with some perspective (Larrañeta, 1966). One of the adopted methods for this aim is that of the time series. In this work these series are analysed with the objectives of determining catches behaviour and carrying out short-term predictions.

Modeling available historic series, as well as adoption of analytical (VPA) and stochastic models for time predictions, in conjunction with spatial modeling of resources distribution, obtained by means of geostatistical techniques, could make possible a spatio-temporal modeling and simulation for pelagic fishery resources.

Materials and methods

Data based in monthly landings (in kg) of the 4 fishing areas selected in the Spanish Mediterranean (South Mediterranean, Levante, Tramuntana and Balear) since 1940 to 1993, were used. These data were supplied by the *Anuarios de Pesca Marítima* published by *Secretaría General de Pesca Marítima de España* (published as *Estadísticos de Pesca* when it first appeared). Percentage of contribution to the whole Mediterranean landings was calculated for each one of the 4 areas. The relationship between the 4 areas was analysed with Spearman correlation by ranges coefficient and calculating the respective matrix (Fig. 1).

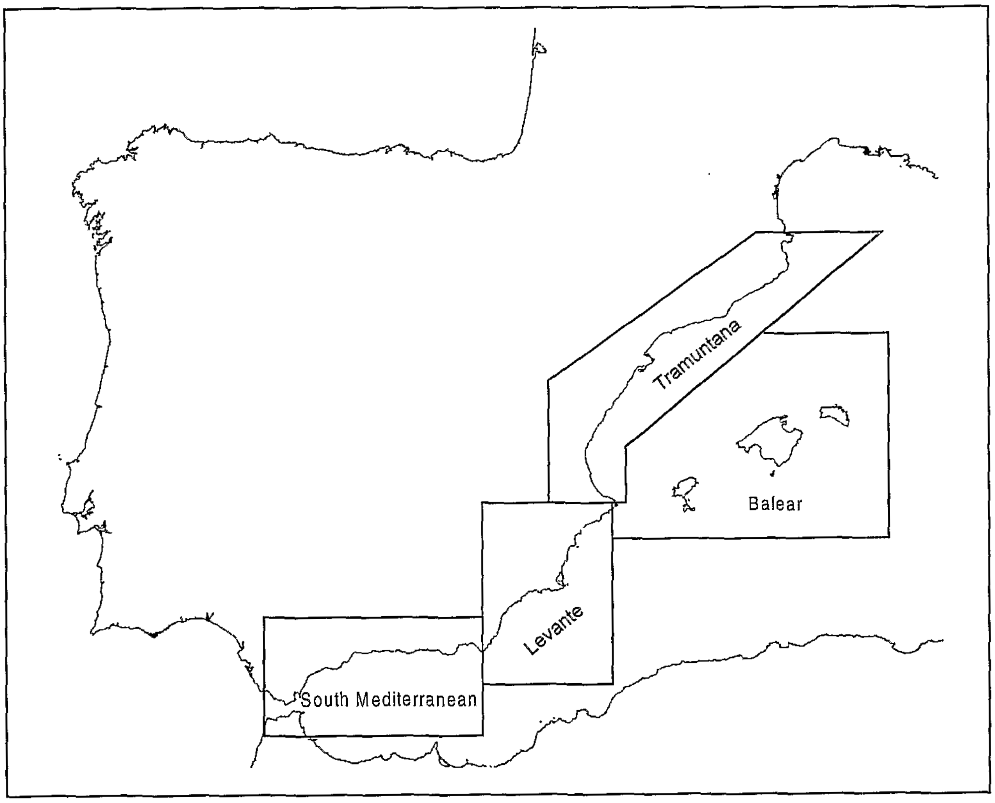

Fig. 1. Considered regions in the study area.

Time series analysis was carried out for each area. First, a global view of the trend was achieved by means of the linear regression model. Next, a deeper analysis applying Box and Jenkins methodology on ARIMA (Autorregresive Integrate Moving Average) models, which is exposed in the usual treatises on time series analysis (Kendall, 1984; Diggle, 1995). This methodology has already been used successfully for pelagic fisheries in Greek waters (Stergiou, 1988, 1989, 1991 and 1993) and more recently in the Canary Islands for demersal fisheries (González-Pajuelo and Lorenzo, 1994).

The Box and Jenkins modeling procedure requires the series to observe conditions of stationarity and inevitability and it consists in 4 steps: identification, estimation, verification and prediction. The identification is achieved through the use of two autocorrelation functions, simple and partial, comparing them with the theoretical autocorrelations of the ARIMA processes. For the estimation it is necessary to apply the goodness of fit criteria, mainly the least square and maximum likelihood criteria. Model is validated trough the analysis of the estimated residuals between real values and those simulated by the model.

Results and discussion

The percentage of contribution of the 4 Mediterranean regions to total Spanish landings was 62.4% for sardine and 37.7% for anchovy. The global average for these areas was 2,987 kg/month and 1,271 kg/month for sardine and anchovy respectively. Contribution of each region to total Mediterranean area is shown in Table 1. It can be seen that the areas with higher contribution for both species were South Mediterranean and Tramuntana, while the less relatively important was Balear.

Table 1. Percentage of contribution of each region to total Spanish Mediterranean landing, for anchovy and sardine

Region	Anchovy (%)	Sardine (%)
South Mediterranean	44.7	35.2
Levante	10.1	14.9
Tramuntana	44.9	49.3
Balear	0.3	0.6

Relationships within regions are presented in Table 2. Both species show significant relationships ($P<0.01$); although coefficient values are not high. Calculated values within Tramuntana and Balear areas for sardine are higher, presumably due to their proximity and their ecological features. This relationship is not observed for anchovy in the same areas, probably because there are practically no catches in Balear region. Generally, catches behaviour relationships through the years show weak covariation.

Linear series trend along time (Table 3), were largely significant ($P<0.001$) in the 4 areas for sardine and in Levante and Tramuntana for anchovy. Except in South Mediterranean region, this relationships present parallel and increasing trends. Correlation coefficients (r), did not reach higher values than 0.60, thus the model is not satisfactory to explain these relationships, although it establishes a first index for the analysis.

All the catch series have strong seasonal behaviour. Monthly catches evolution for anchovy and sardine in the Spanish Mediterranean are represented in Figs 2, 3 and 4 resulting that it is very similar to that achieved in Greece, for the same species, with data from 1981 (Stergiou, 1988). In both cases catches increase in march and decrease in the last months of the year, but they differ in spring and summer months. There is a decrease for Spanish sardine catches in June while a stronger reduction has place in July for Greek sardine.

Table 2. Spearman correlation by ranges coefficients within landings in the 4 considered Spanish Mediterranean regions, (A) for anchovy (B) and for sardine

(A) Anchovy

Regions	South Mediterranean	Levante	Tramuntana
Levante	0.10*	-	-
Tramuntana	-0.22***	0.23***	-
Balear	0.23***	0.19***	0.08 NS

(B) Sayrdine

Regions	South Mediterranean	Levante	Tramuntana
Levante	0.02 NS	-	-
Tramuntana	-0.12**	0.46***	-
Balear	-0.24***	0.18***	0.45***

*P<0.05; **P<0.01; ***P<0.001; NS: P>0.05

Table 3. Linear model parameters applied to (A) anchovy and (B) sardine landings trend in the four Spanish Mediterranean considered regions

(A) Anchovy

Region	Origin value	Slope	Correlation coefficient
South Mediterranean	594.9720	-0.1339	-0.0401 NS
Levante	79.2702	0.1622	0.2259***
Tramuntana	0.0	2.2975	0.5598***
Balear	2.4879	0.0012	0.0383***

(B) Sardine

Region	Origin value	Slope	Correlation coefficient
South Mediterranean	1,731.8400	-2.2221	-0.5695***
Levante	227.9580	0.7084	0.3726***
Tramuntana	808.9290	2.1782	0.4501***
Balear	5.5338	0.0374	0.3399***

*P<0.05; **P<0.01; ***P<0.001; NS: P>0.05

Logically sardine catches are affected by their biological annual cycle. Reproduction has place in autumn-winter with a variable duration each year (Abad and Giráldez, 1993). The youngest individuals are recruited to fishery school in spring, migrating from coastal to deeper areas (Bás *et al.,* 1989). During spring-summer, adults become in a sexual resting period in which they need to increase their food supply to get for the next spawning a reserve which depends on the planktonic production intensity. In Western Mediterranean three maximum for planktonic production can be observed (Margalef, 1969; Rodríguez, 1983).

