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ASSESSMENT OF THE MEDITERRANEAN SWORDFISH STOCK BASED ON GREEK AND ITALIAN FISHERIES DATA

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SUMMARY

An assessment of the Mediterranean swordfish stock has been performed based on historical catch per unit effort and size data from the main Greek and Italian fisheries. Results of the applied VPA model and the analysis of the various catch curves suggest the existence of relatively stable recruitment and exploitation patterns. Further investigation is suggested on the assumption that the length composition of the catches of the examined fleets is representative of the Mediterranean situation and on the sensitivity of stock estimates on the methods employed for calculating standardized CPUE time series.

RÉSUMÉ

Une évaluation du stock d'espadon de la Méditerranée a été réalisée en se fondant sur la capture historique par unité d'effort et les données de taille des principales pêcheries grecques et italiennes. Les résultats du modèle de VPA appliqué et l'analyse des diverses courbes de capture suggèrent l'existence de schémas de recrutement et d'exploitation relativement stables. Il est suggéré de mener davantage de recherche en partant de l'hypothèse que la composition de taille des captures des flottilles examinées est représentative de la situation méditerranéenne, et sur la sensibilité des estimations de stock sur les méthodes employées pour calculer les séries temporelles de la CPUE standardisée.

RESUMEN

Se ha realizado una evaluación del stock de pez espada del Mediterráneo basándose en la captura histórica por unidad de esfuerzo y en los datos de talla de las principales pesquerías griega e italiana. Los resultados del modelo de VPA aplicado y del análisis de las diferentes curvas de captura sugieren la existencia de un reclutamiento y unos patrones de explotaciones relativamente estables. Se sugiere que se desarrollen más investigaciones sobre el supuesto de que la composición por tallas de las capturas de las flotas examinadas es representativa de la situación del Mediterráneo y sobre la sensibilidad de las estimaciones del stock a los métodos empleados para calcular las series temporales de CPUE estandarizada.

KEY WORDS

Stock assessment, swordfish

1. INTRODUCTION

Swordfish *(Xiphias gladius)* is a large pelagic species of high commercial value heavily exploited in the Atlantic Ocean and the Mediterranean Sea. Past genetic studies supported by the EU indicated that there is practically no mixing between Atlantic and Mediterranean individuals and suggested that all Mediterranean individuals form a unique stock (Kotulas *et al*. 1995). Swordfish landings in the

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Mediterranean showed a strong upward trend from about 4000 metric tons in 1976 to 20000 tons in 1988. Since then, landings fluctuate between 13000-15000 tons.

A preliminary assessment of the Mediterranean stock, carried out in 1995 during a joint GFCM/ICCAT Swordfish Workshop, revealed that the stock might be close to over-exploitation (ICCAT 1996). Concern has been also expressed regarding the large percentage of juveniles in the Mediterranean fisheries. However, the assessment was not considered sufficiently reliable for an in-depth evaluation of the state of the stock, as the available time series of data was rather limited. It has been suggested that further collection and analysis of data from the commercial fishery is needed in order to improve our knowledge about the state of the stock and achieve a rational management of the resource.

The main objective of the project work was to study the dynamics and exploitation pattern of the Mediterranean swordfish stock through the analysis of a series of past fisheries data that have been collected from the main Greek and Italian fisheries. It should be noted that Greece and Italy are among the most important swordfish producers in the Mediterranean accounting for about 70% of the total production.

2. MATERIALS AND METHODS

Data collection

Swordfish fisheries data have been collected within the frames of data collection schemes based on representative sampling of fishing boats landing their catches on the main landing ports of the Aegean, Cretan, Levantine, Ionian and Tyrrhenian seas **(Figure 1)**. Collected fisheries data included spatial and temporal information on catch, effort and size distribution of the catches by gear.

In the case of Greece, sampling covered the two main swordfish fleets operating in the country, the fleets of Kalymnos and Hania. Generally, catches of both fleets represented 50-70% of the total Greek production. The fleets exploit the Aegean, Cretan and Levantine seas. Swordfish fishing is carried out using drifting surface long-lines through February to September while is prohibited by a national regulation from October to January. Recently, the traditional long lines have been modified, resembling the ones used for the tuna fishery in the Atlantic. The modified gear, which is known as American-type long-line, is set deeper than the traditional and uses fluorescent material to attract the fish.

In the case of Italy, data have been collected from the Sicilian fleet, which is the largest in the Mediterranean. The fleet mainly exploits the Tyrrhenian Sea but occasionally expands its activities into a much wider area. It accounts for about 70% of the total Italian catch. The fishing gears used by the Sicilian fleet are: harpoons, driftnets and long-lines. Nowadays, harpoon catches are very low and in terms of biomass represent a negligible percentage of the total catches. The long-line fishery operates mainly from August to December and targets both the adult and the juvenile stocks using big or medium-size hooks respectively. The driftnet fishery mainly operates in the central and southern Tyrrhenian Sea and the fishing season usually lasts from late April to August.

