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BIOLOGICAL ASPECTS OF SPANISH (CHUB) MACKEREL (*Scomber japonicus*, Houttuyn, 1782) IN THE BAY OF BISCAY FROM THE BASQUE COUNTRY CATCHES

by

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ABSTRACT

Fish total and gutted weight and length relationships, sex ratio, monthly evolution of condition factor, stomach repletion, maturity stages and gonosomatic index, and mean length at first maturity of Spanish (Chub) mackerel (*Scomber japonicus*, Houttuyn, 1782) in the Bay of Biscay are presented.

485 Chub mackerel from commercial landings caught mainly in the South-eastern Bay of Biscay (ICES Divisions VIII b,c), in the period [1989-1993] and 1997, are studied. The length range of specimina is between 13.6 and 47.5 cm of total length. All fish more than 30 cm length (4 and more years old) are found in spawning condition in May and June, spent in August, and from September to January in resting condition. Stomach repletion index is maximum from September to November. The fishery get usually the lowest catches from February to June and the highest values from September to November. Sex ratio observed for fish more than 30 cm length is close to 1:1. The total length (mm) - total weight (g) relationship is described by the multiplicative model: $W = 0.00000102549 * L^{3.376}$; $r = 0.995$.

Key words: Bay of Biscay, biology, chub (spanish) mackerel, Scomber japonicus, fishery, reproduction.

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INTRODUCTION

Spanish (Chub) mackerel (*Scomber japonicus,* Houttuyn, 1782) is, as the Atlantic common mackerel (*Scomber scombrus,* L. 1758), a medium-size pelagic species. It is abundant in Pacific and Atlantic waters, and supports a very important fishery. In Table 1 the official landings of both species by sea area, in the years 1991-1993, are presented, after FAO (1995).

Chub Mackerel (*S. japonicus*)				
		Landings (t)		
Sea area	FAO	*1991*	*1992*	*1993*
Nort.East. Atlantic	27	10672	9165	8122
Nort.West. Atlantic	21	0	0	0
Mediterranean Sea	37	19615	26599	31620
Centr.East. Atlantic	34	140631	80359	54975
Centr.West. Atlantic	31	380	316	924
South.East. Atlantic	47	16614	4351	4806
South.West. Atlantic	41	11465	10038	11860
Nort.East. Pacific	67	20	785	30
Nort.West. Pacific	61	617536	668902	1153494
Centr.East. Pacific	77	67650	38036	31481
Centr.West. Pacific	71	1577	3344	4838
South.East. Pacific	87	293682	112253	159155
South.West. Pacific	81	2163	2691	800
Centr.West. Indic	51	0	0	1
Total		1182005	956839	1462106

Mackerel (*S. scombrus*)				
		Landings (t)		
Sea area	FAO	*1991*	*1992*	*1993*
Nort.East. Atlantic	27	689498	737370	799289
Nort.West. Atlantic	21	61816	37486	31869
Mediterranean Sea	37	8444	8529	10287
Total		759758	783385	841445

Table 1. Official landings of Spanish (Chub) Mackerel (*S. japonicus*) and Mackerel (*S. Scomber*), by sea area, in the period [1991-1993]. (After FAO, 1995).

In the Northeast Atlantic, also both species of mackerel (*Scomber sp.*) are present, but the common mackerel (*S. scombrus*) is more abundant, being the *S. japonicus* fishery restricted practically to the southern Bay of Biscay, southern Portugal, Bay of Cadiz, Canary Islands and western Marocco and Sahara waters. Southern Bay of Biscay might be considered as the upper limit of this Northeast Atlantic fishery. The presence of some specimina of *S. japonicus* has been reported also recently from Irish waters (Quigley and Flannery, 1994), but they do not support at present a commercial fishery. Spain, Portugal and France are the only three countries involved in the Spanish mackerel's Atlantic European fishery.

S. japonicus is caught in significant amounts only in the more south-eastern part of Bay of Biscay -ICES Divisions VIII b and (central and east) VIII c-, i.e. approximately from the mouth of the Garone river (France) to the coast of Cantabria (Spain) (Figure 1), as it happens also with the Mediterranean horse mackerel (*T. mediterraneus*). A probable explanation of the presence of so "isolate islands" of these species in only this corner of the North-eastern Atlantic might be found in the water's "Mediterranean" condition (for its temperatures range) of the south-eastern Bay of Biscay (Lucio, 1996).

Basic information on the Spanish fishery of *S. japonicus* in the Bay of Biscay (landings and length distributions by quarter, gear and sea division, has been reported routinely to the ICES Mackerel Assessment Working Group from the end of the 80's henceforth (Martin and Lucio 1989; Martin 1989; Lucio and Villamor, 1990, 1991, 1992, 1993). However studies on growth, reproduction and feeding of *S. japonicus* in the Bay of Biscay are unknown. Only preliminary information about the length/weight relationship for this species and about its reproduction season was presented by Lucio (1993).

From the 80's information on growth and reproduction and on some other biological characteristics of Spanish mackerel from others different areas of the north-eastern Atlantic waters has been published. So, for *southern Portugal* (Martins *et al.*, 1983; Martins and Gordo, 1984; Martins, 1996; Martins and Cardador, 1996); for *Gulf of Cadiz* (Rodriguez-Roda, 1982); for *Canary Islands* waters (Castro and Lorenzo, 1991; Castro, 1993; Castro and Del Pino, 1995; Lorenzo-Nespereira and González-Pajuelo, 1993; Lorenzo *et al.*, 1995; Ramos *et al.*, 1991); and for *Mediterranean sea* (El-Sherif *et al.*, 1995; Gasim *et al.*, 1989; Giama *et al.*, 1987; Greze and Salekhova, 1987). Recent biological information on *S. Japonicus* from other Atlantic and Pacific sea areas are also available: for *central and south-eastern Atlantic* (Habashi *et al.*, 1987; Kuderskij *et al.*, 1993; Ostapenko, 1987; Pájaro, 1993; Provotorova and Berembejm, 1993; Scherbich and Venidiktova, 1993; Tarverdieva, 1985); *for south-western Atlantic* (Forciniti and Perrota, 1988; Goberna, 1985; Perrota, 1992 and 1993; Perrota and Christiansen, 1993; Perrota *et al.*, 1989); *for eastern Pacific* (Aguayo, 1986; Alekseev and Isakov, 1986; Cisneros *et al.* 1990; Gluyas-Millan, 1984 and 1994; Gluyas-Millan and Gomez-Muñoz, 1993; Gluyas-Millán and Uraga, 1990; Konchina 1985, 1990; Morales-Nin, 1988; Pardo and Oliva, 1992); *for western Pacific* (Asano and Tanaka, 1989; Ivanov, 1989; Murayama *et al.*, 1995; Ozawa *et al.*, 1991; Sato, 1990; Stovbun, 1992)...

The aim of this paper is to offer some results about the fishery and the biology (mainly on growth and reproduction) of *S. japonicus* captured by the Basque fleet in the period [1989-1997] in the Bay of Biscay, as so a preliminary analysis of these data, above all in relation with the *S. scombrus* fished at the same years and in the same sea area.

DESCRIPTION OF THE *S. japonicus* FISHERY IN THE BASQUE COUNTRY

In the Basque Country (Spain), the Spanish mackerel (*S. japonicus*) is on the basis of a traditional fishery of a certain economical importance above all for the coastal ("bajura") fleet. The sea area in which the catches are taken is restricted to ICES Division VIII c (more eastern part) and Division VIII b (more southern part), i.e. to the south-eastern part of the Bay of Biscay (Figures 1 and 2). In this area, but at two rather different periods of the year, two *Scomber* species appeared in the catches: *S. scombrus* and *S. japonicus*. Fishermen and people that take part in the marketing distinguish very well both species: usually *S. japonicus* reach higher prices than common mackerel. It is due probably to these two market reasons: the Spanish mackerel catches are not produced in so high quantities in so short time period (supply does not exceed so markedly to demand) and likely the fish condition (more fat content in muscle) renders it more appreciated for canning or for human consumption in fresh. The Spanish official name for Spanish mackerel is "*Estornino*", but in different parts of the country this species has different local names ("*Sarda*", "*Cuerva*",...). As its eye is rather larger than in common mackerel, *S. japonicus* is denominated traditionally in some ports of the Basque Country as "*Betandi*" ("Big-eye"), but in other ports as "*Maka(r)ela*", versus "*Berdela*" or "*Verdel*" (because of the "green" external appearance of common mackerel), or "*Caballa*" (official name in Spanish) for *S. scombrus*.

In the Figure 3.a the evolution of the mackerel landings in the fishing ports of the Basque Country in the in the period [1950-1993] is presented. From the middle of the 70's a more strict allocation of the *Scomber* sp. catches to *S. scombrus* or to *S. japonicus* took place in all the Basque ports.

The marked oscillations observed in the annual landings are not well explained. They might be due to the fluctuations in the availability of the resource, but also and perhaps principally to market reasons. Spanish mackerel is not a main target species to the purse seiner fleet, but a complementary resource for a part of the boats that do not take part in the summer-autumn tuna fishery (live bait). Moreover in some years a part of the fleet can prefer to land their catches in the ports of Cantabria (Spanish contiguous region to the east of the Spanish Basque Country). Any case, the apparent increment of the landings of this species began on the 60s. Probably this resource was always available in determinate months of the year, but a sum of causes did not very interesting its fishery. In general Spanish mackerel is not very appreciated by the common Basque people, used to eat in fresh condition other fish rather more tasty for them and, by other hand, smoked mackerel (and other fish) resulted rather then strange for the most of the people. The developing of new techniques for the purse seiners in the 60s (power block, new devices for fish detection, ...) and the introduction of freezing plants for fish in the 70s allowed to store mackerel and to use it for different purposes: as bait for other fisheries, as raw material for canning, etc.

The Spanish mackerel abundance in the Bay of Biscay has never been evaluated. The strict situation of this stock is unknown. But, based in the historical series of the catches and in the limited effort directed to the resource, it should be possible to advance that it cannot be considered as sufficiently exploited. At present it is not absolutely sure that they form a permanent stock restricted to the south-eastern corner of the Bay of Biscay or that they migrate from/to other more southern waters. The apparent and so many times discussed theme of the warming of the sea water in the recent years, particularly from the end of the 80's, might explain perhaps the observed increment of the catches. Anyhow, the special condition of the waters in the south-eastern Bay of Biscay, by its range of temperatures, might support also the presence of this species in it.

In the period [1987-1993], the range of the annual landings of this species in the Basque Country was between 236 and 2.078 t. (In 1996 the total landings of this species reached the 2,297 t (A.Uriarte and I.Artetxe, pers.comm.)). The landings in the Basque ports represent usually about 2/3 of total Spanish landings of this species captured in the Bay of Biscay along the period [1989-1993] (Lucio and Villamor, 1990, 1991, 1992, 1993).

		S. japonicus				
Division	**Quarter**	**P. seine**	**Hook&Line**	**Gillnet**	**Trawl**	**Total**
VIIIc	I	43.6	0	0	0	**43.6**
	II	86.5	0.3	0	0	**86.8**
	III	457.4	0	0	0	**457.4**
	IV	643.9	0.1	0	0	**644.0**
	Total	***1,231,4***	***0.4***	***0***	***0***	***1,231.8***
VIIIa+b	I	0	0	0.1	0.4	**0.5**
	II	0	0.9	0	0	**0.9**
	III	0	0.6	0	0.3	**0.9**
	IV	0	1.6	0	0.1	**1.7**
	Total	***0***	***3.1***	***0.1***	***0.8***	***4.0***
VIIIa+b+c	I	43.6	0	0.1	0.4	**44.1**
	II	86.5	1.2	0	0	**87.7**
	III	457.4	0.6	0	0.3	**458.3**
	IV	643.9	1.7	0	0.1	**645.7**
	Total	***1,231.4***	***3.5***	***0.1***	***0.8***	***1,235.8***

		S. scombrus				
Division		**P. seine**	**Hook&Line**	**Gillnet**	**Trawl**	**Total**
VIIIa+b+c	***Total***	***4,748***	***5,480***	***378***	***441***	***11,047***

Table 2. Landings (in tonnes) of Spanish mackerel (*S. japonicus*) in the ports of the Basque Country, by quarter, division and gear (Purse seine, Hook and line, Gillnet and Trawl), in 1993. (To comparation, also the annual landings in the Basque Country of common mackerel (*S. scombrus*) from the same divisions and gears are presented).