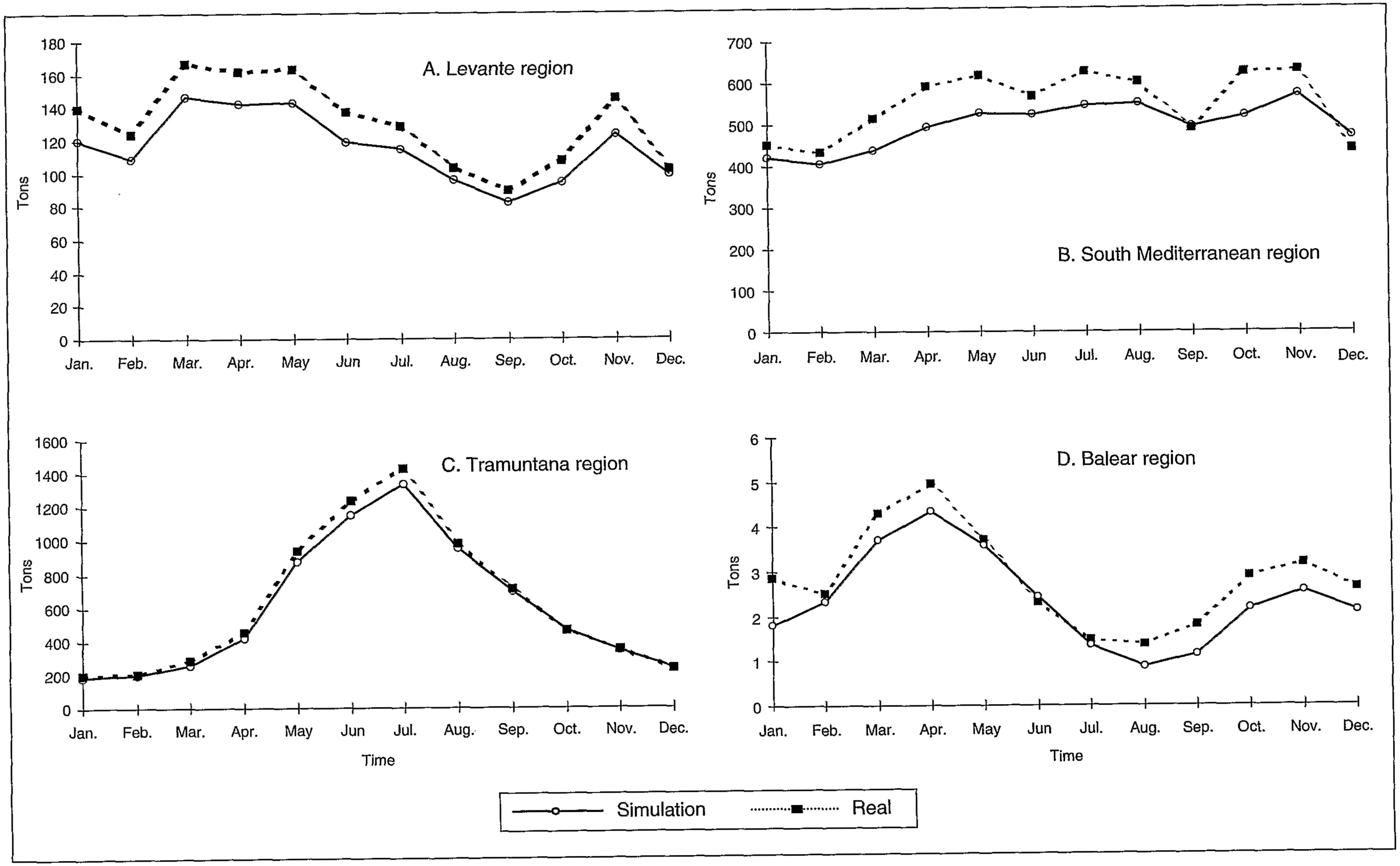

Fig. 2. Monthly averages for anchovy real and simulated catches (1940-1993) in the 4 Spanish Mediterranean considered regions (A, B, C, D).

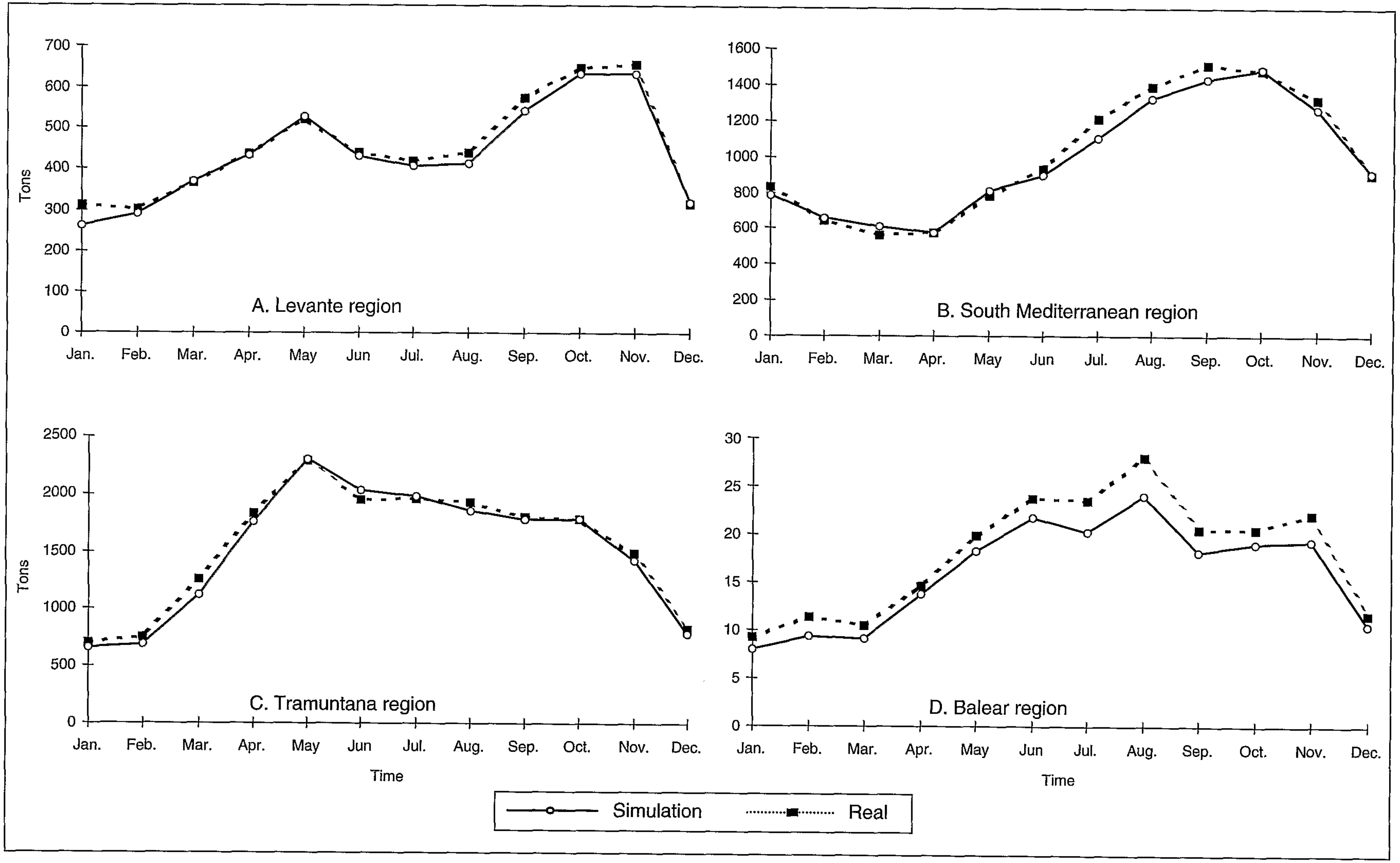

Fig. 3. Monthly averages for sardine real and simulated catches (1940-1993) in the 4 Spanish Mediterranean considered regions (A, B, C, D).

