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Analysis of gear interactions in a hake fishery: The case of the Gulf of Lions (NW Mediterranean)*

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SUMMARY: The hake of the Gulf of Lions is the most important target species of the demersal fishery. It is exploited by four types of gear (two trawls, gillnet and longline) used by two countries (France and Spain). Some analyses of its dynamics, based on 1988 length frequency data by gear, have been performed. These analyses consisted in a VPA (Virtual Population Analysis), plus a Y/R (Yield per Recruit analysis) carried out on two parameter scenarios by sex, under a steady state hypothesis (with constant recruitment). Some estimates of biomass and exploitation level were obtained, and sensitivity to the biological parameters and interaction between types of gear were studied. As a main conclusion, it can be seen that the types of gear fishing mainly small individuals (trawls) have a great influence on the others (gillnets and longlines). It is certain that the stock is overexploited.

Key words: Assessment, gear interaction, hake, Gulf of Lions, NW Mediterranean.

RESUMEN: ANÁLISIS DE INTERACCIONES DE ARTES EN UNA PESQUERÍA DE MERLUZA: EL CASO DEL GOLFO DE LEÓN (MEDITERRÁNEO NOROCCIDENTAL). — La merluza es la principal especie objetivo de la pesquería demersal en el golfo de León. Está explotada por cuatro artes (dos arrastres, redes monofilamento y palangre) que corresponden a dos países (Francia y España). Se han realizado algunos análisis de la dinámica de la merluza, basados en las distribuciones de frecuencias de tallas por arte del año 1988. Estos análisis consistían en un VPA (Análisis de Poblaciones Virtuales), completado con un Y/R (Análisis de Rendimiento por Recluta) llevados a cabo con dos juegos de parámetros para cada sexo, todo ello bajo la hipótesis de estado estacionario (con reclutamiento constante). Se han obtenido estimaciones de la biomasa y del nivel de explotación y se ha estudiado la sensibilidad de los parámetros así como la interacción entre artes. Como principal conclusión, se puede ver que los artes que pescan principalmente sobre los individuos pequeños (arrastres) tienen una gran influencia en los otros (redes monofilamento y palangre). Es seguro que el stock está sobreexplotado.

Palabras clave: Evaluación, interacción de artes, merluza, Golfo de León, Mediterráneo noroccidental.

INTRODUCTION

The Mediterranean hake (*Merluccius merluccius*) is the most important demersal species in the Gulf of Lions. In this area, hake is exploited with four types of gear used by two countries: French trawl, Spanish trawl, French gillnet and Spanish longline. Some studies on this fishery have already been carried out, separately by country: the French one by ALDEBERT and CARRIES (1988, 1991) and the Spanish one by LLEONART (1990). In this paper the first Spanish-French joint study is presented.

The French trawler fleet is composed by 170 units working mainly on the continental shelf and on the upper part of the continental slope (from 30 to 250-300 m). The fishery is multispecific, pelagic as well as demersal species being exploited, but hake is the main demersal target species. The mesh size used is 40 mm and the gear has a high vertical aperture (up to 20 meters). The French gillnet fleet, about 20

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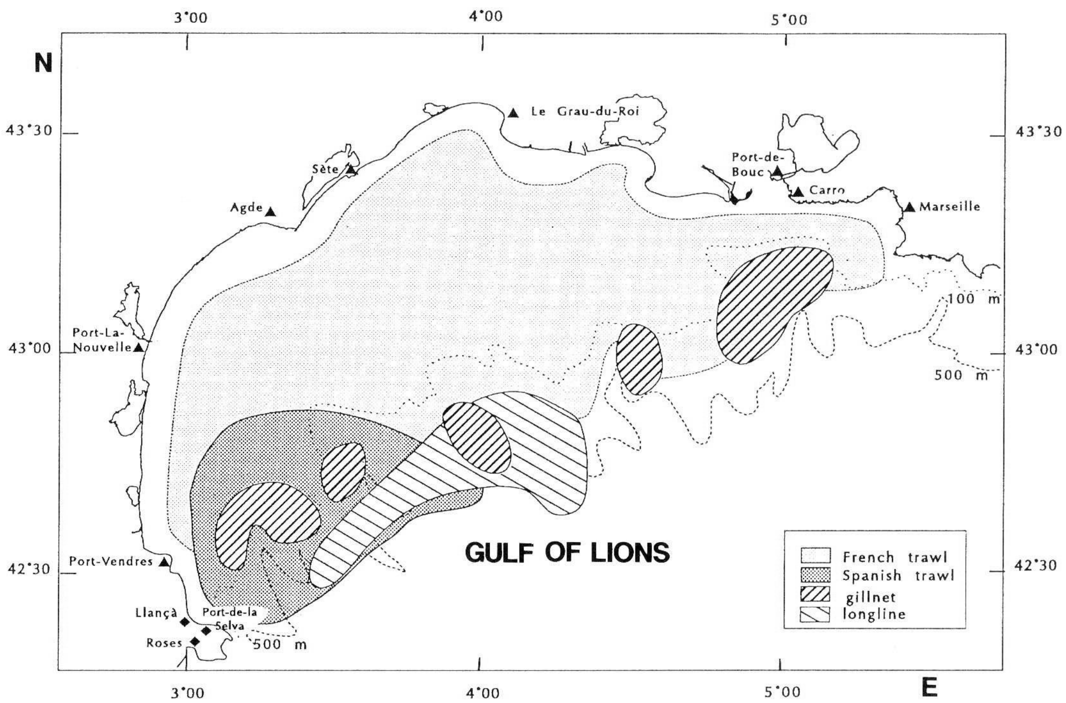

FIG. 1. — Hake fishing areas by gear and landing ports in the Gulf of Lions.

boats, with hake as the target species, works on the outer part of the shelf and slope between 90 and 300 m, mainly in the eastern part of the gulf. The mesh size is 80 mm, and the nets are each 3000 to 5000 meters long. Average annual hake landings for the last ten years are around 2200 tonnes for trawl and 300 tonnes for gillnet.