The mackerel fishery is carried out by different gears (purse seine, hook and line, bottom trawl, long line and gillnet), but the purse seiners obtain traditionally the most of the catches landed (> 99%). In Table 2 the *S. japonicus* landings in the Spanish Basque Country fishing ports, by division and gear, in 1993, are presented, as an exemple.

The *S. japonicus* Basque fishery is characterised by a very marked seasonality. In Table 2, as an example, the *S. japonicus* quarterly landings in the Basque Country, in 1993, are presented. Third and fourth quarter landings represent every year close to the 90% of the annual landings in the Basque ports. Even more, almost 2/3 of these landings take place usually in only three months: September-October-November, being traditionally October perhaps the more important month for the catches of this species (Figure 3.b). The minima landings take place usually from February to June -and yet to August (in these seven months, < 20% of the total landings).

The more important *S. japonicus* and *S. scomber* landings in the Basque ports are produced in different months/seasons: Spanish mackerel principally in September-November, common mackerel, in March-April (Figure 3.c).

Most of the landings correspond usually to rather big fish. In the period [1987-1993] 95% of the fish landed were ≥30 cm total length (and 30% ≥40 cm) (Figure 4.a-b). In 1993, as in other years, not marked differences were found in the fish size of the landings from the different quarters (Figure 4.c) neither from the Division VIIIc or VIIIb.

S. japonicus discards estimations in Divisions VIIIa, b and c, in the different gears of the Spanish fleet were carried out in 1993-1995, based on the information obtained by observers on board of commercial ships (Pérez at al., 1995). The trawler fleet working in Divisions VIIIa,b discards the most of the catches (95%) in the second part of the year (in the first part catches were null), but the amount of the catches were very low (<100 kg/100 fishing hours). In Division VIIIc no catches neither discards by trawlers were estimated by the observers. In the purse seiner fleet very important rates of discards were noticed in the first and second half of the year. In other gears (long liners and gillnets in the same Divisions VIIIa,b,c no catches neither discards were observed.

MATERIALS AND METHODS

The *S. japonicus* biological data have been obtained by means of sporadic analyses of specimina sampled in different years [1989-1991; 1993 and 1997]. The sampling scheme in this time period has been incomplete, because the target species in the *Scomber sp.* sampling was only *S. scombrus*, but any case all the *S. japonicus* specimina were taken at random in the different months. Most of the 1990 samples correspond to June and September-December months and most of the 1993 and 1997 samples to May. As it was not possible to achieve sufficient samples from all the months and from all size categories in not one of these years, all samples from the different years have been considered as forming one "synthetic year sampling" for the present study.

The samples were collected at the Basque Country (Spain) fishing ports of Ondarroa and Bermeo, from the market landings of purse seiners. The catches were obtained in the south-eastern part of the Bay of Biscay, i.e., in the standard ICES Divisions VIII c (eastern part) and VIII b (southern part), as it is shown in Figure 1. Even though the area of origin, by division and, in some cases, by statistical rectangle, was recorded, the present analysis does not take in account these geographical differences because of the scarcity of the samples.

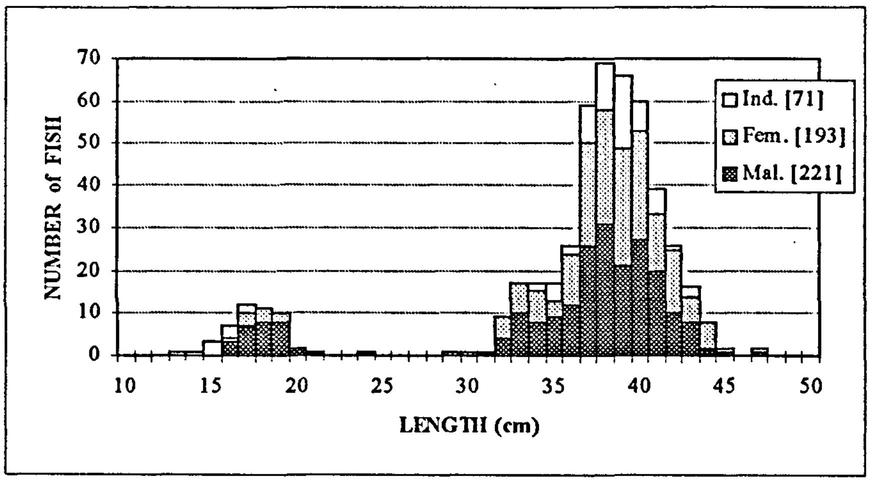
The combination of time period (month) and sampling area (Bay of Biscay as a whole) was regarded as a sampling cell. From the most of the fish analysed, the following data were recorded:

- Total length (in mm)
- Total weight (in g)
- Gutted weight (in g)
- Sex (male, female, indeterminate)
- Weight of the gonads (0.1 g)
- Maturity stage (macroscopically)
- Index of stomach fullness
- Presence of periviscerialis fat
- Age (by otolith (sagitta) reading)

The number of fish analysed by year were so :

Year	*1989*	*1990*	*1991*	**	*1993*	**	*1997*	***Total***
Number	38	286	7	**	68	**	86	485

The fish analysed by sex and length class (cm) were as it follows. In a rough way, they correspond to the usual length composition of the fish landed (Figure 4.a.).



Besides, a routine length sampling scheme for *S. japonicus* (as for *S. scombrus*) has been carried out from 1987 henceforth by AZTI, in relation to landings of *S. japonicus* (and other commercial species) in the Basque Country from the Bay of Biscay. The results have been routinely presented to the Mackerel, Horse Mackerel, Sardine and Anchovy ICES Working Group in form of Working Documents (Martin and Lucio, 1989; Lucio *et al.* 1990; Lucio and Villamor 1991, 1992, ...).

Programs written in VAX BASIC V2.4 for a MicroVax II were used in order to store data and to analyse the results on the basis of different time periods, sexes, sea areas and ranges of length, weight, age, and maturity stage. Other statistical analysis have been carried out by means of Statgraphics Plus 3.0 program.

RESULTS and DISCUSSION

1. Length and Weight relationships

1.1. Total Length/Total Weight relationships. Equations for the relationships between total length and total weight were obtained by least squares linear regression after log transformation of both variables. Confidence limits and statistical comparisons of the slopes and the intercepts of the equations were made following Sokal & Rohlf (1969). The results were:

Considering all sampling areas together, the annual total weight-total length (in mm and in cm) relationships obtained for the period in study [1989-1997] were :

SEX	$W = a * L^b$	Number	r	Length range	Weight range
Males	$W = 0.00000096363 * L^{3.387}$ $W = 0.002349 * L^{3.387}$	221	0.996	[165-475] mm *[16.5-47.5] cm*	[29.5-980.5] g
Females	$W = 0.00000112394 * L^{3.269}$ $W = 0.002569 * L^{3.269}$	193	0.991	[165-474] mm *[16.5-47.4] cm*	[31.5-1008.5] g
All sexes	$W = 0.00000102549 * L^{3.376}$ $W = 0.002437 * L^{3.376}$	485	0.995	[136-475] mm *[13.6-47.5] cm*	[16.5-1008.5] g

No statistically significant differences (α=0.05) were found between sexes in the "b" value, when the length ranges were similar. (95% Confidence Limits (C.L.) are calculated as: ± 1.96 S.E.).

	b		
SEX	Value	95% C.L.	
Males	3.387	3.34707	3.42705
Females	3.269	3.29713	3.42130
All sexes	3.376	3.34869	3.40448

In Figure 5.a-b, the total length/total (and gutted) weight relationship of *S. japonicus* in the Bay of Biscay, both sexes included, in the period considered is shown. Also, for comparison, the total length/total weight relationship of *S. scombrus* in the Bay of Biscay, in the period [1987-1993] (Lucio, 1997) is represented.

1.2. Total Length/Gutted Weight relationship. Gutted weight has been considered the weight of the fish without gonads, digestive tract, liver and heart.

The annual relationship found between total Length (in mm and in cm) (L) and gutted Weight (in g) (W_g) for the period [1989-1997] was calculated as :

	$W = a * L^b$	Number	r	Length range	Weight range
All sexes	$W = 0.00000120463 * L^{3.327}$ $W = 0.002558 * L^{3.327}$	386	0.987	[136-475] mm *[13.6-47.5] cm*	[15.5-865.5] g

1.3. Total Weight/Gutted Weight relationship. The relationship found between total Weight (in g) (W_t) and gutted Weight (in g) (W_g), for the period [1987-1997], was so:

	$W_g = a + b\,W_t$	Number	r
All sexes	$W_g = 6.28 + 0.871\,W_t$	386	0.992

2. Condition factor

The condition factor (CF) values have been calculated in two ways:

$$CF_t = W_t / L^3 \ * 10^8 \qquad \text{and} \qquad CF_g = W_t / L^3 \ * 10^8$$

where W_t is the total body weight (in g),
W_g is the gutted body weight (in g), and
L is the total length (in mm).

It must be pointed out that it was not possible to sample fish ≥30 cm length in February-April and July, and that the sampling for fish <25 cm was always very scarce except in October-November.

2.1. For immature fish (<25 cm length), both sexes combined, the evolution of the CF values in the period [1989-1997] showed an increment around 24% from minima values in winter (February-March) to maxima values in spring (May) (Figure 6.a). Nevertheless these results must to be taken with caution because of the scarcity of the sampling.

2.2. For individuals ≥30 cm length, the monthly evolution of the CF values in the period [1989-1997], followed the same general pattern in males and females (Figures 6.b and 6.c). The evolution of both CF_t and CF_g values presented one maximum in autumn (October-November) and one minimum in spring (May-June). The CF_t values increments from minima in May-June to maxima in October-November were around 19% in males and 13% in females, and the Cf_g values increments between the same months were about 24% in males and 19% in females.

The lowest differences between CF_t and CF_g values took place in December-January, when they were about 8% in both sexes, and the biggest ones in spring (in May-June), when they were about 16% in both sexes.

2.3. The maturity stages seem to have some influence in the CF seasonal evolution (Table 3): in general the lowest values have been found in active and full spent adults (≥30 cm length), males and females, and the highest values in resting fish. Any case the timing of the CF peaks in each stage coincided approximately with those of the whole population: minima in spring and maxima in autumn. The CF values for fish in "full spent" stage appeared higher than for "active" fish in males, but lower than for "active" fish in females. These contradictory results might be explained by the rather low number of "full spent" fish analysed.

