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Somatic Condition, Growth and Reproduction of Hake, *Merluccius merluccius* L., in the Portuguese Coast

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ABSTRACT

Weight/length relationships, condition factor, gonadosomatic and hepatosomatic indices, conversion factor for gutted to total weight and spawning season of hake in the Portuguese Coast (36.92 to 42.22 degrees latitude N; 9.61 to 6.07 degrees longitude W) were investigated for the first time, aiming to fill the lack of information on the biology of hake of the Portuguese waters. Data were obtained from commercial samples collected between 2005 and 2010 and pooled by month. Sex ratio observed in fish below 40 cm was close to 1:1; females were always dominant above 50 cm length. All the parameters were analysed by month and by sex and by combined sexes. The relationships obtained for combined sexes for the entire period concerning the growth in length and weight were: total length-total weight = $0.0038L^{3.172}$, total length-gutted weight = $0.0052L^{3.059}$. The relationship total weight-gutted weight was $W_t = 15.8112 + 0.8480W_g$ and the conversion factor was of 1.1524. The growth rate is similar for both sexes but different when based on total weight or gutted weight. The analysis of the condition factor, gonadosomatic index, hepatosomatic index and the monthly distribution of the maturity stages seem to indicate that hake from the Portuguese Coast has a long spawning season, with three spawning peaks in March, May and August but the start of the spawning season seems independent of the fish length.

Keywords: *Merluccius merluccius*; Portuguese Coast; Biology; Somatic Condition; Spawning Season

1. Introduction

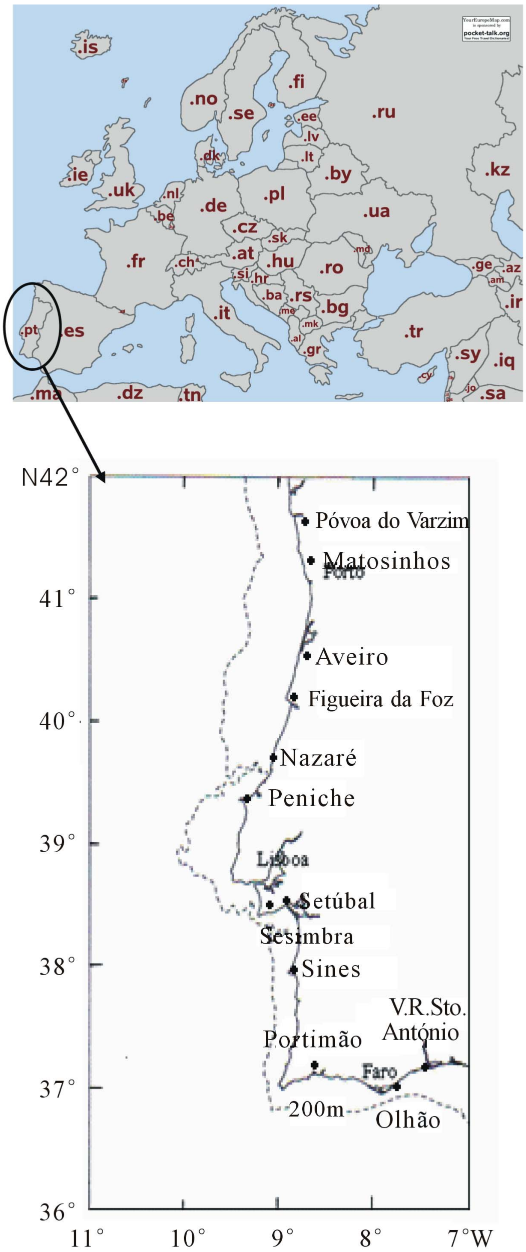
The main target of the investigation of the marine resources is to give new information on the biology and dynamics of the explored populations, by knowing the life cycle and biological characteristics (e.g., recruitment, spawning biomass and fishing mortality) of the species, in order to determine the real conditions of those resources (Piñeiro, 2011) [1]. Two important nursery areas for European hake have been identified north-east Atlantic waters (ICES, 1996) [2]: one area is located off the French coast in the Bay of Biscay and is known as “Le Grand Vasiérè” and another one is in the Celtic sea between the south-west of England and southeast of Ireland; there is no such information for Portugal.

Several technical measures are taken to manage the stocks status. In Portugal those management measures are based on information given by the National Biological Sampling Program, co-financed by the EU within the Data Collection Framework (PNAB-DCF), on the landing composition (by sampling at the fish market), discards at sea (with scientific observers on board commercial vessels) and biology (from biological sampling at the laboratory). Indices of abundance and recruitment are obtained by the research surveys (acoustics, demersal and crustaceans) carried out by IPIMAR (Instituto de Investigação das Pescas e do Mar).