The Spanish fishery is prosecuted in the western part of the gulf and involves a trawler fleet, about 26 boats; it is also a multispecific fishery and hake is the main target species. This fleet works mainly on the shelf from 50 meters depth and occasionally on the slope up to 500 meters depth. Annual hake landings of this fleet are about 300 tonnes. Mesh size for these trawls is 38 mm, and the vertical aperture is about 2 meters maximum. Furthermore, there are 13 boats in the longline fleet with hake as target species, operating on the slope along the canyons between 160 and 600 m depth. Its annual catches are about 130 tonnes. Hooks used for hake are number 3 (Mustad) and there are 1500 to 2000 hooks per longline.

The working areas for each fleet and main landing ports are shown in the Fig. 1.

There are a few studies of multi-gear fisheries. Some are based on bioeconomic models (O'BOYLE *et al.*, 1991) or simulation models (KLEIBER and BAKER, 1987). In this case analysis of population dynamics has been employed to study the fishery. In particular, analysis of interactions between types of gear has been emphasized.

MATERIAL AND METHODS

Length frequency data corresponding to the 1988 landings have been used. These frequencies were obtained by monthly sampling on board fishing boats or in the main landing ports. They represent the actual frequencies of catches for the four types of gear considered. French length frequencies for the trawl were taken at Sète and Port-Vendres and the total number of individuals measured was 18000. Gillnet data were taken in Carro and 3600 fish were measured. Spanish length frequencies were taken in Port de la Selva for both types of gear. The number of individuals measured were 3200 for the trawls and 700 for the longlines. The Spanish length frequencies that involve fewer individuals have been smoothed by standard methods (five classes moving average).

Since there are significant growth differences between sexes (ALDEBERT and CARRIES, 1988), males and females have been analyzed separately. In general, males have a faster growth rate (K) and lower asymptotic length ($L\infty$) than females. These growth differences are apparent in the sex ratio of catches by gear, e.g. the longline landings are mainly composed of females. Special sampling to estimate the sex ratio as a function of length was performed. The length frequency data by sex and gear are shown in Fig. 2 and their main statistics are given in Table 1. It can be seen that trawlers (both Spanish and French) exploit

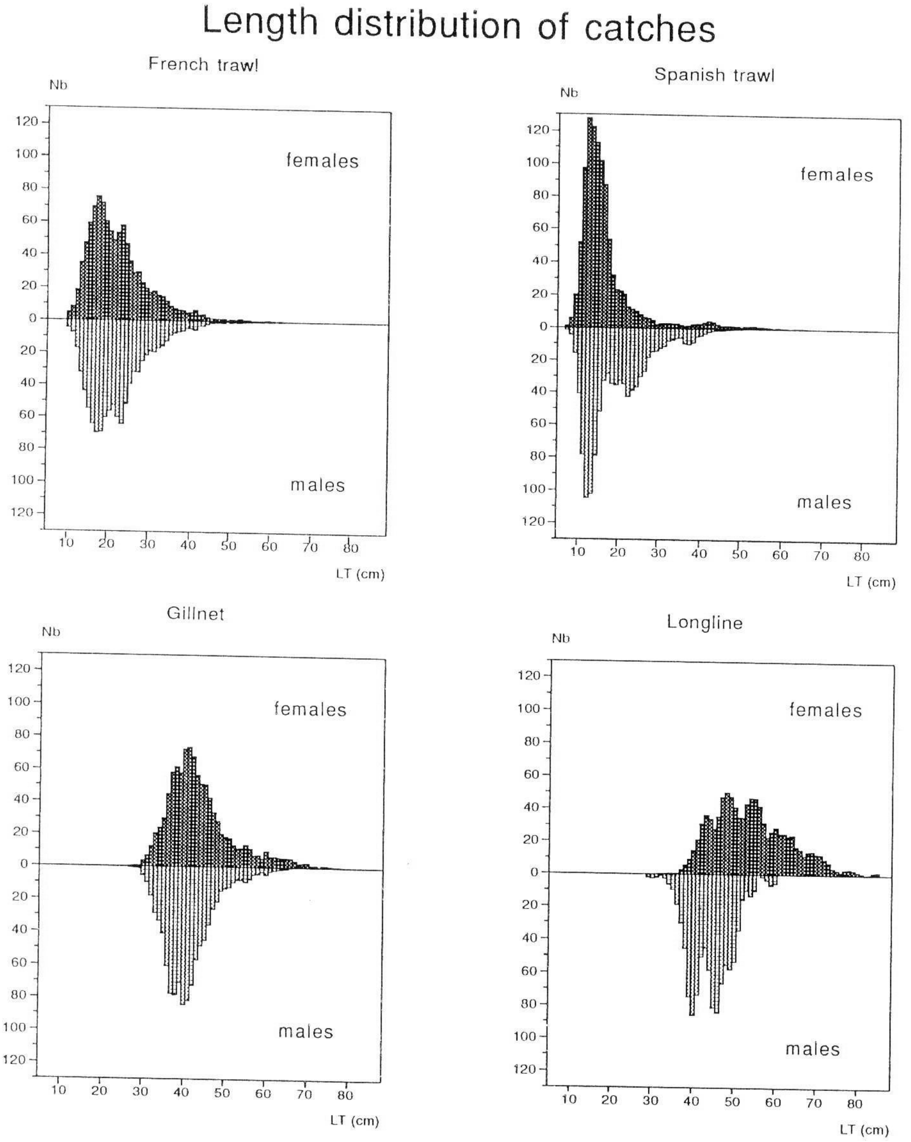

FIG. 2. — Length frequency distribution of hake catches by gear and sex, relative to 1000 individuals in each case.

TABLE 1.— Hake exploitation pattern for different gears, (m) males and (f) females. Lengths are in centimeters.