The available catch - effort data covered the period 1987-1999 and included 4129 individual records. In the case of Greece data included records for both type of long-lines used (Classical and American) and in the case of Italy for long-lines, small mesh and large mesh-size driftnets. Length data included representative Lower Jaw Fork Length (LJFL) measurements taken from the sampled landings. Measurements were categorised by gear, area and time (month and year of capture) and covered the period 1986-1999 (58084 records totally).

Data analysis

The methodological approach that was followed included:

a) Standardization of CPUE rates to examine spatio-temporal variations in relative abundance and identify possible trends.

Independent generalised linear models were used to standardise the CPUE data collected by each country and gear type. Longline catch per unit effort data was available from Italy and Greece. Data from two types of gill net, large and small mesh, were available from Italy.

Fitting of generalised linear models is described in detail in Venables and Ripley (1997), a stepwise approach was adopted, similar to that, for the fitting of analyses of variance. At each step, a new more complex model was compared with a simpler model using an F-test within an analysis of variance (ANOVA). Models that did not reduce the residual variance by a significant proportion were rejected.

In the majority of cases, it was found that an appropriate model for the data was a Gamma error structure with a log link function (McCullagh and Nelder 1983). Initially, models were fitted with just the main effects year, month and area for each gear type; interactions were then added where they were found to be significant. The highest possible level of model complexity would be achieved with interactions between all of the main effects. However, it was determined that the sample design was insufficient for fitting models with all of the potential interactions. In each case, it was necessary to simplify the analysis by assuming that there was a common year effect in the catch rate per unit effort, the population abundance effect, and then to test again for sufficient sample replicates to model month/area interactions. It was determined that, due to missing replicates for some interaction cells, models with full month/area interactions could not be always fitted if month of landing was treated as a categorical factor. For this reason, month of landing was also treated as a continuous variable, fitted as an explanatory variable for a function within a Generalised Additive Models (GAM-Hastie and Tibshirani 1990). This allowed months with only a limited number of data points to be linked to adjacent months within a coherent model structure. The use of GAMs allows the estimation of effects for month/area combinations with limited data and permits the fitting of interactions.

In addition to the Analysis of Deviance tests for appropriate models, graphical plots were produced of the model residuals against fitted values and each model factor. The plots were examined for departures from the assumption of constant variance, the presence of trends and the influence of outliers using Cook’s distance index.

b) Creation of total catch at age tables to examine global changes in the catch composition of the landings.

Catch numbers at length were converted to numbers at age by applying the commonly used method of length slicing. The method uses a growth curve to subdivide the length distribution into age classes. Numbers at length in the catch landed by a fishery were calculated by raising the sample length distributions, by the ratio of the fishery catch weight to the sample weight. Landings by fishery unit were taken from the data available to ICCAT and FAO databases. Sample weight was calculated as the sum of individual fish round weights given by the following combined sex relationships:

Gutted weight (kg) = 0.00000169 x (Lower jaw fork length) $^{3.39}$ (derived from current data; 16585 observations from the Italian fishery)

Round weight (kg) = 1.12 x Gutted weight (ICCAT, 1996)

Tserpes and Tsimenides (1995) fitted a von Bertalanffy growth curve to combined sex observations of length at age, where age was determined by reading anal-fin spine sections. The fitted equation was:

$$L_t = 238.6\,(1\text{-e}^{-0.185\,(t+1.404)})$$

Using the above parameters annual growth classes were calculated and the length distributions subdivided (“sliced”) into age distributions.

c) Estimation of mortality rates through the analysis of the catch curves of each fishery.

Catch curve analysis was applied to each of the years for which catch numbers at age data were available from the individual fishery units. This commonly used regression method assumes that recruitment, selection, natural mortality and catchability are constant for all ages included within the regression.

d) Virtual Population Analysis (VPA) to estimate mortality rates and population numbers at age.

A separable VPA model (Pope and Shepherd 1982) was fitted to the estimates of the total Mediterranean catch numbers at age for the years 1990-1999 and ages 1-9.

The method calculates mortalities and number of fish at age from the catch-at-age tables assuming that, apart from the natural mortality value (0.2 for all ages and years), the following parameter estimates are provided:

- The fishing mortality on one reference age in the last year (terminal F).
- Selection at the oldest age in the final year. Selection at age is the fishing mortality at age relative to that on the reference age.

The reference age selected for fitting the model was age four. Selection at the oldest age was constrained to be equal to that at age four.