MONTH	MALES											
	ACTIVE			FULL SPENT			RESTING + + BEG. MATUR.			ALL STAGES TOGETHER		
	Mean	(n)	S.D.	Mean	(n)	S.D.	Mean	(n)	S.D.	Mean	(n)	S.D.
JAN							922	1		922	1	
FEB												
MAR												
APR												
MAY	808	74	48,9	751	2	9,5				807	76	49,3
JUN	769	33	39,2							770	33	39,2
JUL												
AUG				851	5	27,5				851	5	27,5
SEP							942	18	52,6	942	18	52,6
OCT							954	18	54,4	954	18	54,4
NOV							938	20	43,6	938	20	43,6
DEC							898	20	45,5	898	20	45,5
Total	796	107		822	7		932	77		852	191	

MONTH	FEMALES											
	ACTIVE			FULL SPENT			RESTING + + BEG. MATUR.			ALL STAGES TOGETHER		
	Mean	(n)	S.D.	Mean	(n)	S.D.	Mean	(n)	S.D.	Mean	(n)	S.D.
JAN							797	4	52,9	797	4	52,9
FEB												
MAR												
APR												
MAY	806	69	62,7	744	5	47,1				803	74	48,1
JUN	788	22	40,9							788	22	40,9
JUL												
AUG				847	1					847	1	
SEP							921	19	37,3	921	19	37,3
OCT							935	24	49,5	935	24	49,5
NOV							935	17	27,9	935	17	27,9
DEC							874	22	47,0	874	22	47,0
Total	802	91		761	6		910	86		852	183	

Table 3. Monthly evolution of the Condition Factor values of adult male and female *S. japonicus* (>30 cm) in the Bay of Biscay during [1989-1997], in relation to the maturity stages. Condition factor [CF(g)] has been calculated for gutted body weight - [CF(g) = (W(g) / L^3) * 10^8] ; W in g and L, in mm -, and each general category of the maturity stages: for ACTIVE (in maturation, pre-spawning and partly spent), for FULL SPENT and for the fish resting or at beginning of the annual maturation (RESTING+BEG. MATUR.). Mean values (Mean), standard deviation (S.D.) and number of observations (n) are indicated for each of these three categories and for all stages combined.

3. Sex ratio

Sampling for sex ratio was carried out for each cm-length interval. Individuals were obtained from samples of the landings taken at random. The number of fish ≥30 cm length analysed for sex ratio was 374 in the period [1989-1997]. The smaller fish sexed *de visu* had 16 cm length both in males and in females.

3.1. In Figure 7, the annual sex ratio of Spanish mackerel (≥30cm length) in the period [1989-1997], is represented. From the 374 fish of this size analysed, an annual sex ratio close to 1:1 was found.

In the different size categories no differences in the annual sex ratio were found, excepting for the small fish in which a high proportion of male was observed:

SEX \ Range	[15-29] cm	[30-39] cm	≥ 40 cm	*≥ 15 cm*
Males (%)	75.0	51.5	50.4	*53.4*
Females (%)	25.0	48.5	49.6	*46.4*
Males+Females (n)	*40*	*237*	*137*	*414*

However the departures from the annual sex ratio 1:1 observed in each length class (1 cm) or in each size category might be due rather to the sampling variability and to the relative scarcity of fish examined.

4. Maturity stages

Gonads of *S. japonicus* have an external shape and a general structure very similar to those ones of *S. scombrus*. To assess the condition of the sexual maturation in the fish, initially a maturity key of 10 stages (Basic MSK) was used on a routine basis in the monthly analyses, as for *T. trachurus* (Lucio and Martin, 1989) (Table 4). This approximate MSK was constructed in relation to the relative size and weight and the external appearance and colour of the gonads. Later, for more simplicity and robustness of the assessment, the results have been referred to a shorter and more comprehensive maturity stages key (Simplified MSK). A probable correspondence between the stages of these MSKs and those ones proposed in the Macer's key (1974) for *T.trachurus* is also presented in Table 4.

a) Basic MSK used (1996)	*b) Simplified MSK*	*c) Macer's (1974) MSK*
1. Juvenile (Virgin)	**I Virgin**	1. Virgin
2. Very early beginning of maturation	**II Beginning of maturation**	1-3. Developing virgin 2. Resting (mature fish)
3. In maturation 3'. Again in maturation 4. Pre-spawning 4'. Repeated pre-spawning 5. Spawning 6'. Partly spent	**III Active**	3. Developing (early) 4. Developing (later) 5. Ripe 6. Running 7. Partly spent
6. Full spent	**IV Full spent**	8. Spent
7. Resting	**V Resting**	9. Recovering

Table 4. Correspondence between a) the basic maturity stages key (MSK) as used in 1989-1997 for the routine biological analysis of Spanish Mackerel (*S. japonicus*), b) the simplified maturity stages key employed for different approaches in this paper, and c) the MACER's (1974) maturity stages key for horse mackerel (Macer's MSK).

It should be pointed out that the use of any macroscopical key can be subjected to a certain amount of subjectivism, and also that the discrimination between two contiguous maturity stages presents sometimes big difficulties. This difficulty is probably unsolvable *de visu* above all to discriminate between the stage of "resting" adults and "(very early) beginning of maturation" of adults and juveniles.

To obtain a more consistent interpretation of the basic data, all observations obtained in the period [1989-1997] were considered together. 414 fish -between 16 and 47 cm length- were studied for maturity determination: 221 males and 193 females.

4.1. In Figure 8, the monthly frequencies of maturity stages in males and females of $\geq$ 30 cm length (374 fish: 191 males and 183 females), are represented. Unfortunately no fish of this size were examined in February-April and in July.

. No fish in state "I" (virgin o juvenile) was found in the range [30-47] cm length during any month of the years considered.

. The basic annual pattern of evolution of the maturity stages resulted rather similar in males and females: in spring, fish in phase of reproductive activity; in late summer, autumn (and in winter), fish in post-spawning and resting stage, i.e. in phase of reproductive inactivity.

. The active phase (or "III", i.e., in stage of advanced maturation or pre-spawning or spawning) appeared with maximum frequencies in males and females, only in May (>95%) and in June (100%). Afterwards, in the rest of the year, the reproductive activity disappeared drastically in all the fish examined in this part of the Bay of Biscay (but no fish was analysed in July).

In May-June the proportions of males and females (≥ 30 cm length) found in the different stages were so:

SEX \ Stage	Advanced mature & Partly spent	Pre-spawning	Spawning	Full spent
Males (%)	19.3	57.8	21.1	1.8
Females (%)	74.5	15.3	5.1	5.1

In May 1997 two biological samplings (86 fish of ≥ 30 cm length) were carried out to check the results observed in spring of the period [1990-1993]. The new results confirmed thoroughly the previous ones: all fish were in reproductive activity in this part of the year.

. Fish in stage "IV", i.e., full spent, were found only in May (5%) and in August (100%).

. The scarcity of the sampling (no adult fish examined in February-April and in July) does not allow to know whether males mature earlier -and remain in activity phase later- than females neither whether the bigger fish (≥40 cm length) mature earlier than smaller ones, as it has been found in *S. scombrus*.

. Although it was not easy to discriminate accurately *de visu* the stages "II" (very early beginning of maturation) and "V" (resting), this phase of null or very scarce reproductive activity appeared yet at end of summer (September), was constant in autumn and it remained at least at the beginning of the winter (January), always in a maximum proportion (100%).

4.2. It is not possible to present a consistent distribution of the monthly frequencies of maturity stages for each Division (VIII b,c) of the Bay of Biscay, due to the relative scarcity of the fish analysed monthly in each sea area.

5. First sexual maturity determination

The onset of reproduction in males and females has been calculated from the length-maturity keys obtained from all samples of the period [1989-1997] together considered (Table 5). Only data of May and June were selected for this purpose, due that in these months the maxima of the reproductive activity were found according to the data of the maturity stages (see above chapter 4) and the gonosomatic index evolution (see below chapter 6).

In a rather conservative assumption, not only the stage "I" (virgin or juvenile) but also the stage "II" (very early beginning of maturation in the season in both juvenile and adult fish) were considered as determining the "immature" fish. The fish that presented other stages were considered "mature" -i.e. stage "III" (in condition of advanced maturation or pre-spawning or spawning) and stage "IV" (full spent). Stage "II" was assigned to females with small, pink ovaries and oocytes not visible, and males with very flattened, small and grey testes. To reduce the subjectivism factor, also all fish found in the likely stage "V" (resting) were considered as immature.

In order to smooth the variability in basic data, running means of three 1-centimetre length classes were obtained. The length at which 50% the males and females become mature (L_{50}) was estimated by means of the linear regression of logit transformed percentages (P) of mature males and females against the length class. The logit percentages was calculated as

$$Logit\ P = 0.5 * \ln (P/(1-P))$$

To achieve logit transformed percentages it is necessary that values [≠0] and [≠100] for mature and immature fish appear in the same or in immediate upper or lower length classes, at least in a determinate length range. As in the biological sampling, only real values for mature fish were obtained (excepting at 24 cm length class where one fish appeared immature), it was inevitable -in order to have at least a certain approximation of the maturity L_{50} figures - to introduce estimated values for Immature fish just before the length classes with real values of Mature males or females. In the Table 5 these estimated values have been marked by brackets [...].

Midpoint of the Length (cm)	MALES									FEMALES									Midpoint of the Length (cm)
	May			June			May+June			May			June			May+June			
	Imm (n)	Mat (n)	*Mat (%)*	Imm (n)	Mat (n)	*Mat (%)*	Imm (n)	Mat (n)	*Mat (%)*	Imm (n)	Mat (n)	*Mat (%)*	Imm (n)	Mat (n)	*Mat (%)*	Imm (n)	Mat (n)	*Mat (%)*	
≤20.5																			≤20.5
21.5																			21.5
22.5																			22.5
23.5																			23.5
24.5	1		*0*				1	0	*0*										24.5
25.5																			25.5
26.5																			26.5
27.5																[1]		*0*	27.5
28.5																[1]		*33*	28.5
29.5							[1]		*0*		1	*100*					1	*67*	29.5
30.5							[1]		*33*					1	*100*		1	*100*	30.5
31.5					1	*100*		1	*83*								0	*100*	31.5
32.5					4	*100*		4	*100*					5	*100*		5	*100*	32.5
33.5		2	*100*		7	*100*		9	*100*					6	*100*		6	*100*	33.5
34.5		1	*100*		6	*100*		7	*100*		2	*100*		1	*100*		3	*100*	34.5
35.5		5	*100*		1	*100*		6	*100*					2	*100*		2	*100*	35.5
36.5		3	*100*		3	*100*		6	*100*		5	*100*					5	*100*	36.5
37.5		9	*100*		6	*100*		15	*100*		11	*100*		3	*100*		14	*100*	37.5
38.5		13	*100*		4	*100*		17	*100*		13	*100*		2	*100*		15	*100*	38.5
39.5		9	*100*		1	*100*		10	*100*		13	*100*		1	*100*		14	*100*	39.5
40.5		13	*100*			*100*		13	*100*		12	*100*		1	*100*		13	*100*	40.5
41.5		11	*100*					11	*100*		3	*100*					3	*100*	41.5
42.5		5	*100*					5	*100*		5	*100*					5	*100*	42.5
43.5		1	*100*					1	*100*		3	*100*					3	*100*	43.5
44.5		2	*100*					2	*100*		5	*100*					5	*100*	44.5
45.5+		2	*100*					2	*100*		2	*100*					2	*100*	45.5+
	1	76		0	33		1	109		0	75		0	22		0	97		

Table 5. Length-maturity key of male and female *S. japonicus* in the Bay of Biscay (Divisions VIIIb+c combined), for the period [May-June]. All samples of the years 1989-1997 have been together considered. The percentage of mature has been smoothed by running means of three 1-cm length classes. (To calculate the Logit transformed percentages (see text), estimated values of Immature males or females have been introduced just before the length classes of real values of Mature males or females. They are marked by brackets [...]).