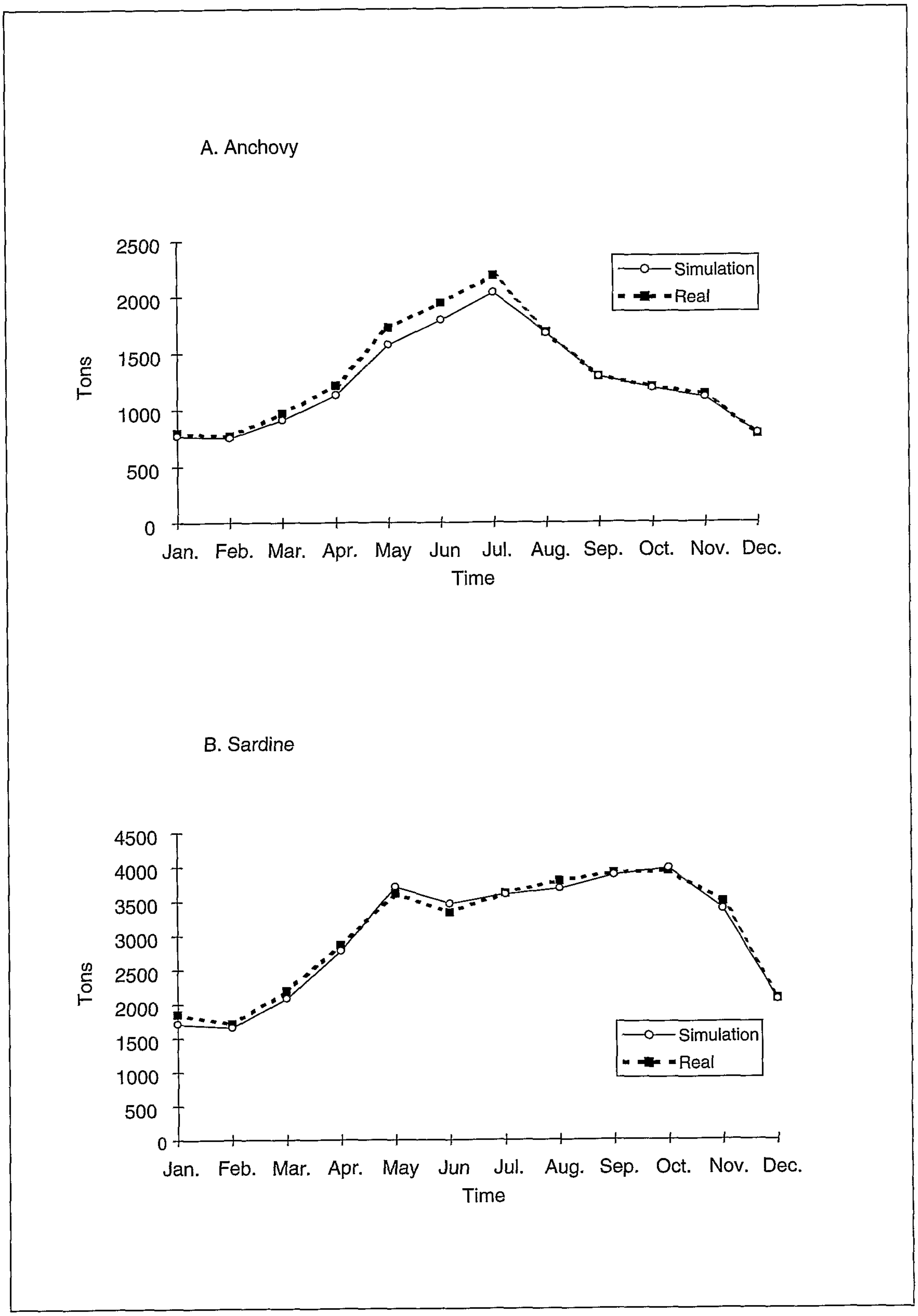

Fig. 4. Monthly averages for anchovy (A) and sardine (B) real and simulated catches (1940-1993) in total Spanish Mediterranean considered area.

Catches decrease in winter months, during spawning time, is common in all areas due to the worst environmental conditions that difficult schools locating. Catch increase during the rest of the year responds to high concentrations of adults, in sexual resting period, and recruits, in food richer areas. The summer stratification process in the water column negatively affect this last situation, since planktonic production is reduced inducing schools dispersion. This migratory behaviour is reflected as capturability fluctuations.

Bellón (1950) reported Sardine catches in the province of Málaga (southern studied area). His data showed a reduction in the period December-April. The maximum was reached in September-October after a strong decrease in July-August. The same trend in seasonality was reported for the Castellón fisheries (central part of the study area) by Rodríguez-Roda and Larrañeta (1954) who highlighted the difficulties of catching sardine in the vernal months, the reproductive period for this species. Greater yields were achieved during the rest of the year, being lower in August-September and with a further increase in October, likely due to environmental conditions affecting the fleet work. In the southern area, the yields in 1985 and 1990 were minimum in the period between April and August, being slightly higher in May (Abad and Giráldez, 1990; Giráldez and Abad, 1991).

The progressive improvements in technology and fleet conditions during the 54 years considered in the study should lead to smaller seasonal variations. Although along the years the monthly catches should be more homogeneous, the vernal reduction, spring increase, smooth inflexion in June and autumn recovery, are still present.

Anchovy fishery exhibits a catch maximum between June and August coincident to their spawning peak (Palomera, 1992; Giráldez and Abad, 1995) the high density of the schools at this moment make them more suitable to be catched. The rest of the year, populations are more disperse making less available the catch of adults during the sexual resting period.

Time series analysis starts with the identification of the most appropriate ARIMA model to explain its evolution.

Autocorrelation and partial autocorrelation as monthly time lag functions show a seasonal strong component, shown in Table 4 and displayed in Fig. 5.

Trying to identify and isolate this seasonal component an autorregresive moving average with a lag of 12, ARIMA component $(1,0,1)^{12}$, has been used. The residuals present autocorrelations and partial autocorrelations typically autorregresive. So a multiplicative seasonal-non seasonal ARIMA $(2,0,0)\ (1,0,1)^{12}$ model has been performed with the aim of modeling catches series Y_t, as a function of their own lag catches and the alterations over them, ε_t.

$$(1-\Phi_1 L-\Phi_2 L^2)\ (1-\Phi_{12} L^{12})\ Y_t = (1-\theta_{12} L^{12})\ \varepsilon_t$$

i.e.,

$$Y_t = \Phi_1\, y_{t-1} + \Phi_2\, y_{t-2} + \Phi_{12}\, y_{t-12} + \Phi_1\, \Phi_{12}\, y_{t-13} + \Phi_2\, \Phi_{12}\, y_{t-4} + \varepsilon_t - \theta_{12}\, \varepsilon_{t-12}$$

Residuals in relation to the model present very low values for the autocorrelations and partial autocorrelations in coherence with its correspondent white noise characterization. It can be observed in Table 5 and Fig. 6.

Once the model has been identified, parameter estimations have been accomplished by means of least square estimation and it is shown in Table 6 for total area and the 4 considered regions.

Durbin-Watson, determination coefficients and U-theil statistics, have been used to verify the model. Results of mentioned statistics together with the parameter estimations are shown in Table 6.

Durbin-Watson statistic is close to its optimal value 2 and over the critical value which allows to accept the independence hypothesis of the residuals (Kendall, 1984).

Table 4. Autocorrelations and partial autocorrelations for total landings in the whole considered area for sardine and anchovy

Lags	Anchovy		Sardine	
	Ac	Pac	Ac	Pac
1	0.807	0.807	0.690	0.690
2	0.610	-0.117	0.417	-0.113
3	0.412	-0.123	0.153	-0.172
4	0.240	-0.065	-0.043	-0.094
5	0.126	0.029	-0.124	0.022
6	0.082	0.092	-0.135	0.006
7	0.113	0.148	-0.122	-0.037
8	0.217	0.213	-0.033	0.102
9	0.373	0.250	0.094	0.136
10	0.553	0.294	0.321	0.325
11	0.694	0.243	0.507	0.225
12	0.753	0.164	0.607	0.191
13	0.655	-0.157	0.493	-0.094
14	0.480	-0.158	0.283	-0.085
15	0.309	-0.027	0.064	-0.048
16	0.170	0.017	-0.098	-0.030
17	0.065	-0.042	-0.162	0.021
18	0.040	0.033	-0.173	-0.038
19	0.058	-0.091	-0.195	-0.143
20	0.159	0.013	-0.114	0.008
21	0.311	0.033	0.043	0.091
22	0.464	0.014	0.252	0.092
23	0.594	0.107	0.472	0.176
24	0.649	0.127	0.583	0.140
25	0.579	0.007	0.490	-0.023
26	0.417	-0.102	0.307	0.009
27	0.239	-0.100	0.084	-0.026
28	0.105	-0.009	-0.061	0.033
29	-0.002	-0.063	-0.193	-0.150
30	-0.023	0.062	-0.211	0.028
31	0.001	-0.037	-0.207	-0.035
32	0.093	-0.016	-0.128	0.004
33	0.235	-0.018	0.034	0.030
34	0.374	-0.053	0.234	0.007
35	0.491	0.029	0.416	0.025
36	0.542	0.059	0.533	0.111

Ac: Autocorrelations; Pac: Partial autocorrelations

Coefficient of determination is significant in all cases, although the variability explained by the model in Balear region is low due to the high number of null catches in these series.