External specification of the level of fishing mortality at all ages, in the final year, requires that the level of mortality be estimated externally to the fitted model. This can be achieved by maximizing the correlation between the model estimates of fishing mortality or population abundance with an additional information series; the smoothed, combined CPUE series previously estimated. The time series of total population weights were derived by calculating the product of the estimated population numbers at age and weight at age; estimated from the isometric growth equations. Fishing mortality at the reference age of the Separable VPA was adjusted to minimize the sum of squares between the CPUE series and total population weight.

As, all Mediterranean swordfish are considered to compose a unique stock, VPA was applied for the whole Mediterranean utilizing the total landings reported by ICCAT and FAO.

3. RESULTS

Standardization

Tables 1-5 show the analysis of deviance results for the models fitted to each fishery data set. Standardised yearly indices are given in **Table 6**. There were large increases in catch rate in the Greek classical fishery in 1998 and 1999, considered to be a gear related change in catchability. High catch rates were also estimated in 1994 for the American type long line and in 1992 for the small mesh Italian drift net fishery. These are considered to be anomalies in a stable time series of catch rates. In general, standardization indicated that all fishery CPUE series present consistent trends in index values through time. If scaled appropriately they can be combined into a single series. ICCAT (1996) estimated standardised catch rates for Greek and Italian long line fisheries and a combined Italian drift net fishery. The historical and current series follow each other in a coherent way showing that the current analysis is consistent with the older study. The ICCAT models did not include interactions and used a log transformation of the CPUE data. The current analysis also includes more data for some of the years examined by ICCAT; therefore the estimates would not be expected to be exactly equal.

A combined index was calculated using the Greek classical long line, the two types of Italian drift net and the Italian long line estimates. The index was derived from both the historical and current series. Each of the time series was scaled to the average index values for the years 1992-1994 in order to enable a common standardization. The extremely high 1992 estimate from the small mesh Italian drift net fishery was not included in the analysis, as it was also based on a small number of data.

Figure 2 plots the standardized values and a quadratic model fitted against time, which was used to smooth the combined series. The figure also illustrates the index values of the Spanish long line catch per unit effort (solid squares) standardized by ICCAT (1996), and not used in this study. They provide a valuable cross validation of the time series. The combined standardized index indicates that population levels have shown a moderate decrease during the late 1980's but has subsequently shown a gradual increase. In the preliminary assessment analysis that follows the curve fitted in **Figure 2** was used for estimating trends in effort and overall CPUE.

Catch-at-age

Tables 7-9 present the numbers at age by country and gear type. Data for ages 0 and 10 and older were too sparse; hence they were not used in the subsequent analysis.

Catch curve analysis

The annual estimates of fishing mortality are tabulated in the **Table 10** and plotted together for comparison in **Figure 3**. The estimates of fishing mortality have remained relatively constant throughout the time period. In absolute terms the values of mortality estimated using the Italian long line and drift net data are higher than those derived from the Greek long line fishery.

Separable VPA

Figure 4 plots the final population weight time series on the CPUE estimates from the GLM modeling for comparison. The correlation of the time series trends shows that the model is calibrated appropriately and the trend in the population and fishing mortality estimates are consistent with the fishery indices.

Tables 11 and **12** present the estimates of fishing mortality and population numbers at age. Selection at age is estimated to be constant after age 4; this is in agreement with the consistent linearity of the log catch numbers at age regression slopes recorded in the catch curve analysis. Fishing mortality rates show a declining trend from 1997 onwards and in the last two years are in the region of 0.4. Recruitment appears to be extremely consistent; there have been no strong or weak year classes. The same is valid for the number of fish in the largest age classes.

4. DISCUSSION

The consistent recruitment rates and stable year classes estimated from the Separable VPA are in agreement with the catch numbers at length for each of the fishery units, which exhibit a very stable distribution throughout the recorded time series. The number of fish in the largest length and age classes has not been reduced over time and the catch numbers at length and age have similar rates of decrease beyond the modal catch classes. This indicates a stock with stable levels of exploitation and recruitment. SVPA model also estimated that the population is currently increasing. The same was found applying a non-equilibrium stock production model in the current data set (Tserpes *et al.*, 2001).

The stock production model also predicted that, at the rate of exploitation currently seen in the fishery, the population would continue to recover.

However, the time series estimates from the fitted models are conditional on the trend in the combined catch per unit effort index series derived from the GLM standardization procedure. The rate of increase in the estimated population abundance in recent years is heavily dependent on the choice of data to which the models are fitted. If the recent high values from the Greek classic long line and the whole of the Italian small mesh drift net series were omitted, it is expected that the rate of increase would be reduced.

A more consistent approach to modelling the CPUE data from each region would be the fitting of a GLM model that includes all of the data series estimated during the project and which uses Julian date rather that the year and month effects. This would allow the use of inverse variance iterative re-weighting so that trends in each time series would be modelled independently, as opposed to the aggregated index in which individuals series trends are lost. A GLM including all regions and gear types would also avoid sensitivity of the CPUE time series to the choice of year for standardising the aggregated index.