5.1. In Table 6.a the approximate L_{50} values are presented by sexes. The results indicate that males mature at a rather bigger size than females, the maturation 50% point lying near 30.8 cm in males and 29.0 cm length in females. (Basic data show that males are found mature at 31.5 cm and females at 29.5 cm).

a) Scomber japonicus

SEX	Logit Pi	L50 (cm)	Range (cm)
Males	-34.331 + 1.152 L	30.80	*[30.5 - 31.5]*
Females	-20. 126 + 0.694 L	29.00	*[28.5 - 29.5]*
All together	- 16.787 + 0.565 L	29.71	*[28.5 - 31.5]*

b) Scomber scombrus

SEX	Logit Pi	L50 (cm)	Range (cm)	"r"
Males	-6.08239 + 0.225579 L	26.96	[22.5 - 39.5]	0.991423
Females	-9.15671 + 0.315166 L	29.05	[23.5 - 38.5]	0.986461
All together	-7.19527 + 0.258951 L	27.79	[22.5 - 39.5]	0.993081

Table 6. Fitted linear regressions (Y = a + X b) to logit transformations of proportions (in %) Logit P = 0.5 * ln (P/(1-P))] with indication of L50 (length at which 50% of fish are estimated mature) of males and females of *Scomber sp.* in the Bay of Biscay : a) *S. japonicus*, from samples of May-June in the period [1989-1997]; b) *S. scombrus*, from samples of March-April-May in the period [1987-1993] (Lucio, 1997). (Ranges include only length classes in which the percentages resulted [> 0 and < 100]. For *S. japonicus* this range has been estimated (see the text)).

5.2. When the L_{50} values of *S. japonicus* of the present work are compared with the ones of *S. scombrus* in the same area of the Bay of Biscay in the period [1987-1993] (Table 6.b), two relevant facts appear: on the one hand, a remarkable bigger size-at first maturity in male *S. japonicus* (2.7 cm more than in *S. scombrus*), and on the other one, a rather similar L_{50} in females of both species.

However these conclusions must be taken with caution due to the scarcity of the sampling. Any case, it seems to be rather clear that the maturation 50% point of *S. japonicus* is lying close to 30 cm length.

6. Monthly evolution of the gonosomatic index

The gonosomatic index (GSI) has been calculated in two ways:

$$GSI_t = W_{gon} / W_t * 10^4 \qquad \text{and} \qquad GSI_g = W_{gon} / W_g * 10^4$$

where W_{gon} is the gonad weight (in g) ,
W_t is the total body weight (in g) ,
W_g is the gutted body weight (in g).

It must be pointed out that it was not possible to sample fish ≥30 cm length in February-April and in July, and that the sampling for fish <25 cm length was always very scarce excepting in October-November.

6.1. The monthly evolution of the GSI in fish ≥ 30 cm length -both sexes and maturity stages combined-, in the period [1989-1997], presented a notable dome shape pattern with maxima values observed in late spring (May-June) and minima in late summer, autumn and winter (Figure 9.a). The decrements of the GSI_t and GSI_g values in ≥ 30 cm length fish from May-June (the peak spawning season) to autumn (in resting season after spawning) were about 95% in both cases, males and females grouped. In juvenile fish (<25 cm length) a rather flat pattern of the GSI evolution was found through the year, as expected for immature fish.

6.2. GSI evolution in males and females showed very similar pattern through the year, being the values obtained for females somewhat bigger than in males, except during the spawning season (May-June) in which the IGS in males resulted consistently higher than in females (Figure 9.b,c).

6.3. In Figure 10 a significant relation between fish size and gonad weight is observed for adult (≥ 30 cm length) males and females, by size stratum and by maturity stage, in the spawning period. Most of the samples from May were obtained at midnight. The relatively high abundance of gonads with hydrated oocytes and the presence of running (spawning) females might support the affirmation, in a first approximation, that *S. japonicus* peak spawning takes place rather in the night.

6.4. The observations on the maximum reproductive activity stages of *S. japonicus* (Figure 8) are in closed agreement with the IGS values peaks (Figure 9.a,b,c). Both series of information confirm that the maximum of the reproductive activity for this species is placed in the second half of spring, i.e. in the months of May-June, in the South-eastern Bay of Biscay. The spawning season of *S. japonicus* takes places later (approximately one-two months) that the one of *S. scombrus* in the same sea area, with a peak spawning season between the end of the winter and the first half of the spring (March-April) (Figure 9.b,c) (Lucio, 1997).

7. Monthly evolution of the stomach repletion and the periviscerelis fat

A first and rather rough approximation of the seasonal pattern of feeding in *S. japonicus* in the period [1989-1997] has been obtained by the *de visu* stomachs examination. A four stages key for the stomach repletion has been used: "Empty", "Almost Empty", "Full" and "Very full". Time of the day and depth of the water have not been taken into account in the obtention of the samples. No data there were from February to April neither in July.

7.1. In Figure 11 the results obtained on the monthly evolution of the stomach repletion in adult fish (≥ 30 cm length) are represented. No relevant differences between males and females have been found in the general pattern. One period of maximum feeding appeared at the end of summer and in autumn (September-November). This period coincides with the highest catches of this species by the Basque fleet.

7.2. In the fish analysed in May 1997, fish eggs and copepods, ... resulted the most abundant prey in the stomach content; also euphausiacei and other little crustaceans were found. In September (1990) many stomachs were detected very full of planktonic preys. In November, although most of the stomachs were filled by plankton, in some of them appeared anchovy items...

7.3. The presence of *periviscerelis fat* in form of *adipose panniculi* is a common and periodic phenomenon in medium-size pelagic fish. It is a related with the feeding and it acts as an energy reservoir for the fish growth and reproduction cost. These adipose panniculi have been observed also in *S. japonicus* of the Bay of Biscay. To quantify the importance of the perivisceralis fat an approximate and *de visu* scale of four degrees has been applied: (FF) Very abundant fat; (F) Abundant fat; (f) some presence of fat; (NO) No visible fat.

In Table 7 the monthly variation values of the perivisceralis fat are presented.

(Fish >30 cm)	*In number (No.)*					*In percentage (%)*				
	FF	F	f	NO	*TOTAL*	FF	F	f	NO	*TOTAL*
JAN	3	1			*4*	75	25	0	0	*100*
FEB					*0*					*0*
MAR					*0*					*0*
APR					*0*					*0*
MAY	0	0	0	147	*147*	0	0	0	100	*100*
JUN	0	0	0	55	*55*	0	0	0	100	*100*
JUL					*0*					*0*
AUG				6	*6*	0	0	0	100	*100*
SEP	31	6		0	*37*	84	16	0	0	*100*
OCT	41	2		0	*43*	95	5	0	0	*100*
NOV	2	1		0	*3*	67	33	0	0	*100*
DEC	2	13	5	0	*20*	10	65	25	0	*100*
	79	23	5	208	*315*	25	7	2	66	*100*

(Fish <20 cm)	*In number (No.)*					*In percentage (%)*				
	FF	F	f	NO	*TOTAL*	FF	F	f	NO	*TOTAL*
OCT				10	*10*	0	0	0	100	*100*
	0	0	0	10	*10*	0	0	0	100	*100*

Table 7. Monthly frequencies -in number and in percentages- of the degree of perivisceralis fat in *S. japonicus* in the Bay of Biscay, in the period [1989-1997], for fish >30 cm and <20 cm length. The approximate degrees of perivisceralis fat have been considered so: (FF) Very abundant fat; (F) Abundant fat; (f) Some presence of fat; (NO) No fat visible.

In (>30 cm length) *S. japonicus*, adipose panniculi have been observed from September to January with a maximum of fat abundance in October, but they did not have been detected in May-June, in spite of the high number of fish analysed, neither in August (full spent fish). Thus the abundance of this perivisceralis fat in adult Spanish mackerel could be associated with both the reproductive resting period and the maximum feeding period. In small fish (<20 cm length), however, adipose panniculi have not been observed in October (the only month sampled); probably young fish in the first year of live do not get to store perivisceralis fat because they allocate immediately the surplus energy in growing very fast (from May-June (its likely birth time) to October, they attain a size between 13-18 cm length).

8. Age determination

The age determination in *S. japonicus* has been made from the otoliths (*sagittae*) reading. A very few number of fish (81) have been aged from two samples of different years: November 1989 and May 1997. Proceedings used in the otolith preparation and reading have been the same as for *S. scombrus*. In general the reading of the *S. japonicus* otoliths resulted easy to do.

The (preliminary) criteria assumed and used for the age determination of this species have been:

1. The agreed date for the birth of Spanish mackerel in the Bay of Biscay has been considered the 1st. January.

2. 'One ring-one year'. It is assumed that this species forms every year one true 'opaque' zone and one true 'hyaline' ring. The formation of the complex of both zones befalls in one year.

3. For practical purposes, the following table has been used in the age assignment of *S. japonicus*, taking in account the kind of the border and the period of the year:

Period of the year	Kind of border	Age assignment
[January-June]	Opaque (O) in adults Hyaline (H) new Opaque (nO) (in juveniles)	Age (years) = (n+1) of H rings Age (years) = (n) of H rings Age (years) = (n) of H rings
[July-December]	new Opaque (nO) new Hyaline (nH)	Age (years) = (n) of H rings Age (years) = (n-1) of H rings

8.1. Due to the scarcity of the fish aged, only a temptative Age Length Key (ALK) for *S. japonicus* in the Bay of Biscay has been obtained (Table 8).

Length	***Age (years)***							**Total**	***Length***
(cm)	***0***	**...**	***4***	***5***	***6***	***7***	***8***	**(n)**	***(cm)***
15								**0**	***15***
16	4							**4**	***16***
17	10							**10**	***17***
18	10							**10**	***18***
19	10							**10**	***19***
20	2							**2**	***20***
...								**0**	**...**
30								**0**	***30***
31								**0**	***31***
32								**0**	***32***
33								**0**	***33***
34			1					**1**	***34***
35			1	1				**2**	***35***
36				1				**1**	***36***
37				5				**5**	***37***
38				7	5			**12**	***38***
39				4	2			**6**	***39***
40				4	4	2		**10**	***40***
41					2			**2**	***41***
42					5			**5**	***42***
43								**0**	***43***
44						1		**1**	***49***
Total (n)	36		2	22	18	3		**81**	***Total (n)***
Mean L	**18,4**		**35,0**	**38,6**	**40,5**	**41,8**			***Mean L***
Age	*0*	...	*4*	*5*	*6*	*7*			***Age***

Table 8. Temptative Age Length Key (ALK) for *S. japonicus* in the southern Bay of Biscay (Divisions VIIIb,c), in the period in the period 1989-1997], obtained by the reading of otoliths. Estimated mean lengths by age class are also presented. (Fish of 0-class correspond to November 1989 and those of 4+ class to May 1997).

8.2. In November (1989) all fish aged in the range [16-20] cm appeared as 0-years old. The opaque border was found in all of them. These fish are assumed to have been born in the past spring.

8.3. In May (1997) all fish aged in the range [34-44] cm resulted 4-7 years old. The hyaline border in the otoliths appeared absolutely predominant (100%). As all fish were mature, the first maturity at age can be estimated at least at 4 years.