U-Theil statistic (Theil, 1966), generally presents values under 1 showing a good fit of the model. In some series (both Balearic series and Levant for anchovy) the statistic could not be calculated due to the excessive number of null catches. In anchovy series for South Mediterranean region, although the model fits globally well, as is shown in Fig. 2 and Fig. 7, the U-Theil statistic gets high value due to punctual collapse of this fishery during some years (1986-1987).

Globally, models present a good fitness in relation to the actual data and it can be observed in Figs 2, 3 and 4, representing the seasonal component real and simulated by the model, and in Figs 7, 8 and 9, representing average values, real and simulated, for the different 10 years intervals in which the studied period is divided. Figs 10, 11 and 12 display the totality of the real and simulated series behaviour, in the last decade.

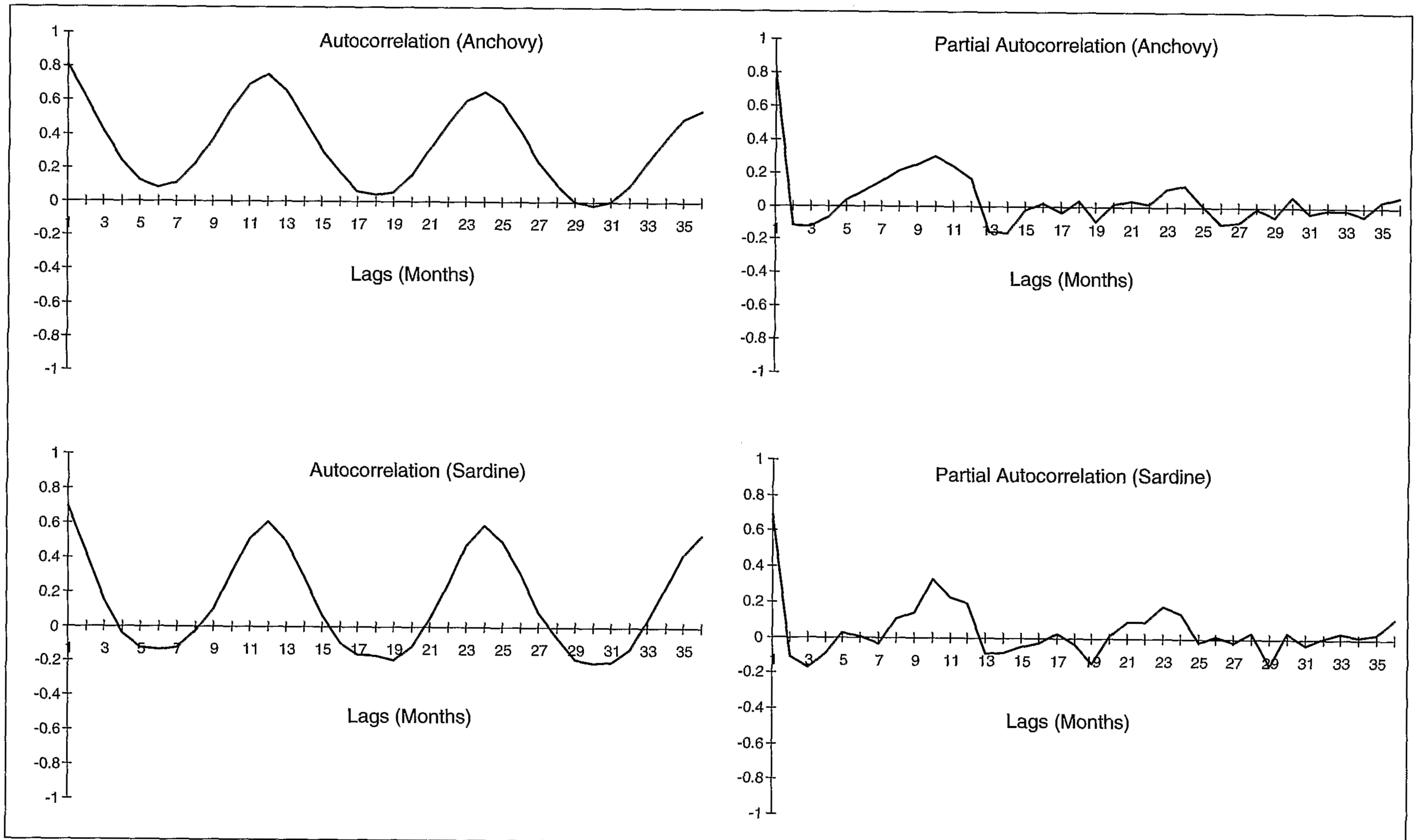

Fig. 5. Autocorrelations and partial autocorrelations as monthly time lag functions for anchovy and sardine total landings in the Spanish Mediterranean area.

Table 5. Autocorrelations and partial autocorrelations for ARIMA seasonal model residuals, for total landings in the whole considered area for sardine and for anchovy

Lags	Anchovy		Sardine	
	Ac	Pac	Ac	Pac
1	0.016	0.016	0.037	0.037
2	-0.052	-0.053	0.006	0.004
3	0.026	0.028	0.023	0.023
4	-0.011	-0.015	-0.0046	-0.048
5	0.031	0.034	0.040	0.044
6	-0.049	-0.052	0.011	0.008
7	0.003	0.009	0.091	0.092
8	-0.010	-0.018	0.123	0.113
9	0.027	0.032	-0.025	-0.031
10	0.155	0.150	0.097	0.096
11	0.149	0.156	0.070	0.068
12	-0.012	0.002	-0.008	-0.006
13	0.070	0.085	0.065	0.051
14	-0.045	-0.057	0.029	0.026
15	-0.010	-0.004	-0.008	-0.030
16	0.041	0.037	-0.041	-0.059
17	0.010	0.032	0.085	0.086
18	0.038	0.040	0.070	0.030
19	-0.043	-0.038	-0.016	-0.033
20	-0.014	-0.053	0.003	-0.014
21	0.080	0.028	0.013	-0.008
22	0.063	0.040	-0.021	-0.026
23	0.047	0.042	0.090	0.096
24	-0.072	-0.074	-0.000	-0.023
25	0.107	0.134	0.052	0.024
26	0.048	0.014	0.094	0.101
27	-0.068	-0.065	0.003	0.007
28	0.031	0.017	0.122	0.102
29	-0.062	-0.069	-0.061	-0.059
30	0.010	0.026	-0.036	-0.038
31	-0.015	-0.029	0.037	-0.001
32	-0.032	-0.055	0.006	0.024
33	0.067	0.042	0.040	0.003
34	0.023	0.011	0.032	-0.005
35	-0.007	-0.026	-0.004	-0.027
36	-0.039	-0.085	0.022	-0.024

Ac: Autocorrelations; Pac: Partial autocorrelations

As it was suggested by González-Pajuelo and Lorenzo (1994) these models tend to slightly underestimate catch values. And differences between simulated values and real catches values are related to seasonal sardine migrations and stock dispersion during summer months and later concentration again in September (Tsimenidis and Caragitsou, 1984).

Finally, models have been applied to establish short-term predictions for 1994. These predictions are presented in Fig. 13, that shows real and simulated catches from 1991 to 1993 and the forecasted by the model for 1994.