Such refinements of the CPUE models would affect stock estimates and this aspect should be examined in future studies. The proportion of juveniles in the catch-at-age tables used in the past ICCAT preliminary assessment (ICCAT, 1996) was much higher than that of the present study, suggesting further investigation on our assumption that the length composition of the currently examined fleets is representative of the Mediterranean situation. Differences in the slicing approaches followed may be also responsible for these discrepancies.

Catch curve analysis indicated that mortality values estimated using the Italian long line and drift net data are higher than those derived from the Greek long line fishery. This may be the situation, but higher mortality rates may also result from violations of the assumption of constancy in the parameters. Trends in catchability resulting from escapement at older ages or the deliberate targeting of younger ages and spatial or depth effects in the distribution of ages available to the gear types will all induce bias in the regression slopes and therefore the estimates of mortality.

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Table 1. The analysis of deviance table used to fit the Italian long line swordfish CPUE Generalized Linear Model.

Model	Terms	Resid.Df	Resid.Dev	Test	Test Df	Deviance	F Value	Pr(F)
1	Intercept	972	502.668					
2	factor(year)	967	481.581	1 vs 2	5	21.087	8.856	<0.000001
3	factor(year) + factor(month)	958	439.411	2 vs 3	9	42.169	11.068	<0.000001
4	factor(year) + lo(month)	963.202	442.534	2 vs 4	3.80	39.046	24.090	<0.000001
5				3 vs 4	-5.20	-3.123	1.41	0.2128
6	factor(year) + factor(month) + factor(area)	956	379.847	3 vs 6	2	59.564	78.032	<0.000001
7	factor(year) + factor(month) * factor(area)	insufficient replicates for a unique definition of all coefficients						

Final model: 6 cpue = intercept + factor(year) + factor(mon) + factor(area)
Error structure: Gamma
Link: log

Table 2. The analysis of deviance table used to fit the Italian large mesh drift net swordfish CPUE Generalized Linear Model.

Model	Terms	Resid.Df	Resid.Dev	Test	Test Df	Deviance	F Value	Pr(F)
1	Intercept	762	396.2706					
2	factor(yr)	753	369.1799	1 vs 2	9	27.09072	7.004086	<0.000001
3	factor(yr) + factor(mon)	747	273.7527	3 vs 2	6	95.42715	44.66965	<0.000001
4	factor(yr) + lo(mon)	747	273.7525	4 vs 3	0	0.000176		
5	factor(yr) + factor(mon) + factor(area)	746	252.9247	5 vs 4	1	20.82801	59.78385	<0.000001
6	factor(yr) + factor(mon) * factor(area)	insufficient replicates for a unique definition of all coefficients						

Final model: 5 cpue = intercept + factor(yr) + factor(mon) + factor(area)
Error structure: Gamma
Link: log

Table 3. The analysis of deviance table used to fit the Italian small mesh drift net swordfish CPUE Generalized Linear Model.

Model	Terms	Resid.Df	Resid.Dev	Test	Test Df	Deviance	F Value	Pr(F)
1	Intercept	161	1331.675					
2	factor(yr)	157	660.228	1 vs 2	4	671.4472	40.11546	<0.00001
3	factor(yr) + factor(mon)	153	339.1140	3 vs 2	4	321.1141	29.77988	<0.00001

Final model:	3	cpue = intercept + factor(yr) + factor(mon)
Error structure:	Poisson	
Link:	none	

Table 4. The analysis of deviance table used to fit the Greek classic long line swordfish CPUE Generalized Linear Model.

Model	Terms	Resid.Df	Resid.Dev	Test	Test Df	Deviance	F Value	Pr(F)
1	Intercept	1841	994.2978					
2	factor(yr)	1832	827.1486	2 vs 1	9	167.1492	35.14088	<0.00001
3	factor(yr) + factor(mon)	1825	771.9222	3 vs 2	7	55.22644	16.36005	<0.00001
4	factor(yr) + lo(mon)	1828.65	774.6969	4 vs 3	-3.647	-2.77467	1.577417	0.18301
5	factor(yr) + factor(mon) + factor(area)	1821	767.6119	5 vs 4	7.648	7.08497	1.949304	0.05231
6	factor(yr) + factor(mon) * factor(area)	insufficient replicates for a unique definition of all coefficients						

Final model:	5	cpue = intercept + factor(yr) + factor(mon) + factor(area)
Error structure:	Gamma	
Link:	Log	

Table 5. The analysis of deviance table used to fit the Greek "American" long line swordfish CPUE Generalized Linear Model.