	Minimal length		Maximal length		Mean length	
	m	f	m	f	m	f
Spanish trawl	7	7	60	65	19.2	16.7
French trawl	10	10	66	88	22.6	22.6
Gillnet	27	27	67	86	41.7	44.2
Longline	29	29	60	85	44.7	54.3
Total (4 gears)	7	7	67	88	22.3	22.1

TABLE 2.— Biological parameters of hake used for analysis. $L\infty$, K and t_0, von Bertalanffy growth parameters. Length-weight relation numbers: a and b. M, natural mortality; *F term*, Fishing mortality of the last length class. Plus-group, length that accumulates classes. Fecund.L50, length with 50 % mature individuals.

set num.	#1 fem.	#2 mal.	#3 fem.	#4 mal.
$L\infty$ (cm)	110	66	80.2	55.8
K	0.11	0.195	0.113	0.179
t_0	0.3	0.3	−0.524	−0.42
a	0.00564	0.00564	0.0069	0.0069
b	3.069	3.069	3.03	3.03
M	0.15	0.15	0.2	0.2
F term.	0.15	0.15	0.15	0.15
plus-group		60	70	50
Fecund.L50	43	27	43	27
L75-L25	8	6	8	6

a wide range of lengths, but most of the catches are composed of immature individuals. Gillnets and longlines exploit the adult population.

The biological parameters are extremely important in the population analysis: growth parameters as well as mortality rates determine in most cases the general trends of the results. In this study we used the parameter sets calculated by ourselves (ALDEBERT and CARRIES, 1988; RECASENS, 1992) which lie within the normal ranges found in the literature (QUESADA, 1991). The length-weight relationship parameters have no less importance than the others, but good data to compute them are easier to obtain, so their estimation becomes much more precise.

As far as parameters are concerned, two analyses have been carried out. Each of them includes both sexes (which have different parameters). In Table 2 the four parameter sets are presented. The sets 1 (females) and 2 (males) were calculated with "Compleat ELEFAN" package (GAYANILO *et al.*, 1988) on the basis of the 1988 length frequency distributions (RECASENS, 1992). The sets 3 (females) and 4 (males) were calculated from otolith readings of Gulf of Lions hake (ALDEBERT and CARRIES, 1988). Determination of the first annual ring is uncertain in this species. On the other hand, the reproductive pattern of this species does not show any constant peak. This was confirmed by monthly observations of the hake sexual cycle in the Gulf of Lions from April 1990 to March 1991: spawning or nearly spawning females were observed every month but no obvious spawning peak was identified. Some calculations of natural mortality by the usual methods (TAYLOR, 1958; RIKHTER and EFANOV, 1976; PAULY, 1980) were made. Values fell between 0.15 and 0.2 and these values are used for the analyses. These values equal those calculated for *M. merluccius* in the Atlantic ocean (M=0.2) (TRUJILLO *et al.*, 1991) and are lower than values used in other species like *M. capensis* (M=0.3) where there are some factors that affect populations like predation or cannibalism (LLEONART *et al.*, 1985), factors that have no significance in *M. merluccius*. Except for the analysis corresponding to set parameter 1, the last class was plus-group because the $L\infty$ value was closest to the maximum length observed and this affects the VPA analysis. The use of plus-group does not made any significant difference to results as shown in previous trials (FARRUGIO *et al.*, 1991).

The landing data are statistics of monthly catches by port provided by the Spanish fishermen's associations (named "Confraries") and by the French Fisheries Administration ("Direction des Pêches maritimes"). Since some landings are not registered, the total catch is undoubtedly higher than that registered; some data were therefore corrected according to direct observations at the landing places. The distribution of total catch by sex and gear for the year 1988 is shown in Table 3 in absolute values (tonnes) and in percentage. Catches and landings are equivalent, since there is no significant discard of young individuals and it is usual to find on the market individuals below the legal length. It can be observed that most of landings correspond to trawl catches (81 %).

The methodologies used to analyze these data are the packages VIT (LLEONART and SALAT, 1992) and MSFLA (IFREMER unpublished), which both use pseudocohorts of length classes. VIT was run using the catch equation; MSFLA uses the POPE (1972) equation following the method described by JONES (1983). Some trials were carried out to compare both programmes, but no significant differences were found (FARRUGIO *et al.*, 1991). Virtual Population Analysis (VPA) was performed for each parameter set with the two softwares, and also Yield per Recruit analysis (Y/R). The Y/R uses the F vector obtained

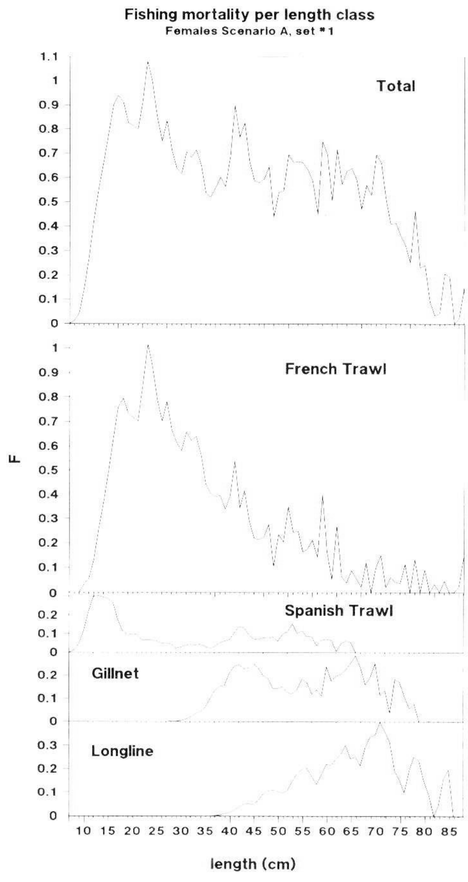

FIG. 3. — Hake fishing mortality (F) distribution by length class and gear in absolute numbers. Scenario A and parameter set #1.

TABLE 3. — Catches of hake per sex and gear in the Gulf of Lions in 1988 in tons (Qt) and in percentages (%).