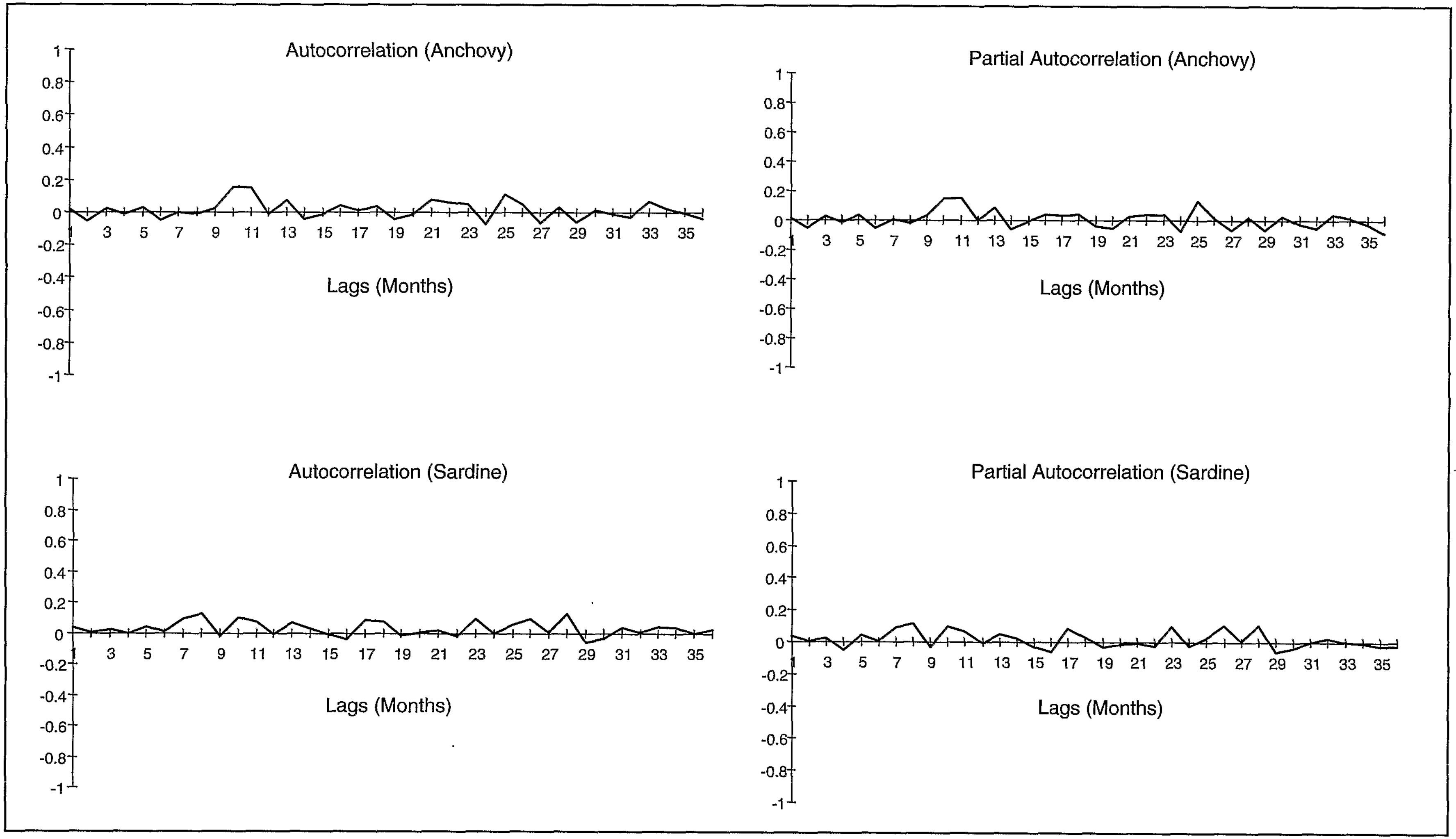

Fig. 6. Autocorrelations and partial autocorrelations for the ARIMA seasonal model residuals, for anchovy and sardine total landings in the Spanish Mediterranean area.

Table 6. Parameter estimations achieved by means of square minimum for the 4 considered regions and for the whole area for anchovy and sardine

	Φ_1, α	Φ_2, α	Φ_{12}, α	θ_{12}, α	D-W	CD	U-T
Anchovy							
Levante	0.462, 0.000	0.086, 0.010	-0.673,0.000	0.931, 0.000	1.998669	0.310	0.721
Southmedit.	0.646, 0.000	0.157, 0.000	-0.586,0.000	0.783, 0.000	2.067499	0.618	1.350
Tramuntana	0.271, 0.000	0.217, 0.000	-0.521,0.000	0.987, 0.000	1.800717	0.815	1.023
Balear	0.306, 0.000	0.137, 0.000	-0.923,0.000	0.978, 0.000	1.873192	0.201	***
Total	0.530, 0.000	0.169, 0.000	-0.590,0.000	0.952, 0.000	1.945785	0.758	0.850
Sardine							
Levante	0.515, 0.000	0.008, 0.794	-0.764,0.000	1.012, 0.000	1.975539	0.575	***
Southmedit.	0.428, 0.000	0.204, 0.000	-0.744,0.000	0.951, 0.000	1.932965	0.724	0.807
Tramontana	0.405, 0.000	0.082, 0.008	-0.812,0.000	1.004, 0.000	1.918304	0.663	0.419
Balear	0.342, 0.000	0.038, 0.237	-0.757,0.000	0.961, 0.000	2.015722	0.340	***
Total	0.465, 0.000	0.119, 0.000	-0.838,0.000	0.997, 0.000	1.919223	0.661	0.722

α: Significance level; D-W: Durbin-Watson Statistic; CD: Coefficient of determination; U-T: U-Theil Statistic
***P<0.001

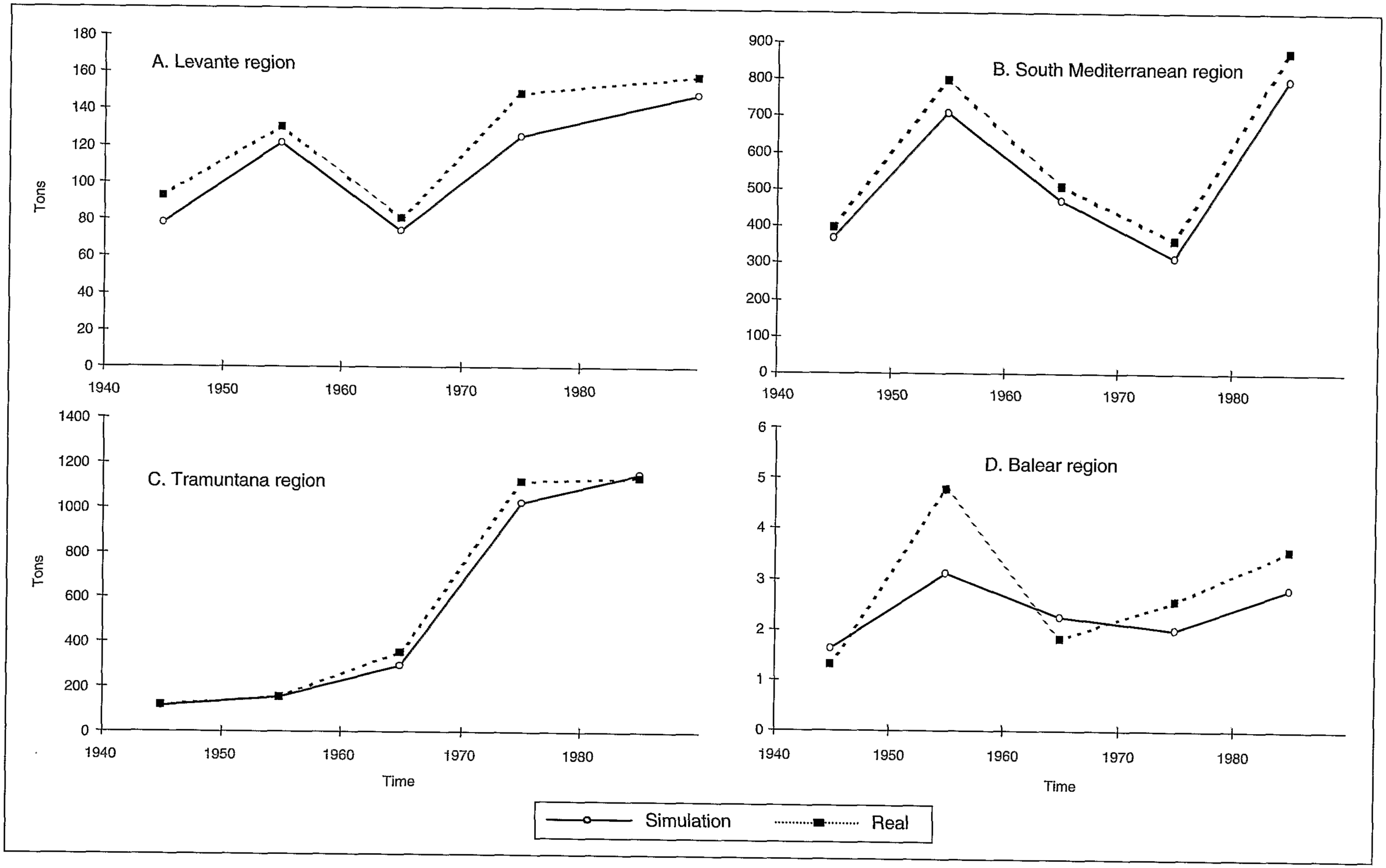

Fig. 7. Ten years averages for anchovy real and simulated catches (1940-1990) in the 4 Spanish Mediterranean considered regions (A, B, C, D).