Model	Terms	Resid.Df	Resid.Dev	Test	Test Df	Deviance	F Value	Pr(F)
1	Intercept	257	173.37					
2	factor(yr)	255	95.79	2 vs 1	2	77.58	95.33	<0.00001
3	factor(yr) + factor(mon)	248	89.60	3 vs 2	7	6.19	2.34	0.0247
4	factor(yr) + lo(mon)	251.66	93.68	4 vs 3	3.3	2.11	1.56	0.1937
5	factor(yr) + factor(mon) + factor(area)	244	82.91	5 vs 3	4	6.69	4.94	0.0008
6	factor(yr) + factor(mon) * factor(area)	insufficient replicates for a unique definition of all coefficients						

Final model: 6 cpue = intercept + factor(yr) + factor(mon) + factor(area)
Error structure: Gamma
Link: Log

Table 6. The time series of standardised catch per unit effort estimates for the five Mediterranean swordfish fisheries. The small bottom table indicates the standardisation used (month and area) in each case.

	Greece				Italy					
	Clasical long line		American long line		Long line		Large mesh drift net		Small mesh drift net	
Year	CPUE	s.e	CPUE	s.e	CPUE	s.e	CPUE	s.e	CPUE	s.e
1987	97.88	9.34								
1988	119.68	9.95								
1989										
1990	111.66	9.26					2.72	0.22		
1991	152.63	11.15					2.69	0.31		
1992	61.01	3.65			31.27	4.23	4.69	0.32	29.46	2.70
1993	100.39	8.27					6.02	0.55		
1994	113.43	8.53	1126.74	222.32	28.84	2.99	4.68	0.34	1.73	0.38
1995	84.06	7.08			35.02	3.78	7.02	0.49	2.95	0.49
1996							4.14	0.38	2.82	0.58
1997					28.78	3.55	7.75	0.70	3.66	0.53
1998	222.26	23.52	295.94	46.28	41.07	4.71	3.05	0.32		
1999	183.65	17.41	211.23	31.66	38.77	4.29	3.74	0.39		

		Month	Area
Greece	Clasical long line	5	Crete
	American long line	5	Crete
Italy	Long line	5	Lipari
	Large mesh drift net	5	Lipari
	Small mesh drift net	5	Lipari

Table 7. The combined sex numbers at age calculated for the Greek long line fishery by length slicing. Data for the years 1996 and 1997 are substituted from the Italian drift net fishery raised to the Greek long line catch weight.

Age	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
0	499	19	155		191	65	978	493	497	0	*0*	*0*	0	0
1	3716	1927	5577		610	2685	4731	16154	19923	2707	*1014*	*167*	0	170
2	9871	3309	13270		25079	15752	15046	40840	14095	4932	*5911*	*2281*	3288	5397
3	19132	6871	7848		12273	17651	21039	23511	42195	7746	*19475*	*10918*	18555	12043
4	8706	7026	4621		5565	8187	7665	4020	7725	6031	*9431*	*5781*	9747	9941
5	5046	4924	2840		3316	6026	3785	1858	5015	2171	*2889*	*2222*	5402	5908
6	3216	2628	1781		1601	3832	1735	1365	3072	2171	*1282*	*827*	2584	3295
7	1608	1985	904		1334	1834	631	910	1581	1126	*440*	*393*	1174	1250
8	665	759	542		610	1015	315	303	1581	402	*306*	*92*	939	682
9	444	409	207		191	393	284	228	723	322	*134*	*109*	0	170
10	222	272	52		114	262	126	0	226	295	*77*	*33*	470	114
11	55	58	77		76	65	32	0	361	0	*0*	*0*	235	57
12	0	0	0		38	0	32	0	90	0	*0*	*0*	0	57
13	0	39	0		0	65	0	0	0	0	*19*	*8*	0	114
14	0	0	0		38	33	32	0	45	0	*0*	*8*	0	57
15	0	0	0		38	33	0	38	0	0	*0*	*8*	0	0
16+	0	19	26		0	65	63	0	181	0	*0*	*17*	117	114

Table 8. The combined sex numbers at age calculated for the Italian drift net fishery by length slicing.

Age	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
0					0	0	0	0	0	0	0	0	0	0
1					506	885	412	0	7066	6928	2145	548	12979	608
2					7443	7748	10403	3027	26480	16012	12506	7474	20980	19689
3					54557	33463	48231	37100	49362	44078	41201	35782	78408	52157
4					12790	19554	20938	22651	22287	12866	19953	18945	35026	28165
5					4263	7305	12090	13180	10004	6485	6111	7282	17691	11561
6					2312	2988	4892	5272	4523	3368	2712	2710	10401	4564
7					650	1439	2399	1757	2906	1950	931	1287	4267	2260
8					795	517	1256	976	1618	1123	648	301	1156	782
9					289	295	412	586	660	517	283	356	444	304
10					145	37	150	195	231	236	162	110	178	130
11					0	0	37	0	198	281	0	0	89	130
12					0	0	37	0	66	133	0	0	178	0
13					0	37	19	0	132	30	40	27	89	43
14					0	37	56	98	33	74	0	27	0	0
15					0	37	19	0	33	0	0	27	0	0
16+					0	37	94	98	198	118	0	55	0	0

Table 9. The combined sex numbers at age calculated for the Italian long line fishery by length slicing. Data for the years 1990 and 1993 are substituted by the years 1991 and 1992 respectively raised to the catch weights for 1990 and 1993.