Hake in Portuguese coast is caught mainly by the polyvalent fishing (hooks and purse seine) and trawl, together with some other species of fish and crustaceans: horse mackerel (*Trachurus trachurus*), monkfish (*Lophius* spp.), megrim (*Lepidorhombus* spp.), chub mackerel (*Scomber colias*), Atlantic mackerel (*Scomber scombrus*), blue whiting (*Micromesistius poutassou*), shrimp (*Penaeus* spp.) and Norway lobster (*Nephrops norvegicus*). An important feature about hake is the fact that most of the larger individuals are landed gutted because ovaries get a very high price at the fish market.

In Portugal hake is studied since the middle of the 1960 decade (Monteiro and Dias, 1965 [3]; 1966 [4]) and several papers have been produced since then regarding many different areas, much of them related to abundance and distribution of adults, eggs and larvae (Cardador, 1995 [5]; Ibaibarriaga *et al.*, 2007 [6]), fisheries, stock assessment and selectivity (Campos and Fonseca, 2003 [7]; Cardador, 1988 [8], 1991 [9]; Dias and Cunha, 1984 [10]; Fonseca *et al.*, 2005 [11]; Moura and Cardador, 2005 [12]; Santos *et al.*, 2002 [13]) and recruitment (Caramelo, 1983 [14]; Cardador *et al.*, 2005 [15]; Mendes *et al.*, 2008 [16]). Although in the beginning of the eighties years Marecos *et al.* (1982) [17] have developed some work on age and growth of the Portuguese hake, only later the biological study of the species increased, with particular interest on age and growth (Godinho *et al.*, 2001 [18]; Jardim *et al.*, 2004 [19]; Salgado *et al.*, 2003 [20]) and maturity (Costa *et al.*, 2009) [21], with special reference to the first microscopic maturity scale proposed by Gonçalves *et al.* (2004) [22] for the portuguese component of the Southern stock of hake, similar to the one used by IEO (Instituto Español de Oceanografía) that also studies the same hake stock, and implemented to distinguish correctly immature from resting females (Costa and Gonçalves, 2009 [23]; Costa *et al.*, 2009 [21]), which are, as for many other species, not possible to distinguish macroscopically (Domínguez-Petit, 2007 [24]; Saborido-Rey and Junquera, 1998 [25]). Some other subjects have also been studied by Portuguese researchers, like parasites (Marques, 1985 [26]; Silva, 1984 [27]), feeding (Cabral and Murta, 2001 [28]; Hill and Borges, 2000 [29]) or lipid content (Gonçalves *et al.*, 2004 [30]).

In the bibliography there are no references to important issues on the Portuguese hake, such as, sex ratio, physical condition or length-weight relationships. Therefore, the aim of this paper is to present the results of a biological study on the reproduction of the hake of the Portuguese coast for the last six years, based on the length distribution of captured fish, sex ratio, total length-total weight and total length-gutted weight relationships and the conversion factor between total and gutted weights. The somatic condition of the individuals was assessed by the condition factor, the gonadosomatic and the hepatosomatic indices and the spawning season was identified by the annual evolution of the maturity stages and the monthly changes in the gonads weights.



Map 1. Geographical distribution of the portuguese fishing ports where hake biological sampling was carried out in the period 2005-2010.

2. Materials and Methods

This work reports the results of the analysis of a 6-year time series (January 2005-December 2010) of some of the biological parameters that characterize the physical condition and reproduction of the Portuguese hake.

Our study was based on two sources of data:

1) random samples collected from landings at 12 fishing ports distributed by the portuguese NUTS II: Matosinhos and Póvoa do Varzim (North), Aveiro and Figueira da Foz (Center), Nazaré, Peniche, Sesimbra and Setúbal (Lisbon and Tagus Valley), Sines (Alentejo), Portimão, Olhão and Vila Real de Santo António (Algarve), which location is shown in **Map 1**.

2) samples collected by IPIMAR technicians on board of commercial vessels operating in this sea area, in order to obtain information on the smaller individuals rejected to the sea by the fishing fleet.

In total 8212 samples were collected and after being screened to exclude those presenting sampling errors, such as total weight lower than gutted weight, 4935 were analysed. Given the large amount of information, impossible to present entirely in this kind of work, annual data were pooled by month and dealt by sex and by combined sexes, since hake stock assessment is based on combined sexes.