	Total		Females		Males	
	Qt	%	Qt	%	Qt	%
French trawl	2013.1	68.4	1002.5	64.3	1010.6	73.1
Spanish trawl	381.1	13.0	179.9	11.6	201.2	14.5
Gillnet	384.5	13.1	235.3	15.9	149.2	10.8
Longline	162.1	5.5	140.5	9.0	21.6	1.6
Total	2940.8		1558.2		1382.6	

TABLE 4. — Results of VPA for different values of biological parameters in 1988.

	Scenario A		Scenario B	
	Fem. (1)	Mal. (2)	Fem. (3)	Mal. (4)
Initial nb (*1000) (recruitment)	15286	14783	19845	20604
Mean annual number (*1000) population	21872	23126	43327	46149
Recruitment in weight (tons) R	33.638	32.708	49.791	51.695
Mean annual Biomass (tons)	2345	2067	7238	5518
Biomass balance (tons) D	1910	1601	3006	2486
% Fishing dead (in biomass)	81.6	80.6	51.8	55.6
Mean age of Population (years)	2.08	2.14	2.44	2.44
Critical age (years)	3.31	2.5	4.95	3.27
Critical virgin age (years)	10.87	8.45	8.25	6.87
Mean length of Population (cm)	18.8	18.6	21.0	20.1
Critical length (cm)	31	23	37	27
Critical virgin length (cm)	75.6	52.5	50.4	40.7

by VPA. This method has been applied to the data in two scenarios: A, defined by parameter sets 1 and 2 and B, defined by sets 3 and 4. The Y/R analysis includes the equilibrium curves. All analyses were ran with disaggregated data by sex and gear.

RESULTS

The main global results of the VPAs are summarized in Table 4. The biomass balance (D) is the amount of biomass renewed during the unit of time (year), corresponding to the sum of weight gained by recruitment or growth and of weight lost by natural or fishing mortality. The critical ages and lengths correspond to the maximum cohort biomass (exploited and virgin stocks).

The F vectors are presented in Figs. 3, 4, 5 and 6. The terminal F was chosen after a series of trials with the objective of stabilizing F for recent years. Nevert-

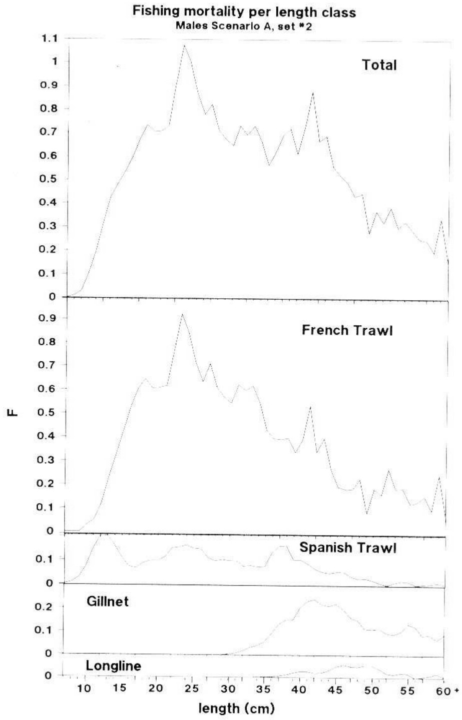

FIG. 4. — Hake fishing mortality (F) distribution by length class and gear in absolute numbers. Scenario A and parameter set #2.

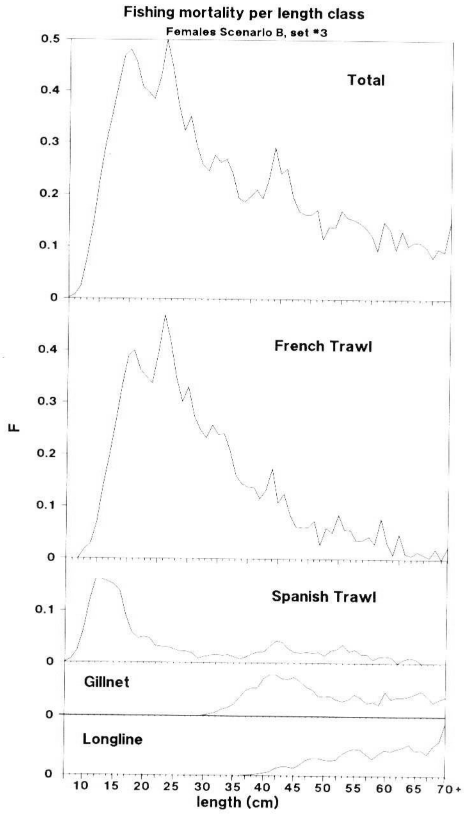

FIG. 5. — Hake fishing mortality (F) distribution by length class and gear in absolute numbers. Scenario B and parameter set #3.

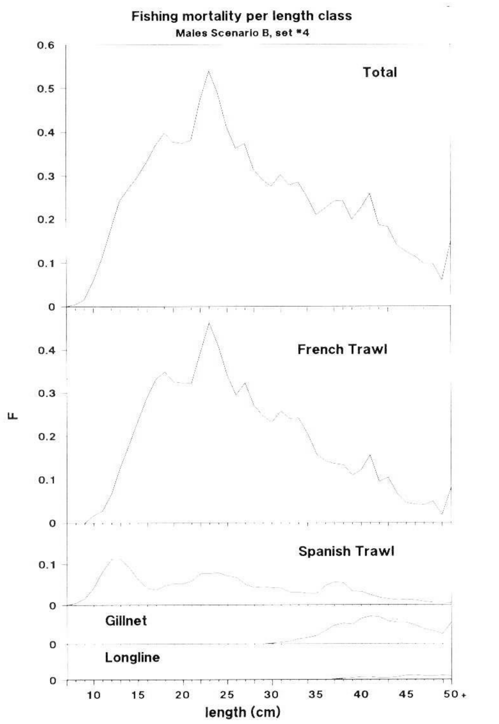

FIG. 6. — Hake fishing mortality (F) distribution by length class and gear in absolute numbers. Scenario B and parameter set #4.