Age	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
0					*0*	0	0	*0*	0	0	0	0	0	0
1					*30734*	23216	11123	*11128*	1414	11943	84504	47063	31545	11382
2					*73762*	55718	52062	*52084*	47881	68329	77219	111851	73673	49412
3					*44919*	33931	45032	*45052*	58708	36289	26225	26893	33101	46600
4					*11190*	8453	6952	*6955*	8451	11599	1457	4890	8509	12454
5					*4098*	3095	2317	*2318*	1143	3216	2914	1834	2698	2276
6					*3467*	2619	1777	*1777*	331	861	0	0	1038	402
7					*1419*	1072	309	*309*	180	115	0	0	1038	0
8					*315*	238	386	*386*	120	0	0	0	311	134
9					*158*	119	154	*155*	30	0	0	611	0	134
10					*0*	0	232	*232*	0	0	0	0	0	0
11					*0*	0	77	*77*	0	0	0	0	0	0
12					*0*	0	0	*0*	0	0	0	0	0	0
13					*0*	0	0	*0*	0	0	1457	0	0	0
14					*0*	0	0	*0*	0	0	0	0	0	0
15					*0*	0	0	*0*	0	0	0	0	0	0
16+					*0*	0	0	*0*	0	0	0	0	0	0

Table 10. The estimates of annual fishing mortality rate derived from catch curve analysis for the three fisheries.

		1986	1987	1988	1989	1990	1991	1992
Italy	Drift Net					0.60	0.72	0.60
	Long line						0.68	0.68
Greece	Long line	0.43	0.31	0.47		0.45	0.40	0.52
		1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Italy	Drift Net	0.56	0.53	0.50	0.61	0.64	0.68	0.67
	Long line		0.94	1.07	1.07	1.20	0.71	1.06
Greece	Long line	0.51	0.43	0.31			0.43	0.52

Table 11. The Separable VPA model estimates of combined sex swordfish fishing mortality for the Mediterranean fishery.

	Year									
Age	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1	0.0699	0.077	0.0747	0.0814	0.0985	0.0801	0.0729	0.0639	0.075	0.0553
2	0.2859	0.3147	0.3055	0.3329	0.4027	0.3276	0.298	0.2611	0.3068	0.2259
3	0.6156	0.6775	0.6577	0.7168	0.8669	0.7054	0.6416	0.5621	0.6605	0.4863
4	0.5064	0.5573	0.541	0.5896	0.7131	0.5802	0.5278	0.4624	0.5433	0.4
5	0.4975	0.5476	0.5316	0.5794	0.7007	0.5701	0.5186	0.4543	0.5339	0.393
6	0.5101	0.5614	0.545	0.5939	0.7183	0.5845	0.5317	0.4658	0.5473	0.4029
7	0.4809	0.5293	0.5139	0.56	0.6773	0.5511	0.5013	0.4392	0.516	0.3799
8	0.4774	0.5254	0.5101	0.5559	0.6723	0.547	0.4976	0.4359	0.5123	0.3771
9	0.5064	0.5573	0.541	0.5896	0.7131	0.5802	0.5278	0.4624	0.5433	0.4

Table 12. The Separable VPA model estimates of combined sex population numbers at age in the Mediterranean. Population numbers are the smoothed model estimates.

	Year									
AGE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1	635100	707400	831200	873600	898500	894000	1299500	1104800	917800	411500
2	608500	485200	536700	632000	659900	667800	677100	992000	851800	701900
3	367800	374400	290100	323900	371400	362600	396500	415500	634200	526600
4	152700	162600	155600	123000	129700	128700	148500	174300	199500	283300
5	67000	75400	76300	74200	56000	52400	59600	72900	92100	99300
6	37500	33400	35700	36700	34100	22900	24500	29600	38800	46200
7	16500	18400	15600	17000	16600	13700	10600	12000	15600	19300
8	8200	8300	8900	7600	7900	7000	6500	5300	6500	7900
9	3200	4100	4000	4400	3600	3300	3300	3300	2900	3300