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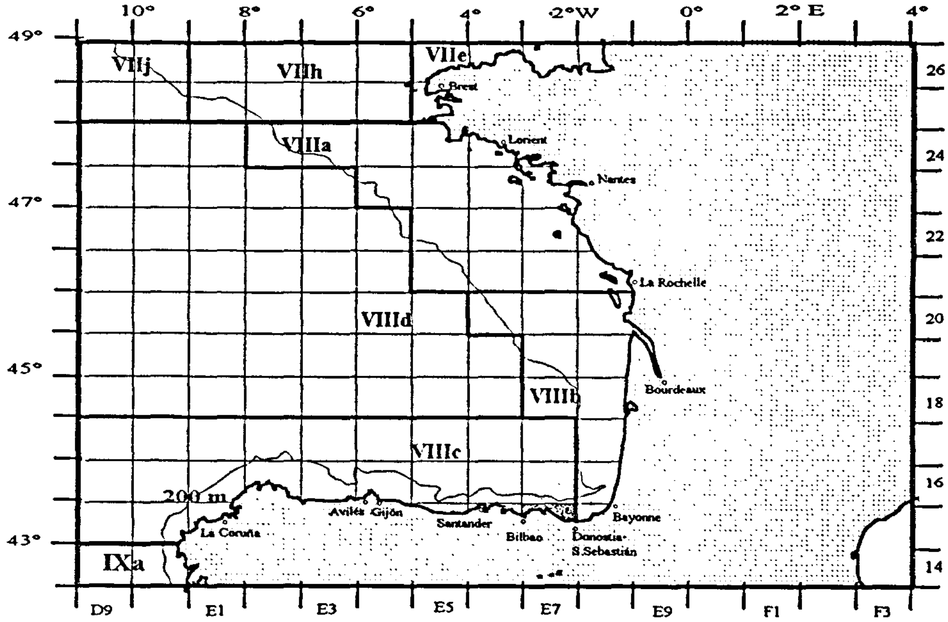


Figure 1. Map of the ICES Divisions in the Bay of Biscay. Almost all the catches of Scomber japonicus landed in the Basque Country (Spain) have been taken in Div. VIIIc and only a small part in Div. VIIIb, in the period [1987-1993].

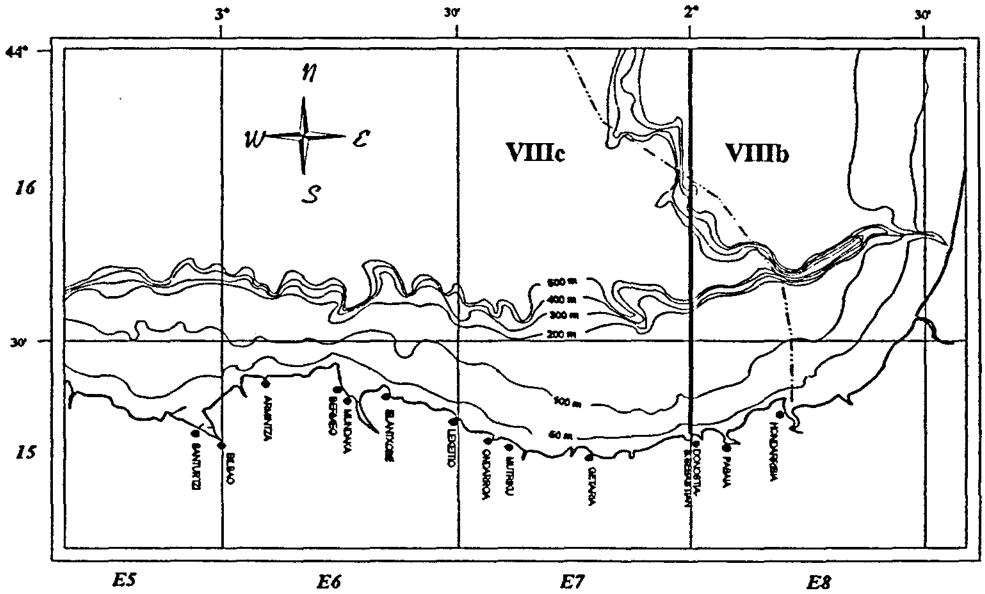
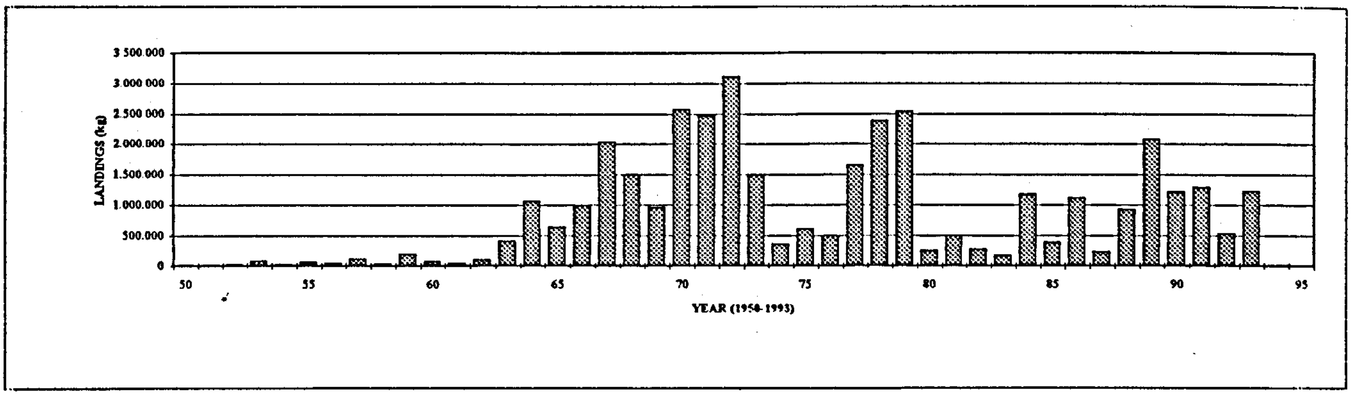
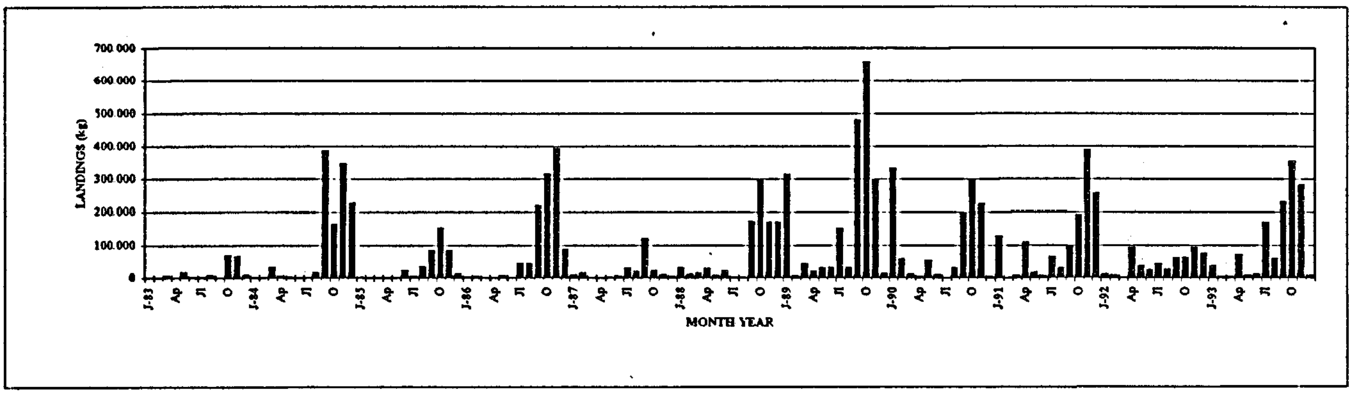


Figure 2. Map of the coast and fishing ports of the Basque Country (Spain), and ICES statistical rectangles of Divisions VIIIb and VIIIc-eastern part, where usually the main catches of Scomber japonicus have been taken in the period [1987-1993]. [(—..—) : Agreed line of separation of the French and Spanish waters].

a) S. japonicus annual landings (1950-1993)



b) S. japonicus monthly landings (1983-1993)



c) S. japonicus and S. scombrus monthly landings (1987-1993)

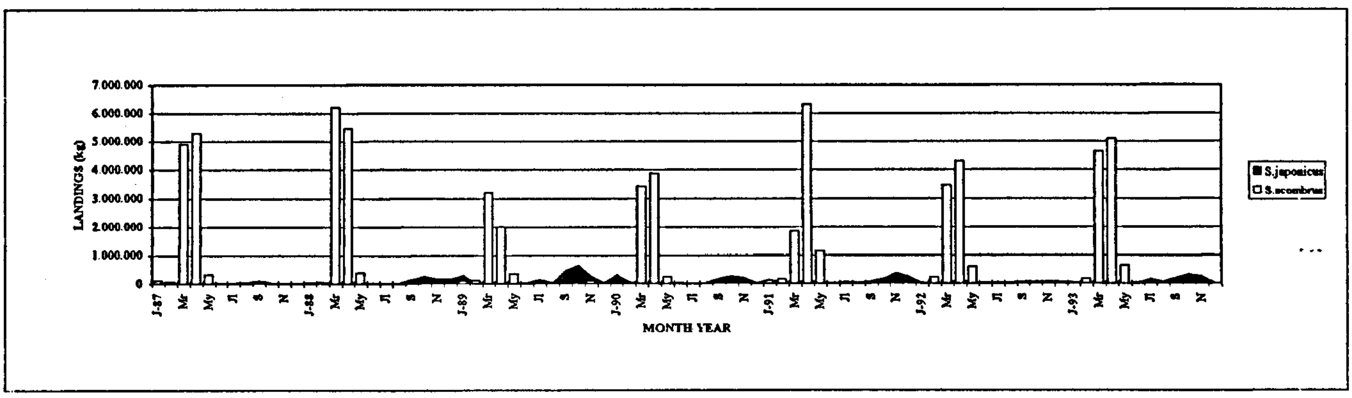
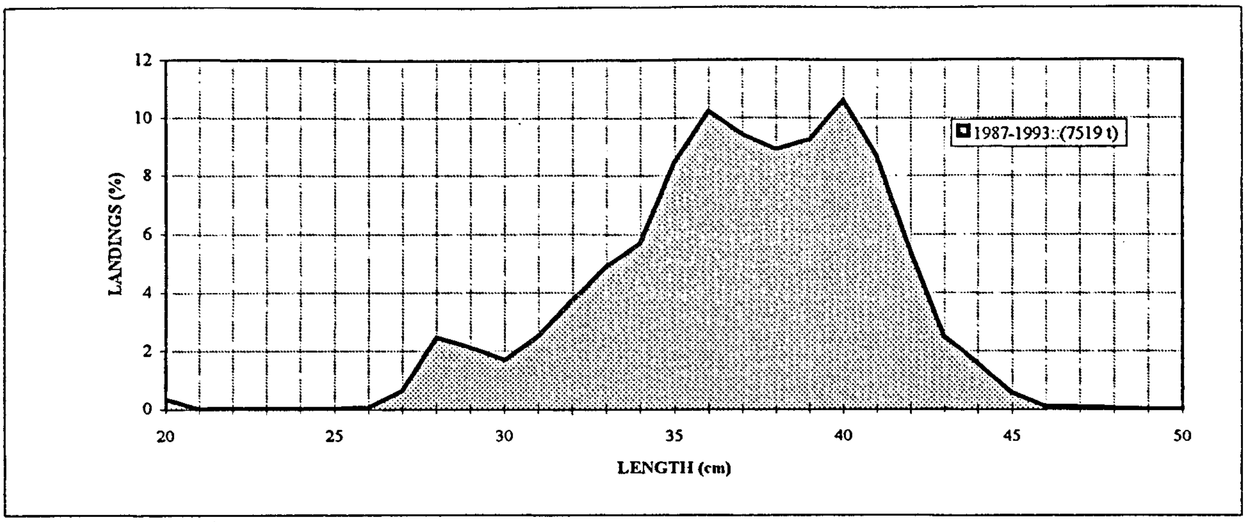
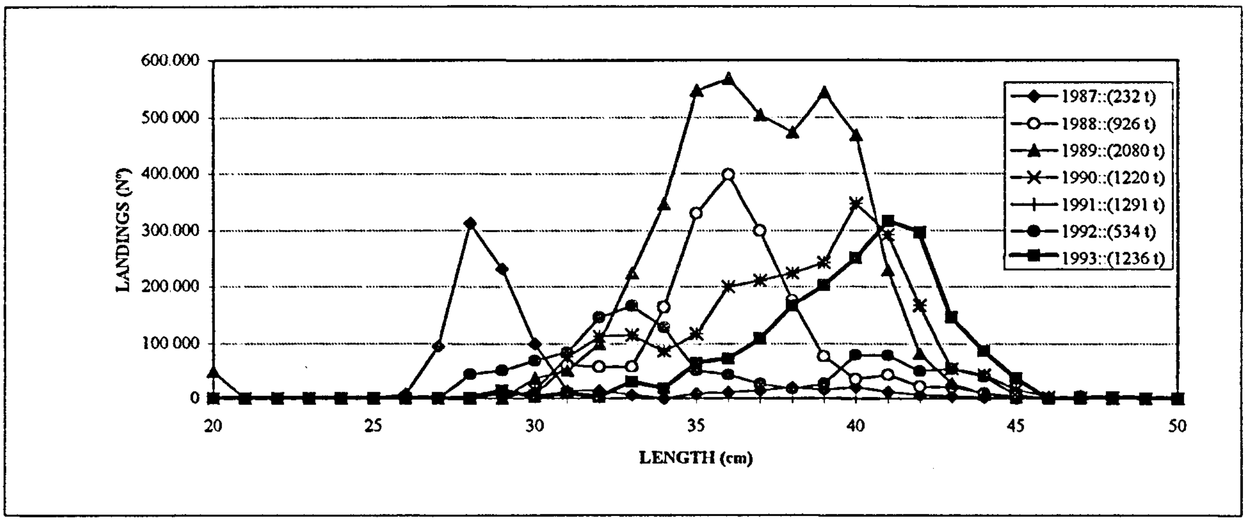