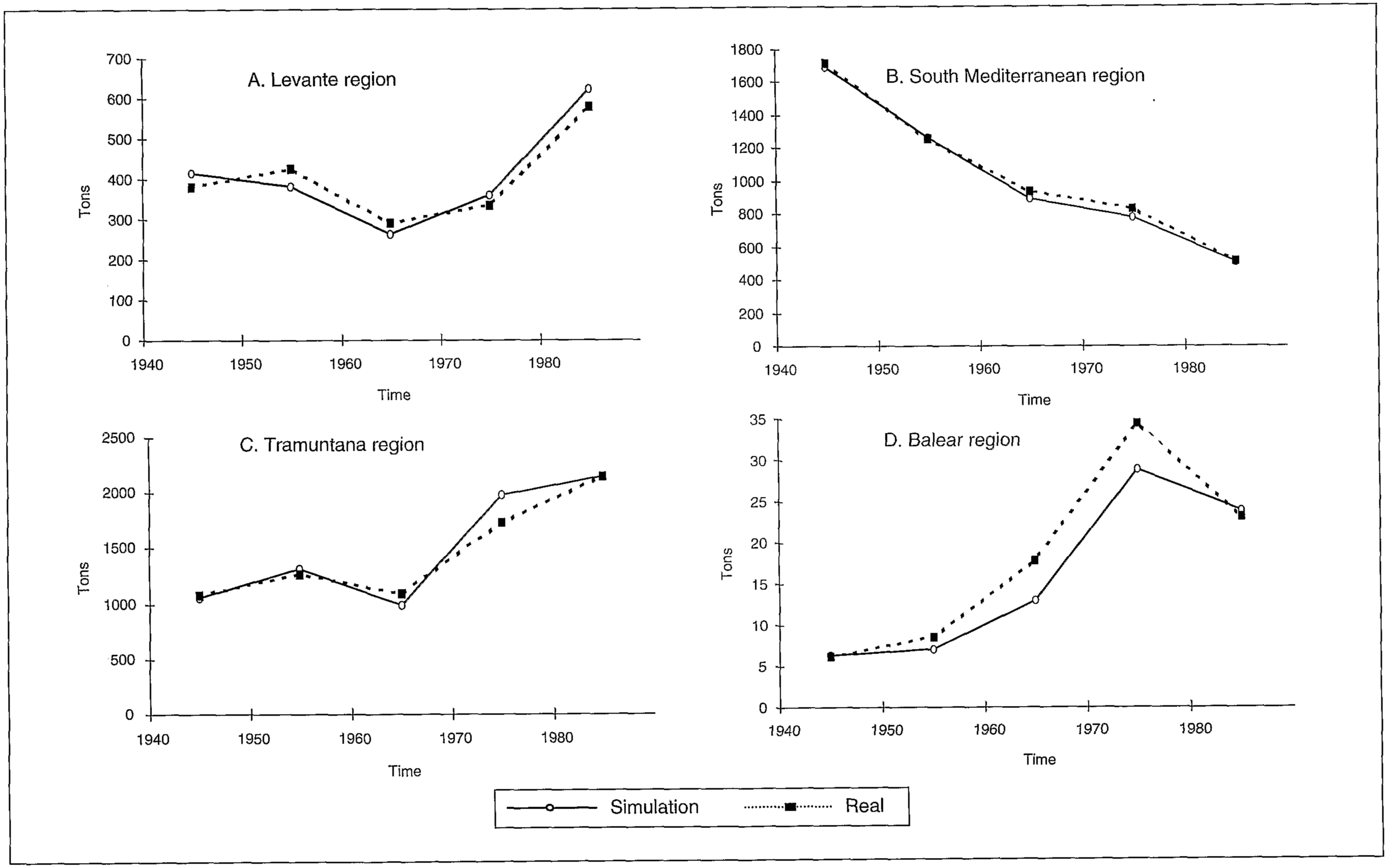

Fig. 8. Ten years averages for sardine real and simulated catches (1940-1990) in the 4 Spanish Mediterranean considered regions (A, B, C, D).

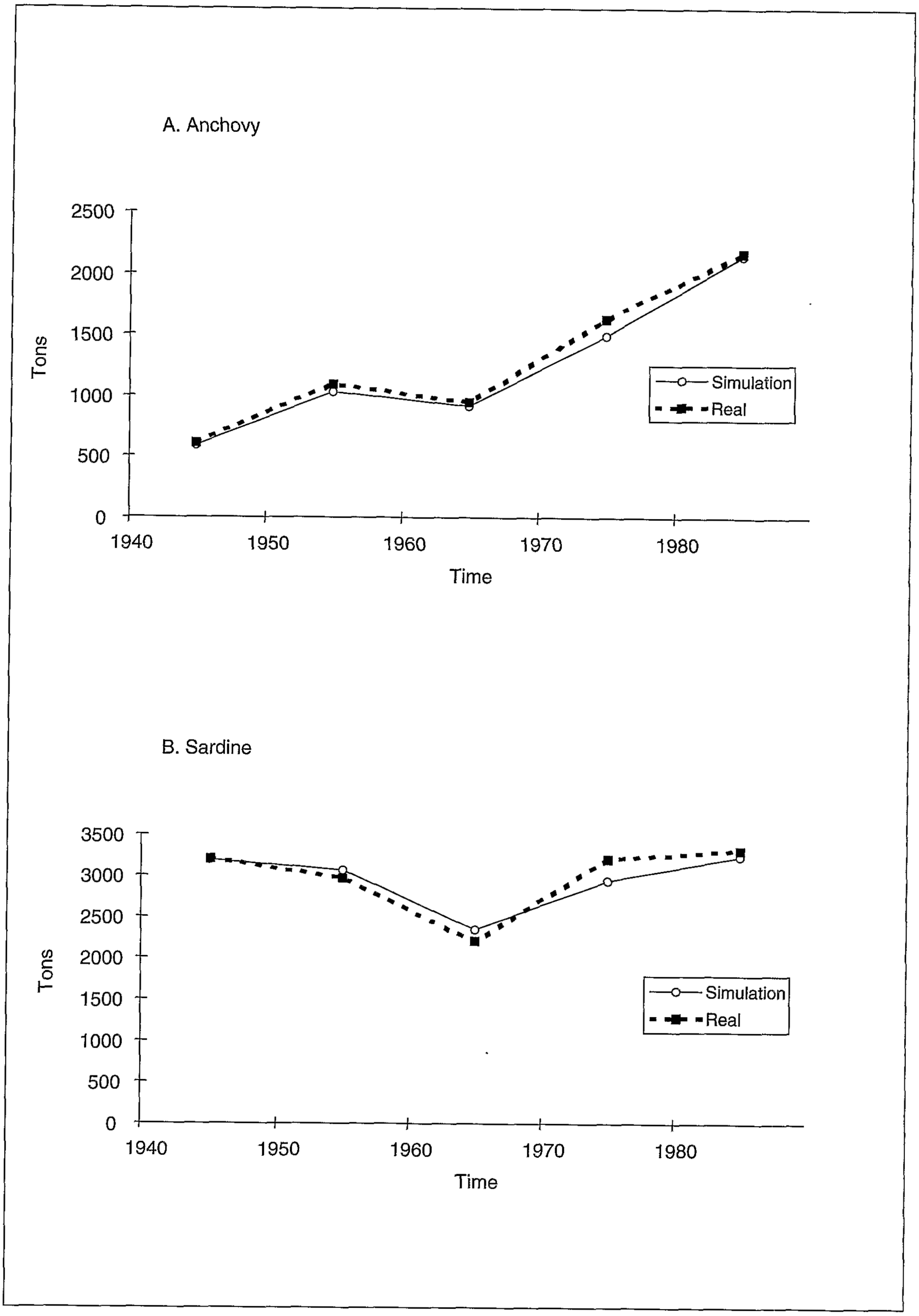

Fig. 9. Ten years averages for anchovy (A) and sardine (B) real and simulated catches (1940-1990) in the total Spanish Mediterranean considered area.