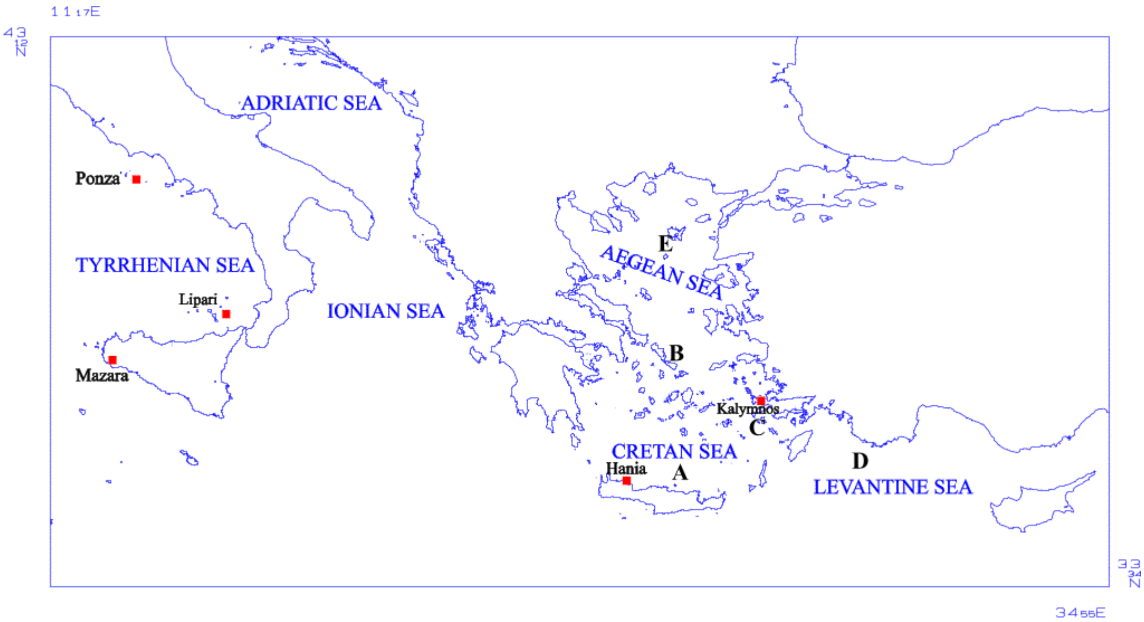

Figure 1. Map of the central-eastern Mediterranean indicating the seas exploited by the studied fleets and the location of the main landing ports. The area exploited by the Greek fishing fleets has been divided in five sub-areas based on the fleets' activity pattern (see text for details). A = Cretan sea, B = Central Aegean, C = Southeastern, D = Levantine and E = North Aegean.

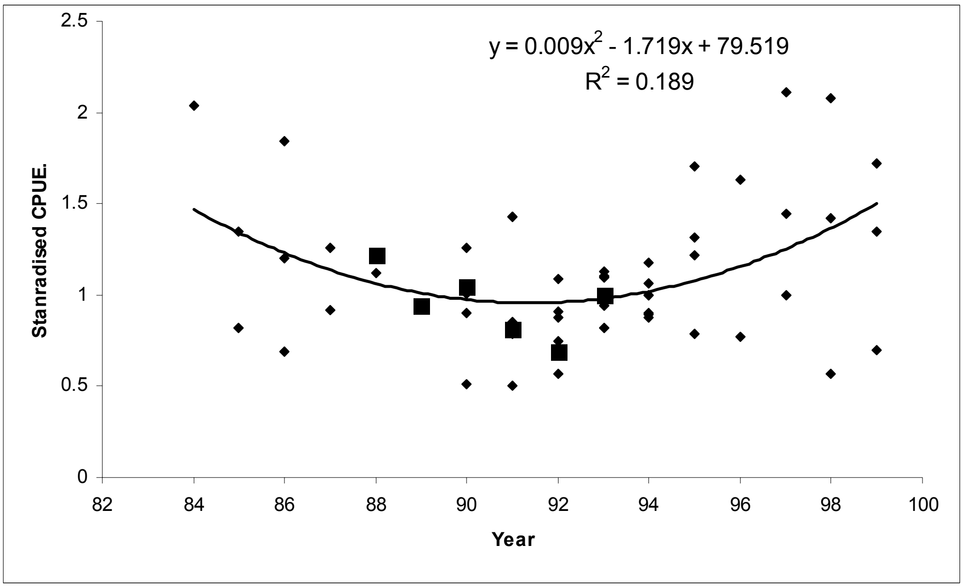

Figure 2. The time series of standardised CPUE estimates for four swordfish fisheries, with a fitted quadratic smoother. The Spanish long line catch per unit effort series (ICCAT 1996) is shown as solid squares).