Figure 3. Evolution of the annual landings of S. japonicus and seasonality of the landings of both Scombrus species in the Basque Country fishing ports :
a) S. japonicus annual landings in the period 1950-1993. b) S. japonicus monthly landings in the period 1983-1993.
c) S. japonicus and S. scombrus monthly landings in the period 1987-1993.
Most of the landings of S. scombrus are made in March-Abril whereas most of the landings of S. japonicus are in September-November.
Nearly all the catches are taken in the southern Bay of Biscay (Divisions VIIIb and VIIIc-eastern part).

a) Synthetic length distribution :: [1987-1993] :: Divisions VIII b+c



c) Annual length distributions :: [1987-1993] :: Divisions VIII b+c



c) Quarterly length distributions :: 1993 :: Division VIIIc

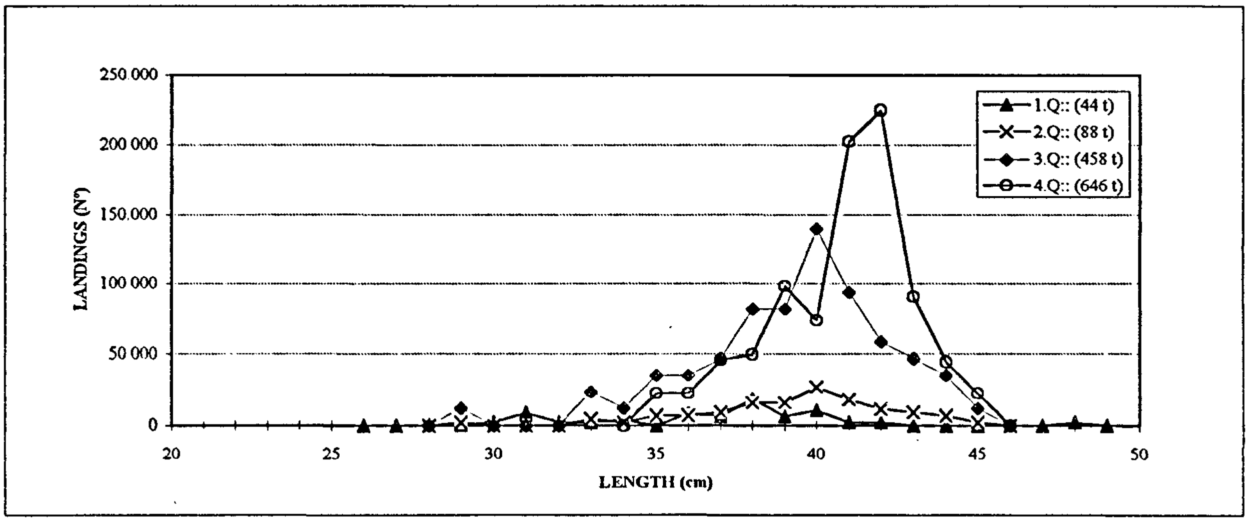
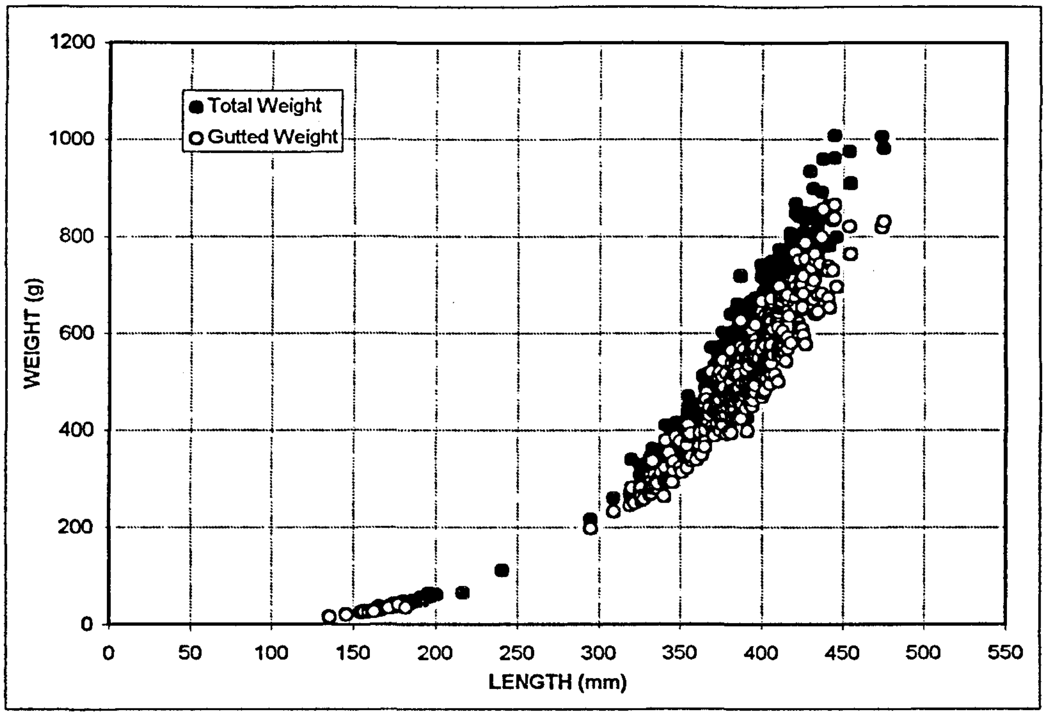


Figure 4. Length distributions of the landings of Scomber japonicus in the Basque Country fishing ports, in the period [1987-1993]:
a) Synthetic length distribution (%) for Divisions VIII b+c for all the period [1987-1993].
b) Annual length distributions for the same Divisions and period.
c) Quarterly length distributions, in 1993, for Division VIIIc-eastern part.
(In each year/quarter, the number of landings, in tonnes, is indicated).

a) S. japonicus (Total & Gutted Weight)



b) S. japonicus & S. scombrus (Total Weight)

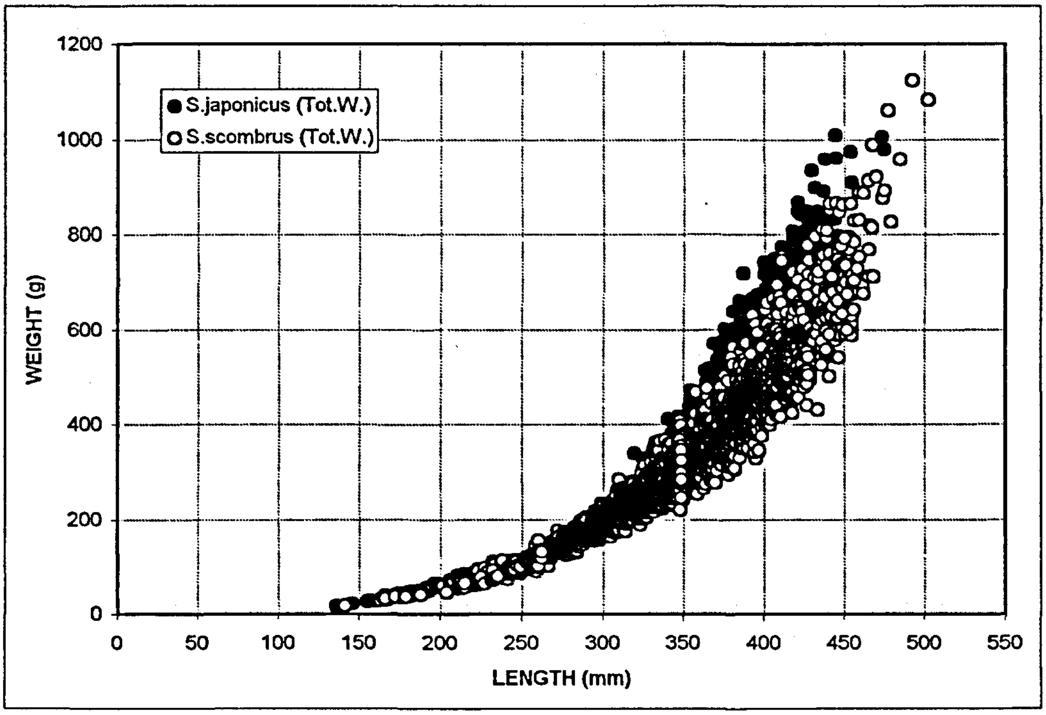


Figure 5. Total Length/Weight relationships of Spanish (Chub) Mackerel (S. japonicus) and Common Mackerel (S. scombrus) in the Bay of Biscay.
a) S. japonicus (Total & Gutted Weight), in the period [1987-1993 and 1997].
$W(tot) = 0.00000102549 * L(t)$ ^3.376 . n = 485 ; r = 0.995 . [L (in mm); W (in g)].
$W(gut) = 0.000001020463 * L(t)$ ^3.327 . n = 386 ; r = 0.987 .
b) S. japonicus & S. scombrus (Total Weight)
For S. scombrus (Total Weight) in the period [1987-1993] (Lucio, 1997):
$W(tot) = 0.00000207263 * L(t)$ ^3.212 . n = 5,980 ; r = 0.98 . [L (in mm); W (in g)]