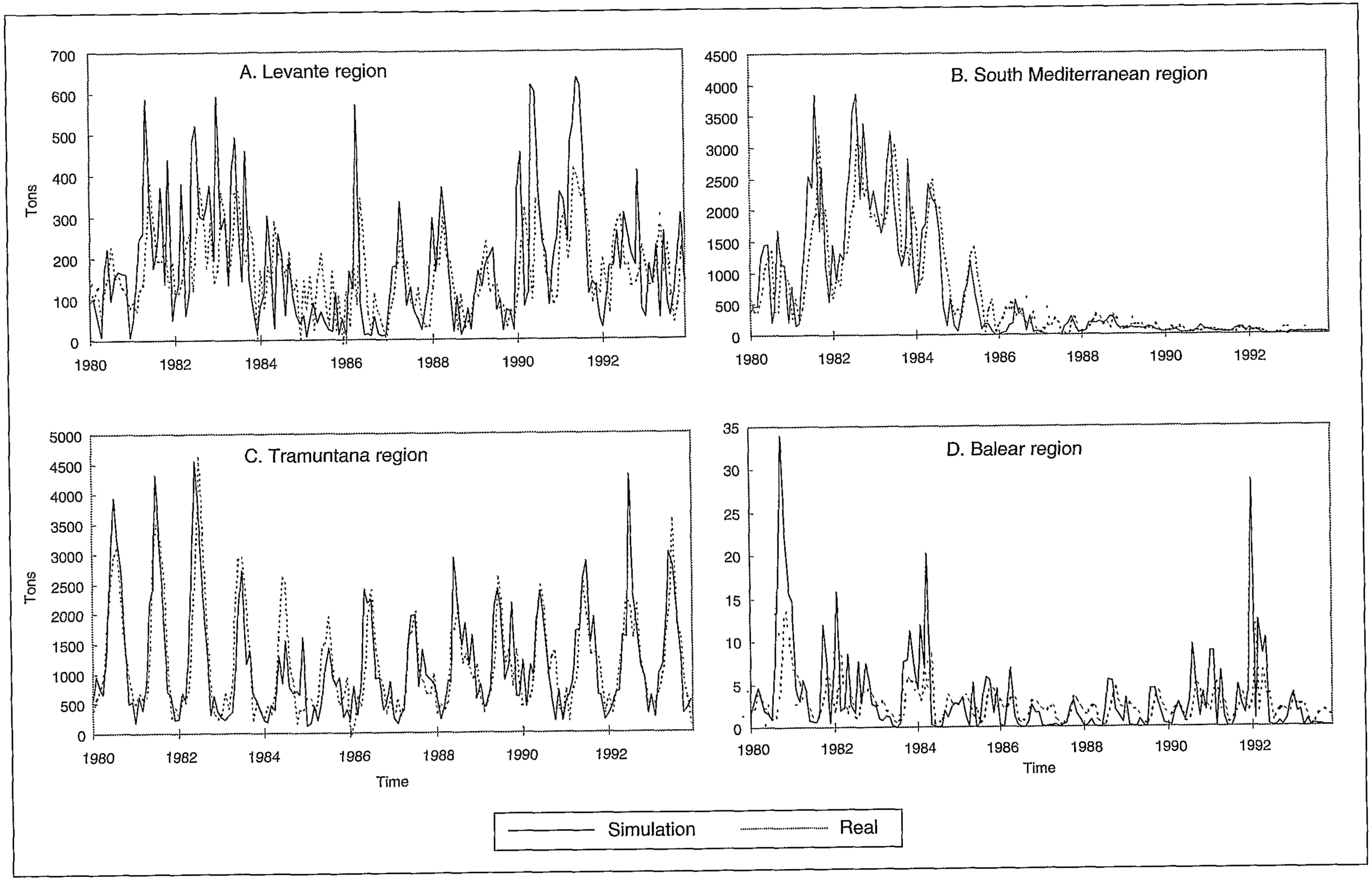

Fig. 10. Anchovy real and simulated catches (1980-1993) in the 4 Spanish Mediterranean considered regions (A, B, C, D).

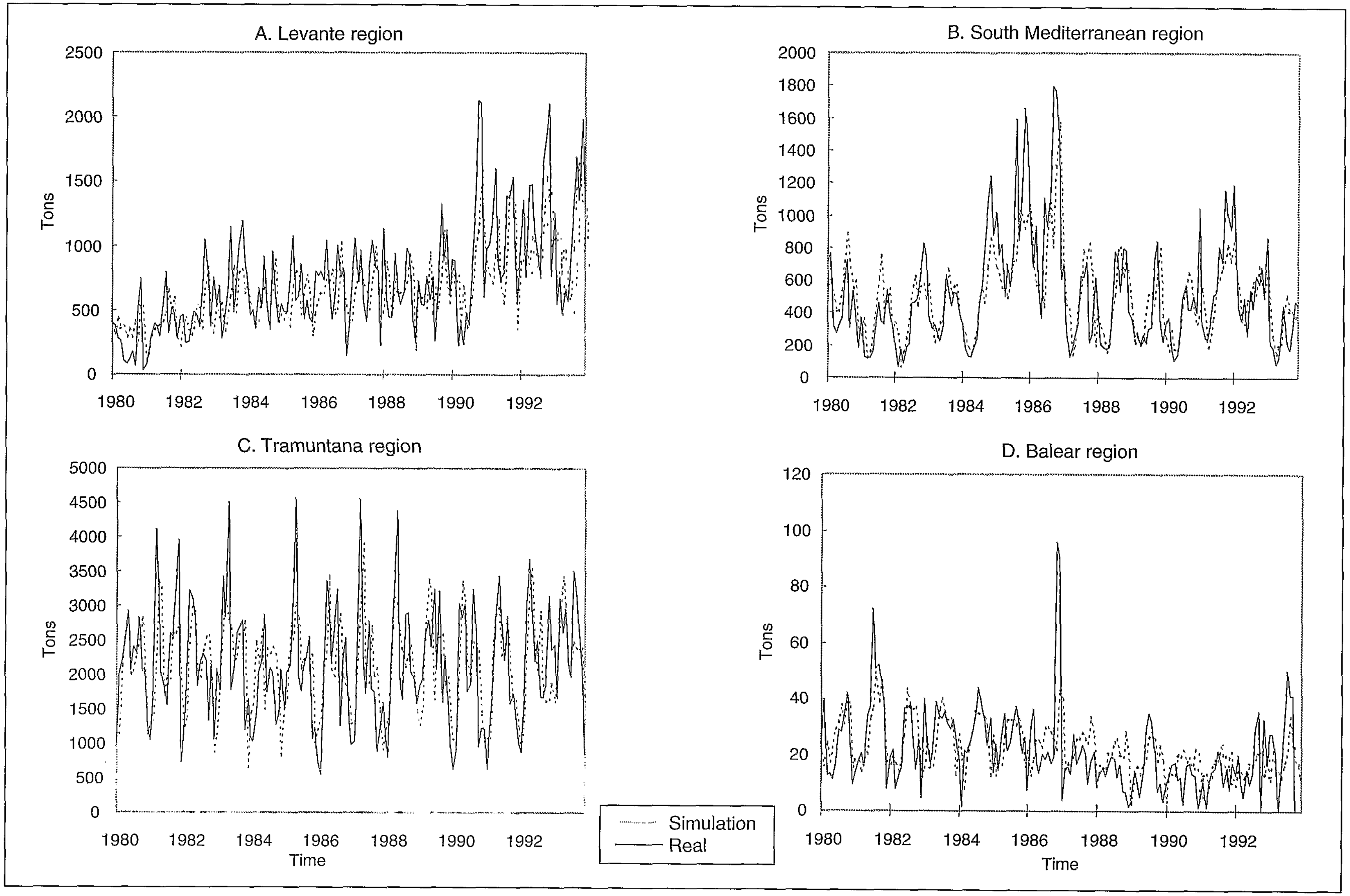

Fig. 11. Sardine real and simulated catches (1980-1993) in the 4 Spanish Mediterranean considered regions (A, B, C, D).