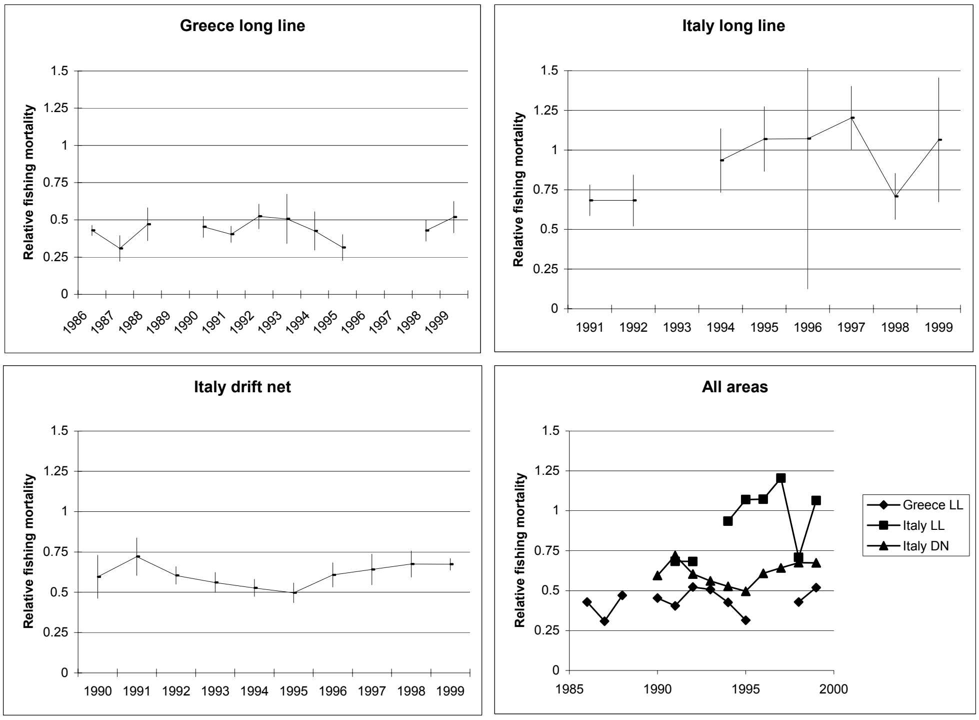

Figure 3. The estimates of fishing mortality estimated for the three fisheries using annual catch curve analysis.

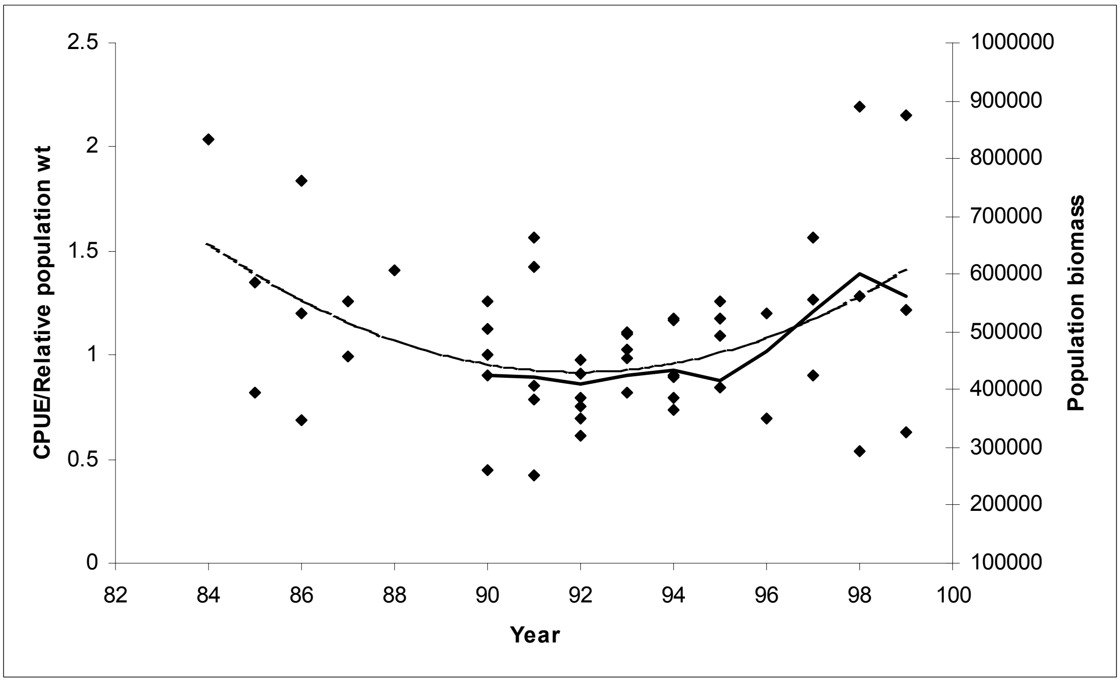

Figure 4. The time series of standardised annual catch per unit effort estimates, derived from a series of GLM models, for four swordfish fisheries (data points) and total population biomass estimated by Separable VPA (solid line). The thinner line is a quadratic smoothing function fitted to the CPUE data in order to illustrate the trend.