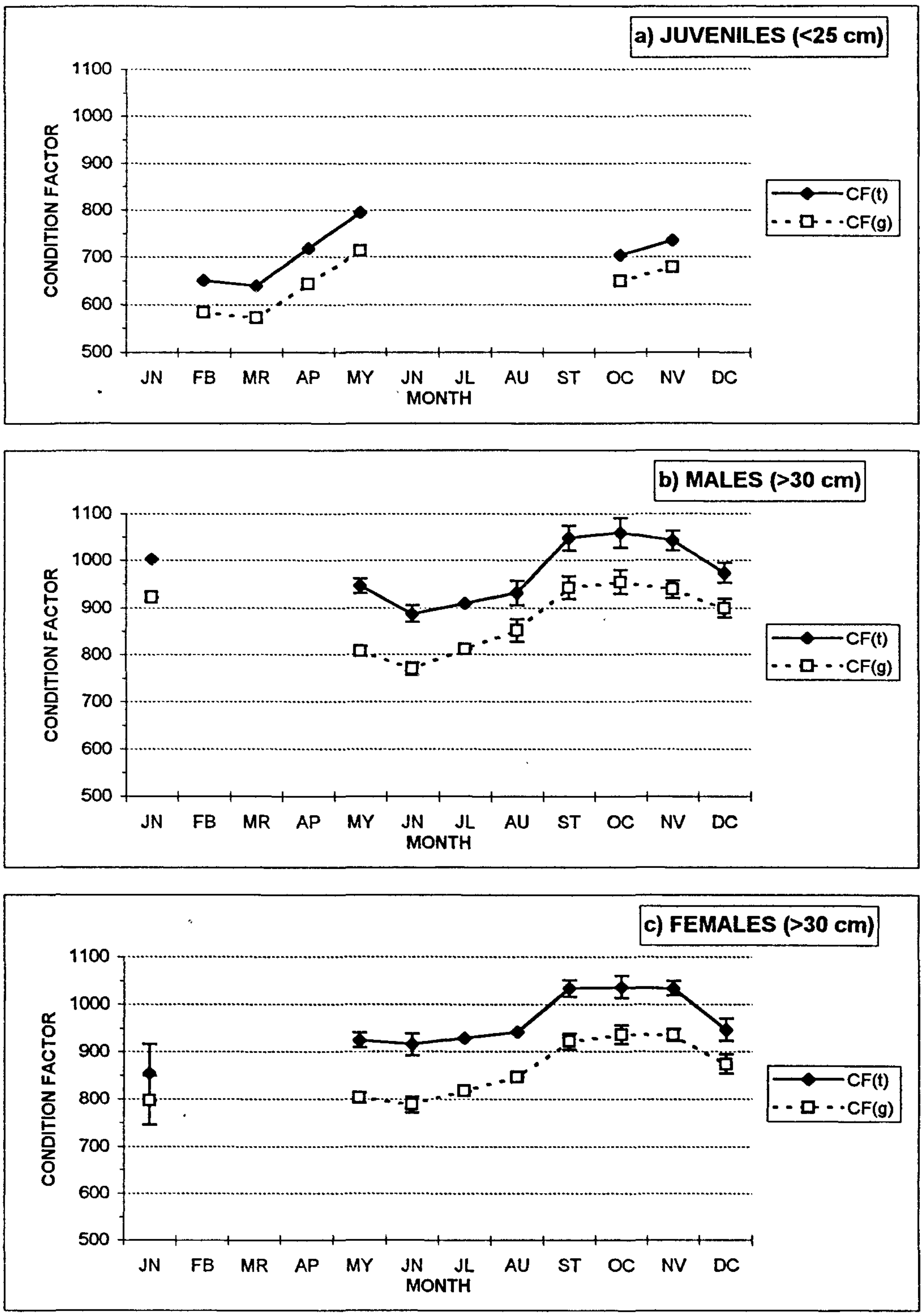


Figure 6. Seasonal variation in the condition factor of Scomber japonicus in the Bay of Biscay, a) juvenile (<25 cm), b) adult males and c) adult females (>30 cm), in the period in the period [1989-1997]. For each month, the mean value -and the confidence intervals (± 1.96 S.E.) for CF(g)- are shown. The evolution of the condition factor for total body weight (CF(t)) and for gutted body weight (CF(g)) is presented.

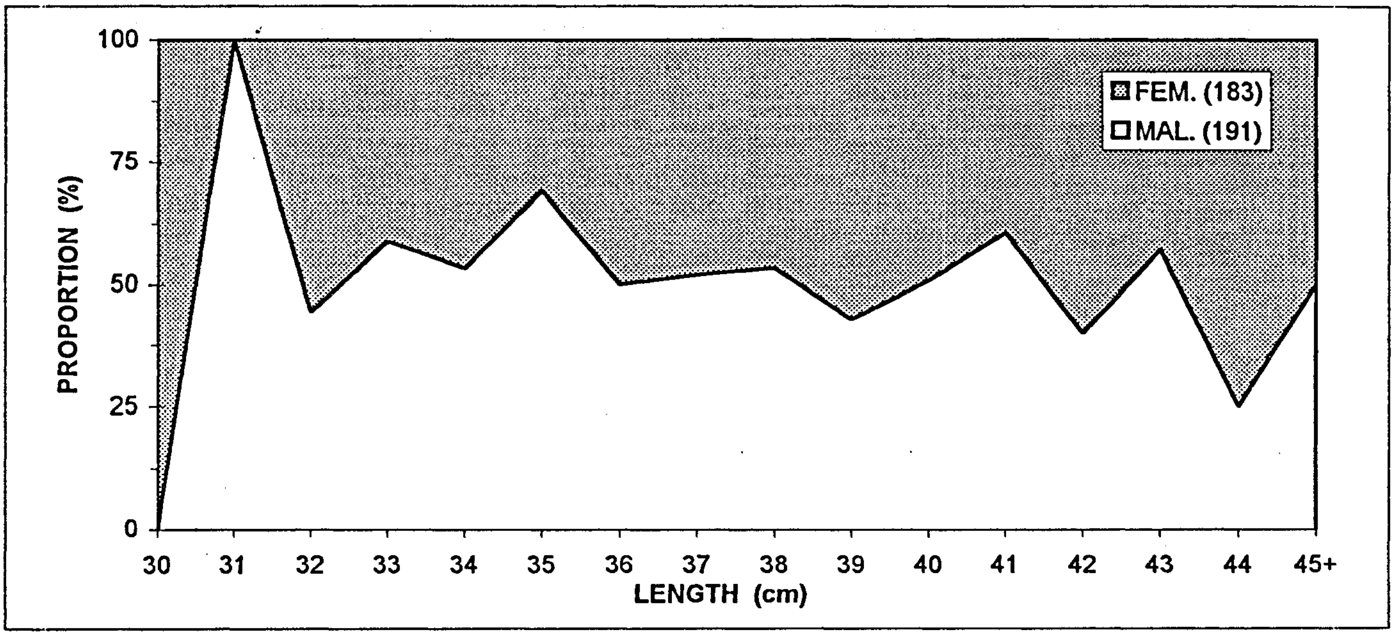


Figure 7. Annual sex ratio by length of Scomber japonicus in the Bay of Biscay, in 1989-1993 and 1997. In brackets the number of (>30 cm length) males and females analyzed.

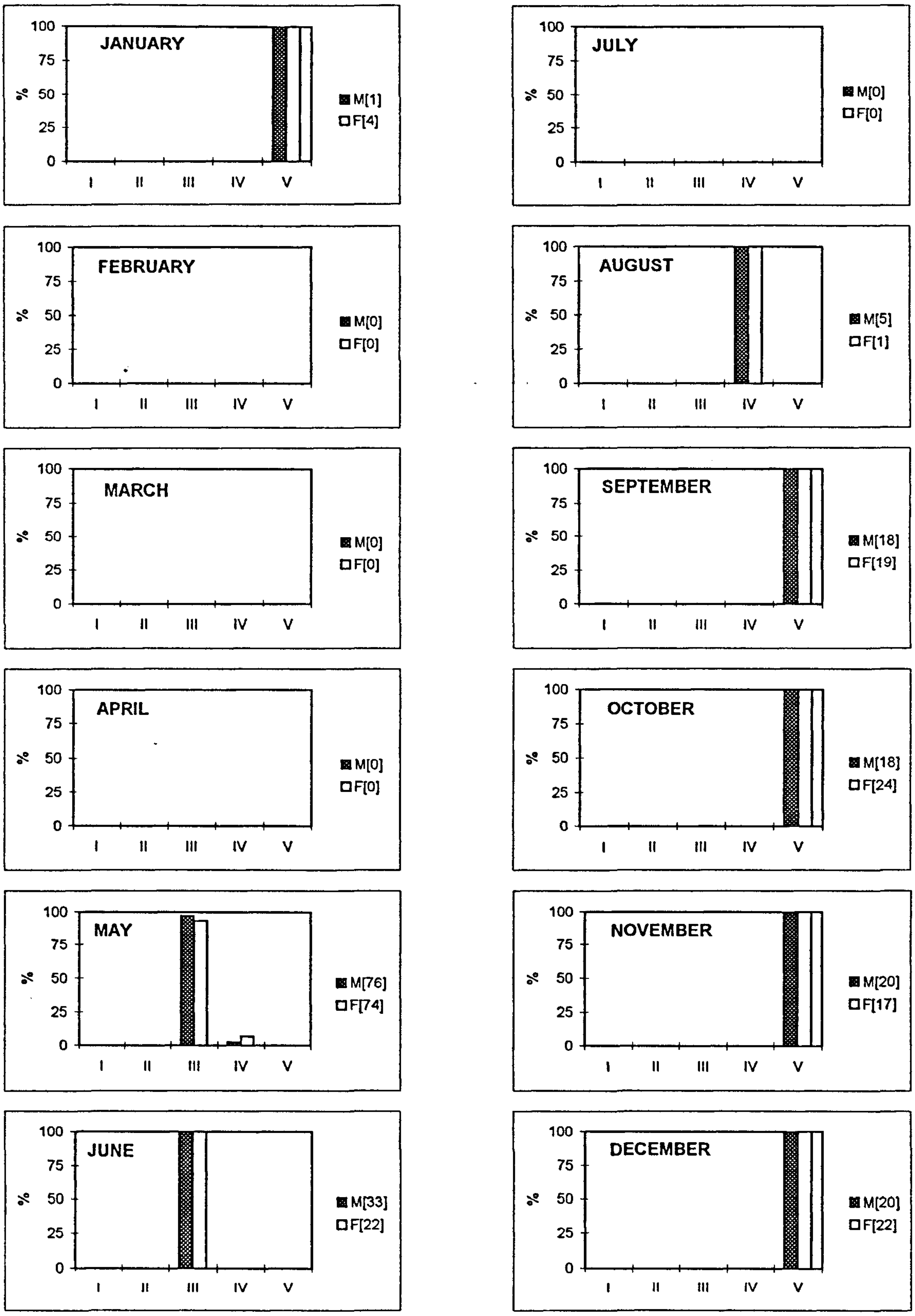


Figure 8. Monthly frequencies (in %) of maturity stages of Scomber japonicus -males (M) and females (F) (>30 cm length)-, in the Bay of Biscay, in the period [1989-1997]. In brackets, the number of fish analyzed per month. (Maturity stages: I: Virgin or juvenile). II: Beginning of maturation (very early). III: Advanced maturation, spawning and partly spent. IV: Full spent. V: Resting).