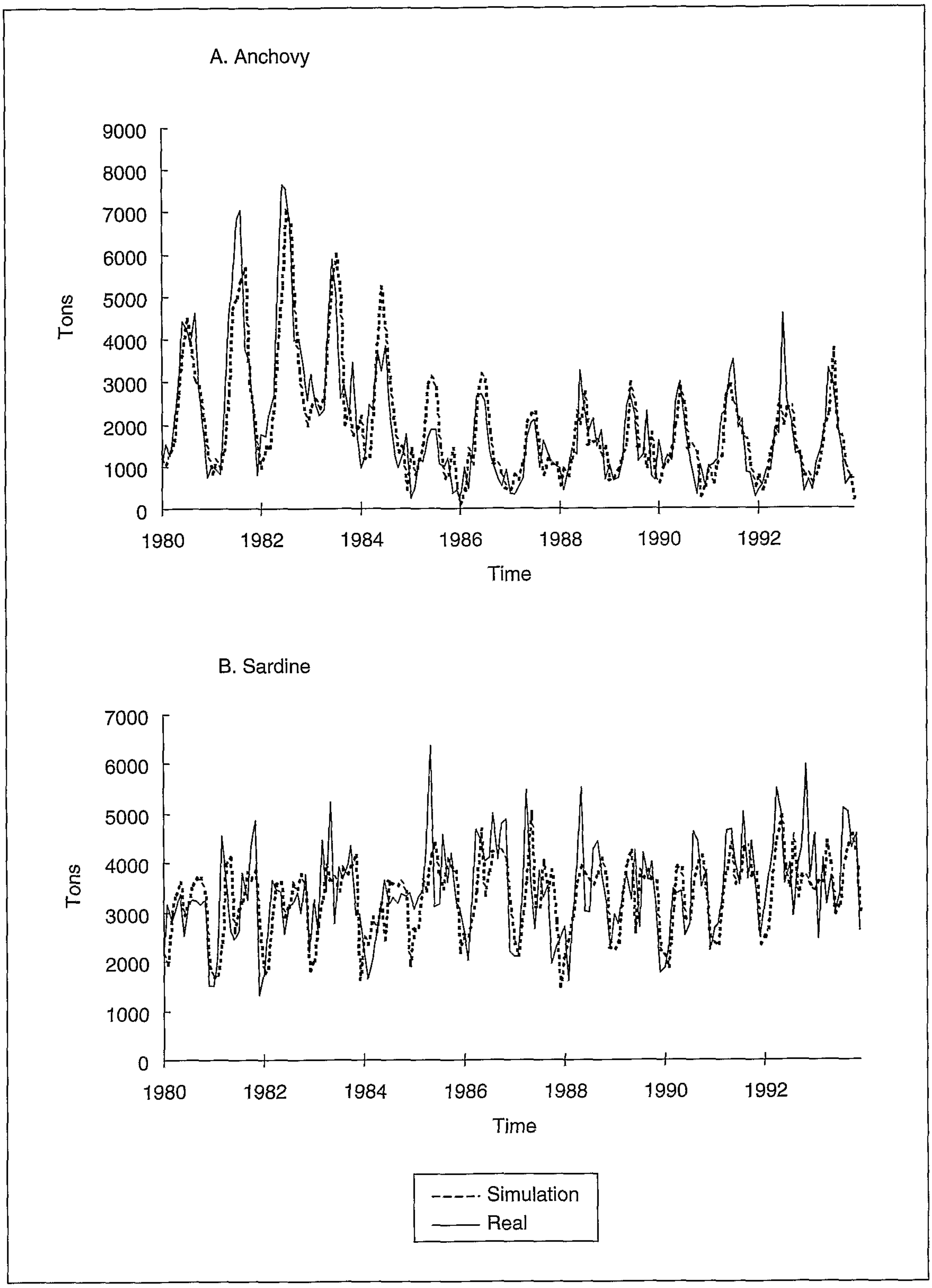

Fig. 12. Anchovy (A) and sardine (B) real and simulated catches (1980-!993) in total Spanish Mediterranean considered area.

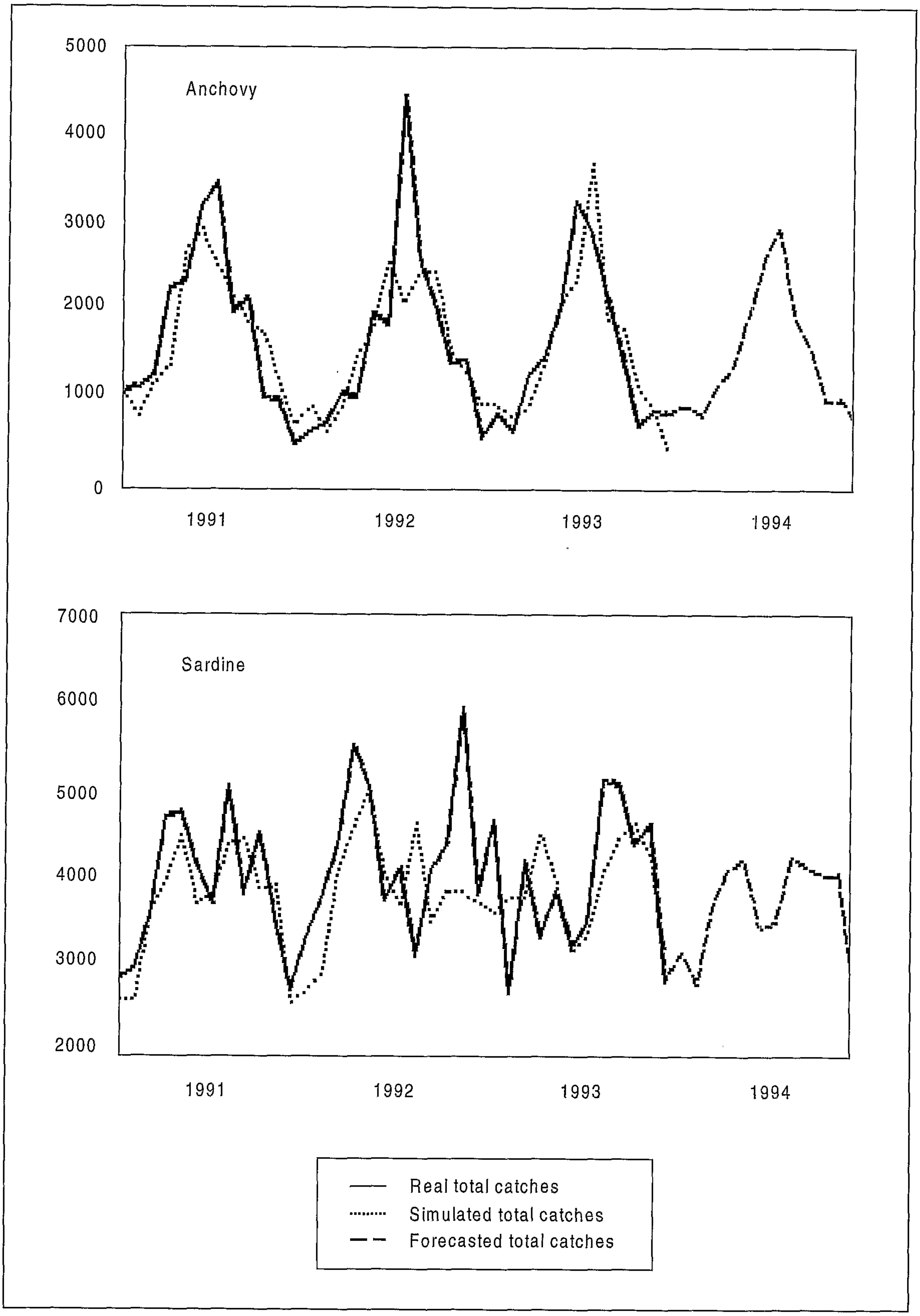

Fig. 13. Real and simulated anchovy and sardine catches from 1991 to 1993 and the forecasted catches for 1994.

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