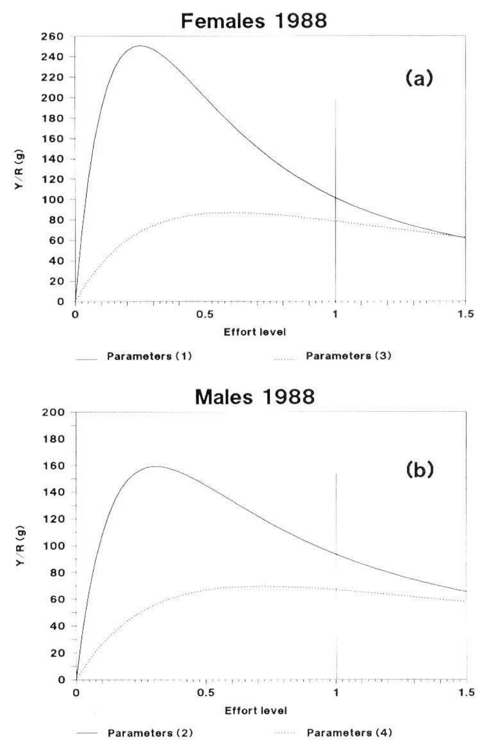

FIG. 7. — Yield per Recruit (Y/R) of hake. Global results, gear aggregated. (a) Females Yield per Recruit by scenario, corresponding parameters (1) to scenario A and parameters (3) to scenario B. (b) Males Yield per Recruit by scenario, corresponding parameters (2) to scenario A and parameters (4) to scenario B.

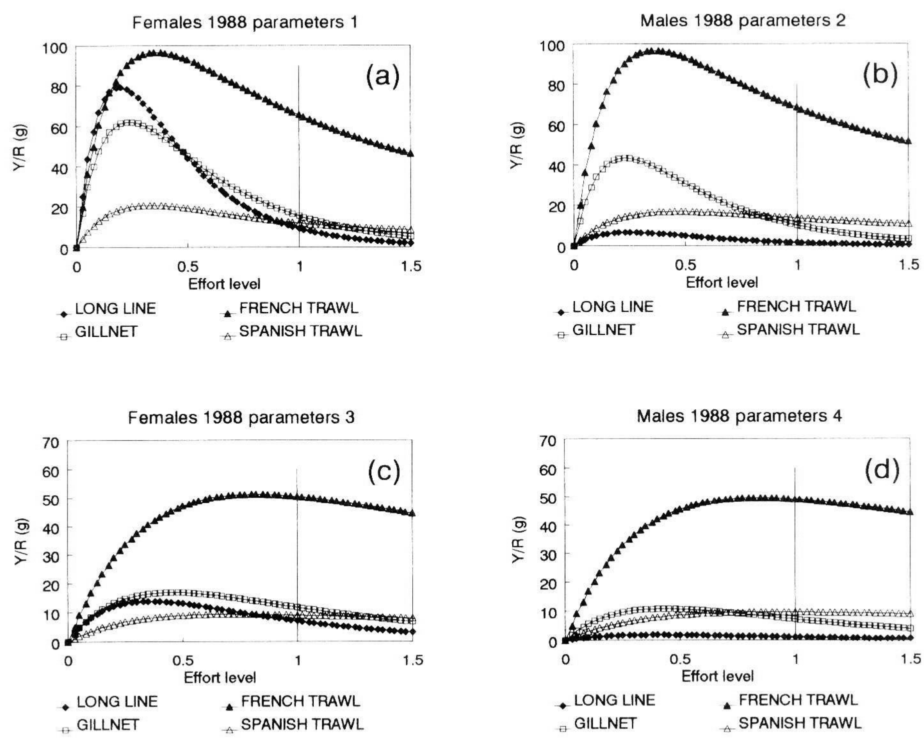

FIG. 8. — Yield per Recruit (Y/R) of hake gear disaggregated, all kinds of gear varying at once. (a) Females Yield per Recruit in scenario A. (b) Males Yield per Recruit in scenario A. (c) Female Yield per Recruit in scenario B. (d) Males Yield per Recruit in scenario B.

heless, convergence is guaranteed when there are more than 60 length classes.

In scenario A, where $M=0.15$, more than 80 % of deaths are caused by fishing, while in scenario B, where $M=0.2$, only half the deaths appear to be caused by fishing. In scenario B, the individual number and the stock biomass necessary to maintain the observed catches are twice those needed in scenario A. Accordingly, in scenario B, the fishing mortality levels needed to obtain the observed catch are half the corresponding values in scenario A.

The Yield per Recruit in equilibrium can be regarded as a surface in a space with as many dimensions as the number of types of gear exploiting the resource. Each axis of this space represents the effort of the corresponding gear. A range of efforts varying from 0 to 1.5, was considered, the present value being equal to 1. To give some idea about the shape of the Y/R surface defined by the effort of the four kinds of gear involved, some sections of this surface have been made. Since there are two scenarios, two sexes and four kinds of gear, the result is four (scenarios × sexes) surfaces of four (gear) dimensions each. Each surface can be sectioned in many directions and their results shown in various forms. In this study a selection of them was chosen.

Results are presented in graphs and tables. In the graphs, the results are expressed in gr/recruit. In the tables they are presented as percentages of differences of landings with respect to the present effort. In this last case the total catch (males + females) is given.

The first sections are on the main diagonal, i.e., all the kinds of gear vary their effort in the same sense; thus, at the first point effort is always 0, at point 0.8, effort is at 80 % of actual values, etc. The gear-aggregated results per sex and scenario are presented in Fig. 7. The same results are found in Fig. 8 and Table 5 for each kind of gear. In Table 6 aggregated results for the two sexes are presented.