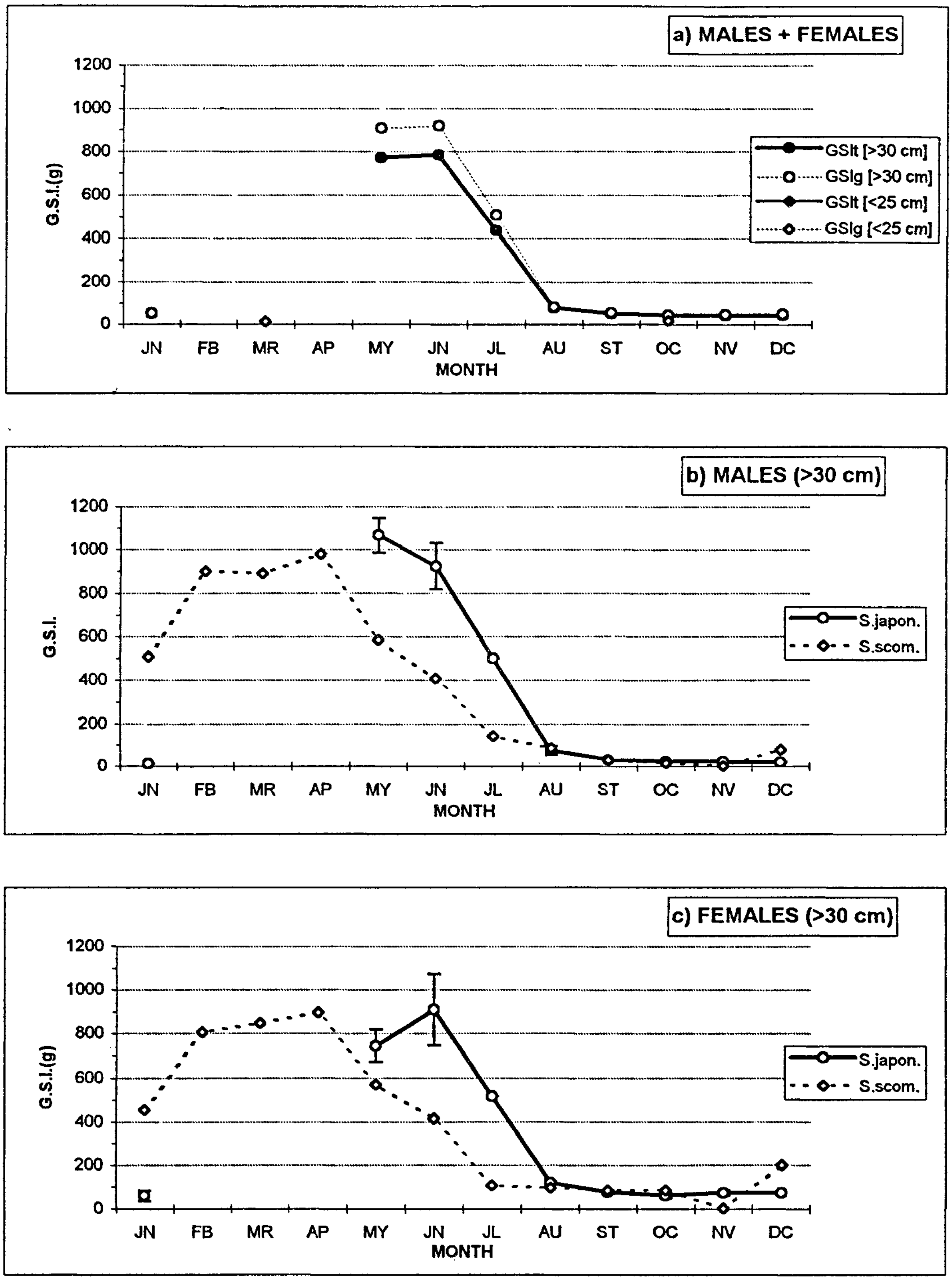


Figure 9. Monthly variations in the gonodomatic index (GSI) of Scomber japonicus in the Bay of Biscay in the period [1989-1997]. (No data for adults (>30 cm) from February to April and data for July have been estimated (interpolated)).
a) Males+Females : Comparison of the GSI in relation to total (GSIt) and gutted body weight (GSIg) in adults (>30 cm length) and in juveniles (<25 cm).
b) Males and c) Females (>30 cm length) : Comparison between the evolution of GSI(g) in S. japonicus and in S. scombrus (in the period [1987-1993]), both in the Bay of Biscay (Lucio, 1997). For each month the mean value and the confidence intervals (± 1.96 S.E.) are presented for data of S. japonicus.

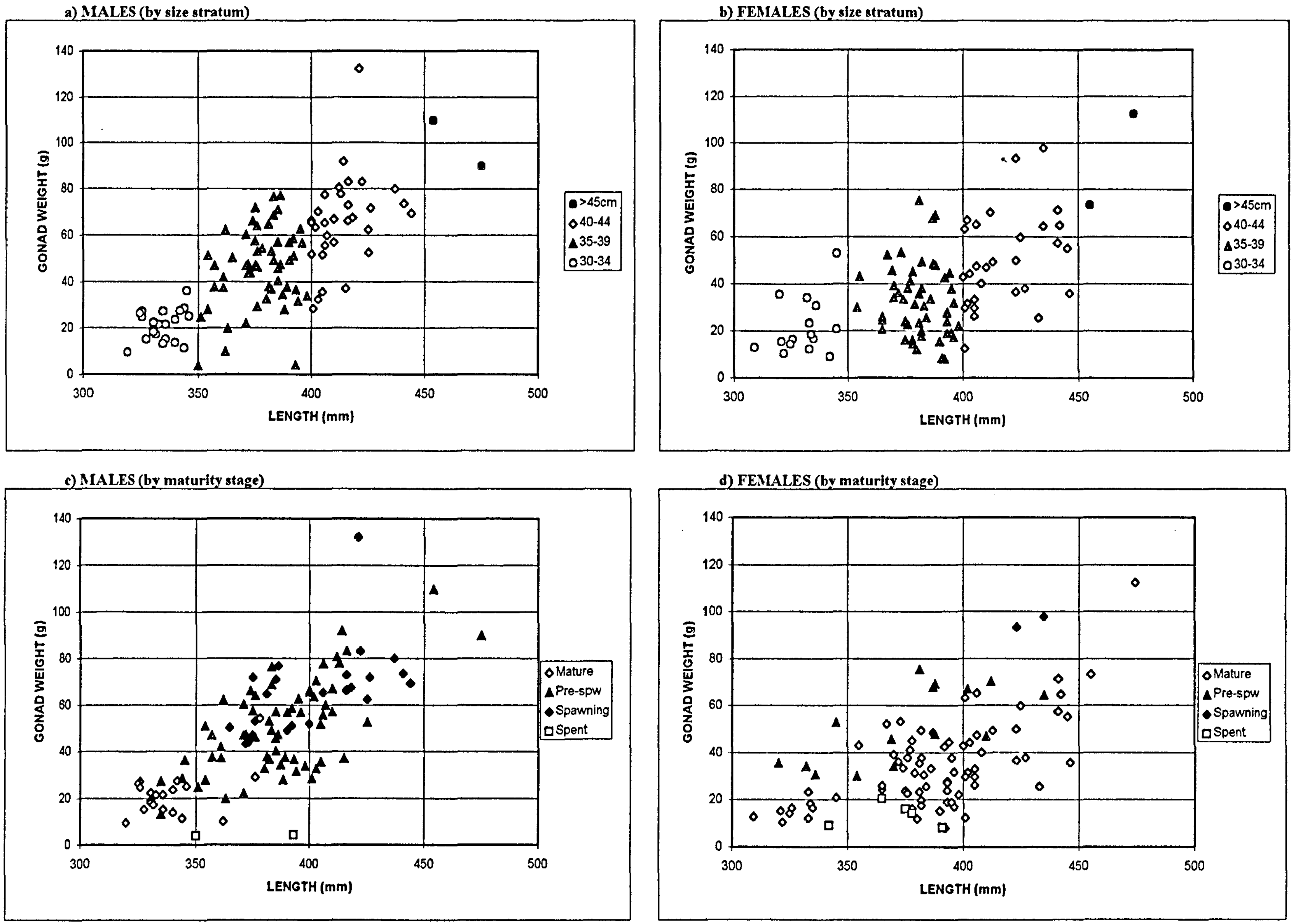


Figure 10. Gonad weight (g) and Length (mm) relationship in Scomber japonicus (>30 cm length) of the Bay of Biscay in May-June, in the period [1989-1997]. a) and b) Males and Females, by size stratum; c) and d) Males and females, by maturity stage

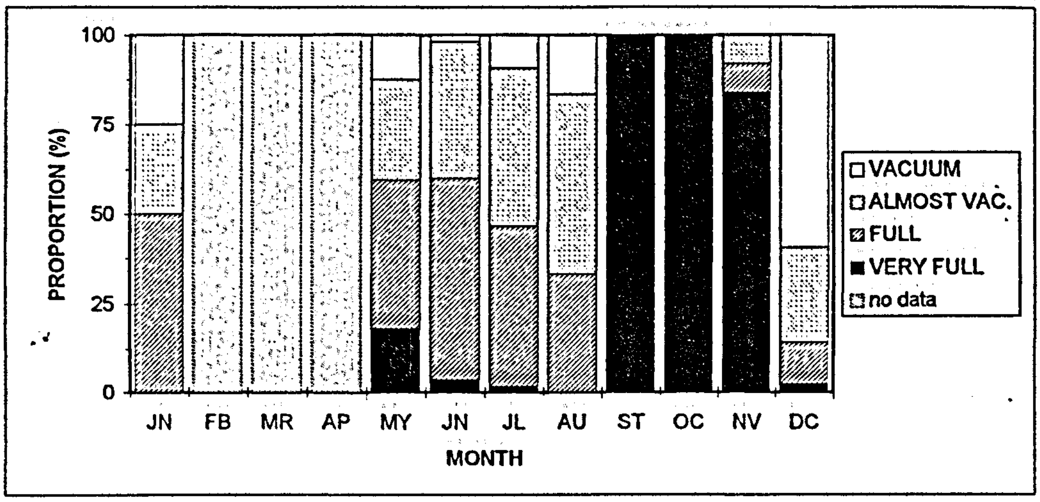
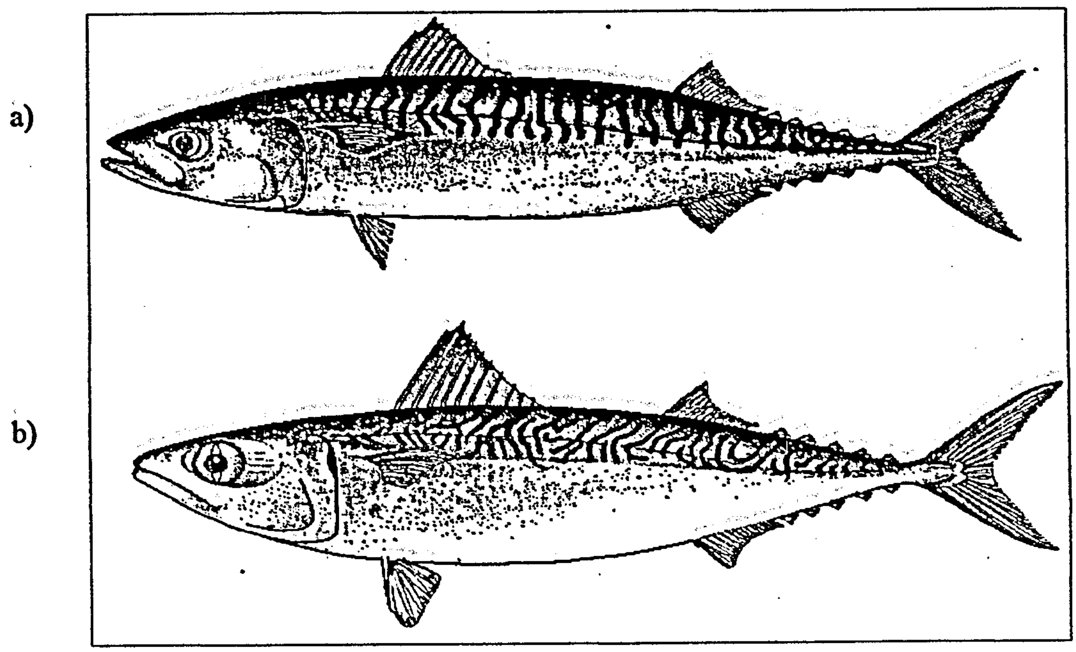


Figure 11. Monthly variation in the stomach repletion index for adult (>30 cm; n=312) Scomber japonicus in the Bay of Biscay, in the period [1989-1997]. (No data from February to April; July data estimated by interpolation).



a) Common Atlantic mackerel [Scomber scombrus (L.1758)]
b) Spanish (Chub) mackerel [Scomber japonicus (Houttuyn 1782)]