The other sections represent the surface for one or two kinds of gear effort variations while the others remain at their present effort level. For each scenario, impact of effort variations of one gear over the three others is displayed in Figs. 9 and 10, taking into account only the female data. The same simulations were then run on landings. Results are presented (females and males together) in Tables 7 and 8. Table 9, shows the impact of both trawls varying together.

Some conclusions can be obtained from these results. The appearance of the population depends mainly on the scenario. In scenario A the population appears to be overexploited while in scenario B overexploitation is not so clear. In general, the Y/R surface is sharper in scenario A than in B. That is, the maxima are higher and nearer the origin, and the slopes are more pronounced. Females yield more biomass per unit effort than males. The French trawl, as is expected from the catches, is the dominant gear. This can be clearly seen by comparing Figs. 9c and 9d with the others. The tendencies appearing in Figs. 9 and 10 are quite similar. The differences are quantitative rather than qualitative.

The activity of the kinds of which gear catch small fish affects the others, but the reciprocal is not true, as it can be seen in Figs. 9 and 10 and in Table 9. This is because constant recruitment has been assumed. A reduction of fishing effort has more effect on catch than an equivalent increase. The simultaneous variation in effort of the two trawler fleets (Table 9) has a very high influence on catches by the other kinds of gear and on total landings; if we consider French and Spanish trawls separately (Table 7a and b), we can see that the French fleet has a higher influence on catch in proportion to the importance of this fleet; however, the impact of the Spanish trawler fleet is rather noticeable, if one takes into account the relatively small number of boats. On the other hand, gillnets and longlines (Table 8a and b), have a very limited effect on the trawl and on total landings; they only have a mutual influence on each other.

DISCUSSION

In the Gulf of Lions, hake is exploited in a more diversified way than in nearby areas such as the Balearic Islands (OLIVER *et al.*, 1991) where it is fished only by trawl, or other parts of the Catalan coast (LLEONART, 1990) where longlines are relatively unimportant. Because of this type of exploitation, the whole population becomes accessible, from indivi-

TABLE 5.— Yield per Recruit: present status per gear and per different values of fishing effort. Values of Y/R are in grammes.

	Scenario A		Scenario B	
	Fem. (#1)	Mal. (#2)	Fem. (#3)	Mal. (#4)
French trawl Y/R	65.6	68.4	50.5	49.0
Spanish trawl Y/R	11.8	13.6	9.1	9.7
Gillnet Y/R	15.4	10.1	11.8	7.2
Longline Y/R	9.2	1.5	7.1	1.1
Current Tot. Y/R	102.0	93.5	78.5	67.1
Maximum Y/R	250.9	159.3	87.0	69.7
Optimal effort for max. Y/R	0.25	0.30	0.60	0.72

TABLE 6.— Effects of change of fishing effort on landings of hake in the long term. All gears together.

*effort	Effects on landings at long term (%) for parameters #1 and #2					Effects on landings at long term (%) for parameters #3 and #4				
all gears	Fr. tr.	Sp. tr.	gillnet	longl.	total	Fr. tr.	Sp. tr.	gillnet	longl.	total
.50	43	43	207	434	86	−7	−6	45	82	5
.70	24	25	99	173	42	0	0	31	50	7
.80	15	16	58	94	25	1	1	21	32	5
.90	7	8	26	39	12	1	1	11	16	3
.95	4	4	12	18	6	1	1	5	8	2
act. f	2013	381	385	162	2941	2013	381	385	162	2941
1.05	−3	−3	−11	−15	−5	−1	−1	−5	−7	−2
1.10	−7	−7	−20	−28	−10	−2	−1	−10	−14	−3
1.20	−13	−12	−37	−47	−18	−3	−3	−20	−27	−7
1.30	−18	−17	−49	−62	−24	−6	−5	−29	−37	−10
1.50	−27	−25	−68	−79	−35	−10	−9	−44	−55	−17

TABLE 7. — Effects of change of fishing effort on landings of hake in the long term. a: French trawl, b: Spanish trawl.

a *effort	Effects on landings at long term (%) for parameters #1 and #2					Effects on landings at long term (%) for parameters #3 and #4				
Fr. trawl	Fr. tr.	Sp. tr.	gillnet	longl.	total	Fr. tr.	Sp. tr.	gillnet	longl.	total
.50	2	107	225	270	60	−21	58	109	123	14
.70	6	52	101	119	30	−8	31	56	62	9
.80	5	31	59	68	19	−5	19	34	38	6
.90	3	14	26	30	9	−2	9	16	17	3
.95	1	7	12	14	4	−1	4	8	8	1
act. f	2013	381	385	162	2941	2013	381	385	162	2941
1.05	−1	−6	−11	−12	−4	1	−4	−7	−8	−1
1.10	−3	−12	−20	−23	−8	1	−8	−14	−15	−3
1.20	−6	−21	−37	−40	−14	1	−15	−25	−27	−6
1.30	−9	−30	−49	−54	−20	1	−21	−35	−38	−9
1.50	−16	−42	−68	−72	−29	0	−32	−52	−55	−14

b *effort	Effects on landings at long term (%) for parameters #1 and #2					Effects on landings at long term (%) for parameters #3 and #4				
Sp. trawl	Fr. tr.	Sp. tr.	gillnet	longl.	total	Fr. tr.	Sp. tr.	gillnet	longl.	total
.50	16	−42	27	33	11	11	−45	17	19	5
.70	9	−23	16	19	7	6	−26	10	11	3
.80	6	−15	10	12	4	4	−17	6	7	2
.90	3	−7	5	6	2	2	−8	3	4	1
.95	2	−4	2	3	1	1	−4	2	2	0
act. f	2013	381	385	162	2941	2013	381	385	162	2941
1.05	−1	3	−2	−3	−1	−1	4	−2	−2	0
1.10	−3	7	−5	−6	−2	−2	8	−3	−3	−1
1.20	−6	13	−9	−11	−4	−4	15	−6	−7	−2
1.30	−9	19	−13	−16	−6	−6	22	−9	−10	−3
1.50	−14	30	−21	−25	−10	−10	36	−14	−16	−5

duals of very small size to the large females that cannot be caught easily in areas where only trawl fishing exists. Such conditions of exploitation could be favourable to overexploitation.

The main result of this study shows the interactions between kinds of gear. The major impact of the two trawler fleets on the hake stock is due in first place to their numerical importance compared with the small number of longline and gillnets. In the second place it is due to the pattern of exploitation. The number of fish caught by trawls is very high and, even if large fish are also caught, the landings consist mainly on small sized fish. Gillnets and longlines catch only quite large fish and the total number of fish caught is low. Their catches depend on the survival rate of younger individuals and therefore on the effect of trawling.

The tendency to overexploitation or at least to

TABLE 8. — Effects of change of fishing effort on landings of hake in the long term. a: gillnet, b: longline.

a *effort	Effects on landings at long term (%) for parameters #1 and #2					Effects on landings at long term (%) for parameters #3 and #4				
gillnet	Fr. tr.	Sp. tr.	gillnet	longl.	total	Fr. tr.	Sp. tr.	gillnet	longl.	total
.50	5	6	−39	42	1	3	3	−45	19	−3
.70	3	3	−21	23	1	1	2	−26	11	−1
.80	2	2	−14	15	1	1	1	−17	7	−1
.90	1	1	−6	7	0	0	1	−8	3	0
.95	0	1	−3	3	0	0	0	−4	2	0
act. f	2013	381	385	162	2941	2013	381	385	162	2941
1.05	0	−1	3	−3	0	0	0	4	−2	0
1.10	−1	−1	6	−6	0	0	−1	8	−3	0
1.20	−2	−2	11	−12	−1	−1	−1	15	−6	1
1.30	−2	−3	17	−18	−1	−1	−2	23	−10	1
1.50	−4	−5	26	−27	−1	−2	−3	36	−15	2

b *effort	Effects on landings at long term (%) for parameters #1 and #2					Effects on landings at long term (%) for parameters #3 and #4				
longline	Fr. tr.	Sp. tr.	gillnet	longl.	total	Fr. tr.	Sp. tr.	gillnet	longl.	total
.50	1	2	8	−35	0	1	1	4	−44	−1
.70	1	1	4	−19	0	0	0	2	−25	−1
.80	1	1	3	−12	0	0	0	1	−17	−1
.90	0	0	1	−6	0	0	0	1	−8	0
.95	0	0	1	−3	0	0	0	0	−4	0
act. f	2013	381	385	162	2941	2013	381	385	162	2941
1.05	0	0	−1	3	0	0	0	0	4	0
1.10	0	0	−1	5	0	0	0	−1	8	0
1.20	0	−1	−3	11	0	0	0	−1	15	1
1.30	−1	−1	−4	15	0	0	0	−2	23	1
1.50	−1	−1	−6	24	0	−1	−1	−3	37	1

TABLE 9. — Effects of change of fishing effort of French and Spanish trawlsl on landings of hake in the long term.

*effort	Effects on landings at long term (%) for parameters #1 and #2					Effects on landings at long term (%) for parameters #3 and #4				
Fr. + Sp. tr.	Fr. tr.	Sp. tr.	gillnet	longl.	total	Fr. tr.	Sp. tr.	gillnet	longl.	total
.50	22	25	318	396	82	−12	−11	145	166	19
.70	17	18	134	160	40	−2	−2	71	80	12
.80	12	12	76	89	24	0	−1	43	48	8
.90	6	6	32	37	11	0	0	19	22	4
.95	3	3	15	17	5	0	0	9	10	2
act. f	2013	381	385	162	2941	2013	381	385	162	2941
1.05	−3	−3	−13	−15	−5	0	0	−8	−9	−2
1.10	−6	−6	−24	−27	−9	−1	−1	−16	−18	−4
1.20	−11	−11	−42	−47	−17	−3	−2	−30	−32	−8
1.30	−16	−15	−56	−61	−24	−4	−3	−41	−44	−11
1.50	−26	−23	−74	−79	−35	−9	−7	−58	−62	−18

heavy exploitation is an important conclusion of the population analyses. This result was already obtained by ALDEBERT and CARRIES (1989) in a study considering only females and French landings without distinguishing gear. The value of present Y/R was lower than the optimum one. According to our results which complete and amplify these previous studies, the optimum effort level is rather widely exceeded. The gears that have the biggest influence on the Y/R are trawls. Small variations of trawling effort can have a large long term influence on both catches and yield.

On the other hand, the comparison of the Y/R values for males and females shows that the observed differences between the two sexes can be mainly caused by the slight relative weight of males in longline and gillnet landings. Instead, Y/R of trawls is rather similar for both sexes. This is a further reason for stu-

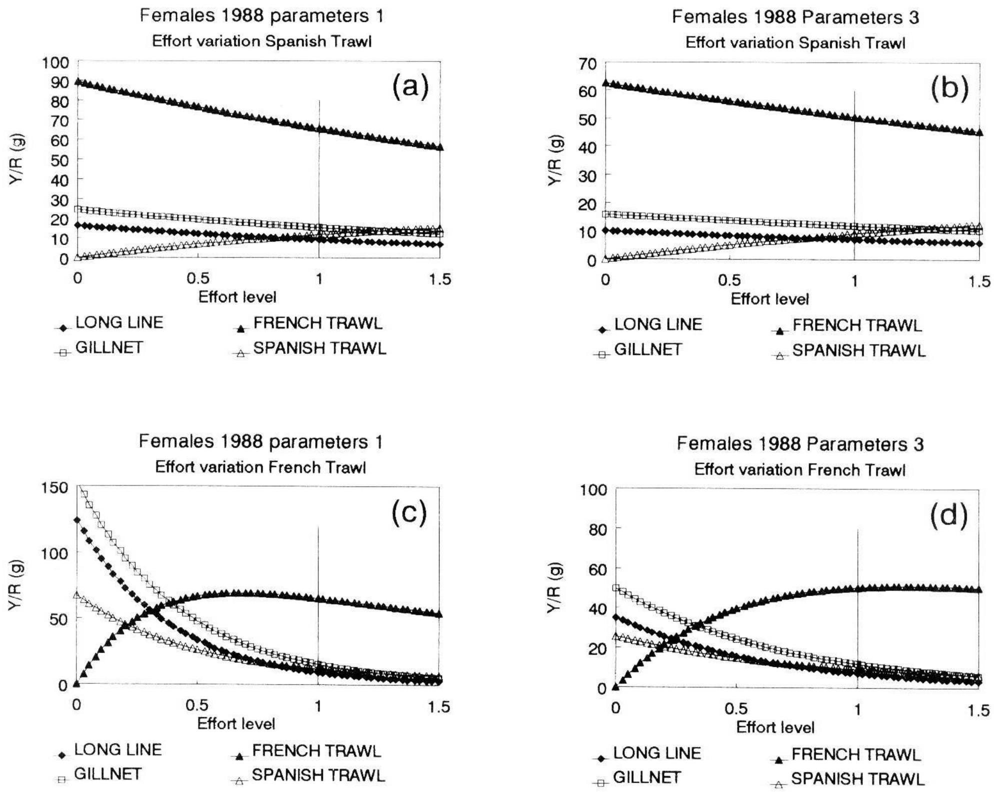

FIG. 9. — Yield per Recruit (Y/R) of female hake gear disaggregated. (a) varying Spanish trawl effort in scenario A. (b) varying Spanish trawl effort in scenario B. (c) varying French trawl effort in scenario A. (d) varying French trawl effort in scenario B.

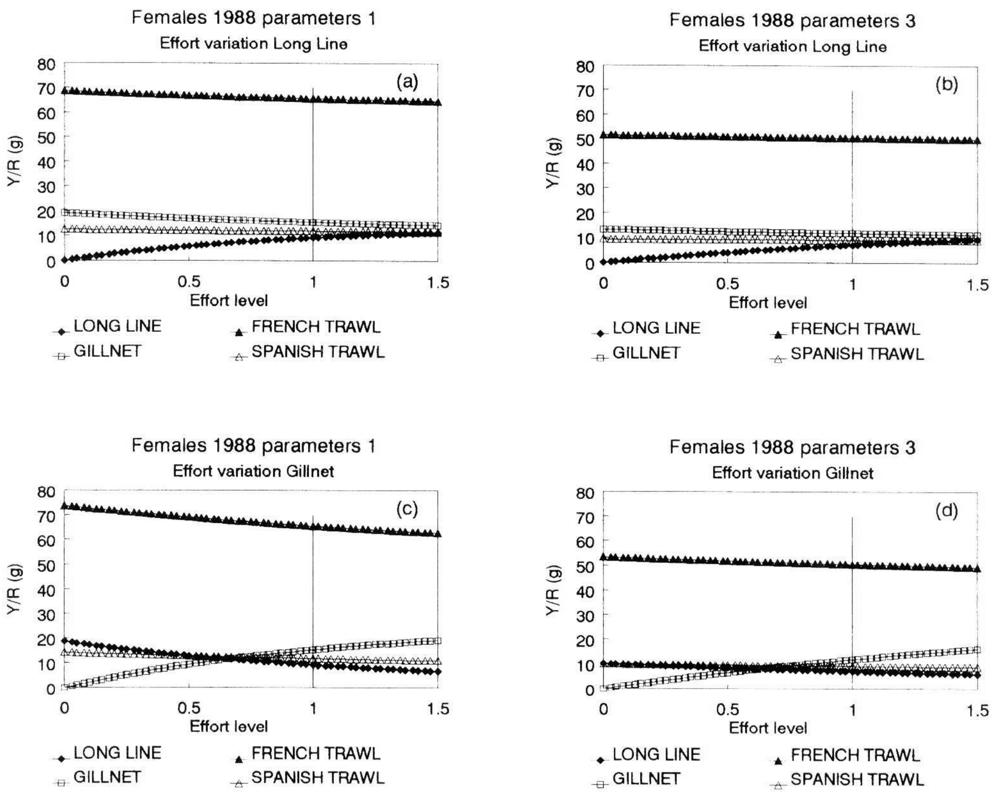

FIG. 10. — Yield per Recruit (Y/R) of female hake gear disaggregated. (a) varying longline effort in scenario A. (b) varying longline effort in scenario B. (c) varying gillnet effort in scenario A. (d) varying gillnet effort in scenario B.

dying females and males separately in areas where the stock is exploited by kinds of gear with different exploitation patterns. It should be less important in areas like the Balearic Islands where the population is exploited only by trawlers (OLIVER *et al.*, 1991).

The effect of the two different parameter sets on both VPA and Y/R analyses, has been discussed previously. In a general way, we can say that the values obtained by VPA, both in numbers and biomass in scenario A are half those obtained in second scenario. Yield per recruit instead has a higher value. Thus overexploitation is more likely in the first case. The conclusions concerning long term landings are comparable. In spite of similar tendencies, the absolute effect of the variations of fishing effort on landings should be much more important in scenario A. It must be noticed that in both cases the decrease of fishing effort has a higher impact than an increase.

In conclusion, the use of adequate biological parameters appears to be a prerequisite to population analyses, especially when results are needed for fisheries management. Also, special attention might be paid to natural mortality. Furthermore recruitment is rarely constant from one year to another. However, if one must be cautious on the absolute values of results, the general tendency remains valid.

These results and conclusions must be viewed in the light of the limits of the methods employed. The restrictive hypotheses used, mainly equilibrium (that involves constant recruitment), and constant natural mortality, are probably far from reality. But the apparent sensitivity of the results to the parameters and the uncertainty of their estimators, lead us to look at the conclusions with prudence. Nevertheless, hake in the Gulf of Lions is almost certainly overexploited.

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