The number of individuals caught by year and the correspondent length range is presented in **Table 1**.

When possible the data collected from each sample were: total length (cm), total and gutted weight (g), sex, maturity stage and gonad weight (0.1 g). Since many of the fish over 40 cm are usually gutted, total weight, sex, maturity stage and gonad weight of 1395 individuals were not recorded. Data were pooled by month.

Weight-length relationships were estimated by fitting an exponential curve, $W = a L^b$, to the data (Ricker, 1973 [31], 1975 [32]). Weights and total lengths were log-transformed and the parameters *a* (the initial condition factor) and *b* (the allometric coefficient) of the W-L relationships were estimated by linear regression analysis, using the least-squares method. The degree of association between the variables W and L was calculated by the coefficient of determination (R^2). The conversion factor for gutted to total weight was also calculated by forcing the linear relationships through the co-ordinates origin.

For fish with all data, total, gutted and gonad weight, the condition factor (CF), the gonadosomatic index (GSI) and the hepatosomatic index (HSI) were also calculated, in this way: $CF_t = W_t/L^3 * 100$ and $CF_g = W_g/L^3 * 100$ (Fulton, 1902) [33]; $GSI_t = W_{gon}/W_t * 100$ and $GSI_g = W_{gon}/W_g * 100$; $HSI_t = W_{liv}/W_t * 100$ and $HSI_g = W_{liv}/W_g * 100$ (West, 1990) [34], where CF_t = condition factor obtained with total weight, CF_g = condition factor obtained with gutted weight; GSI_t = gonadosomatic index obtained with total weight, GSI_g = gonadosomatic index obtained with gutted weight; HSI_t = hepatosomatic index obtained with total weight, HSI_g = hepatosomatic index obtained with gutted weight; W_t = total weight (g), W_g = gutted weight (g), L = total length (cm), W_{gon} = gonad weight (g), W_{liv} = liver weight (g). Condition factor, gonadosomatic and hepatosomatic indices were analysed by sex and within each sex the individuals were also split into immature and mature. Females were considered to be immature with less than 38 cm total length and males were considered immature with less than 26 cm total length, based on the mean of the L_{50} calculated for the years from 2006 to 2009 from the individuals obtained with visceras (Costa *et al.*, 2009) [21].

Conversion factors between gutted and total weights were calculated by sex for all fish sampled.

The weight of the viscera was calculated by sex, as a percentage of the total weight. The spawning season was estimated by studying the percentages of maturity stages assigned de visu to each specimen, based on the macroscopic maturity scale key for hake (ICES, 2007) [35] (**Table 2**) along with the ovary weight and the obtained GSI and HSI.

3. Results and Discussion

Although the studied period started in January 2005 and finished in December 2010, to understand the importance of this species along the years, the hake landings and fish auction market price were analysed for the all decade (2000-2010) and are presented in **Figure 1**.

The annual length distribution of sampled hake landed by the different fishing gears in the studied period is shown in **Figure 2**.

Total lengths of fish sampled ranged from 7.3 to 93.3 cm, with 49.8% of the fish belonging to 30 to 50 cm length. Total length of females ranged from 20.0 cm (with 44.0 g weight) in April, to 82.8 cm (with 5304.0

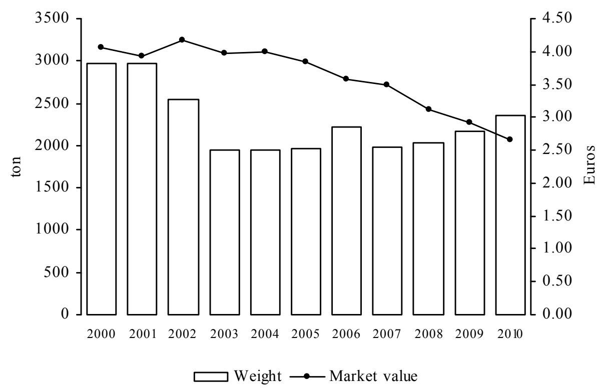


Figure 1. Mean catches and mean market value of hake in the decade 2000-2010. The values correspond to the means of the different fishing gears operating at the twelve ports studied (source: DGPA, 2000 to 2010 [105 - 115]).

Table 1. Number of *M. merluccius* caught during 2005-2010 in the Portuguese coast.

Year	Month												Total	Length range (cm)
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.		
2005	21	105	107	466	91	102	121	29	70	117	79		1308	8.5 - 71.3
2006	14	100	94	102	105	38	117	86	87	33	68		844	8.0 - 71.1
2007	86	104	105	136	105	183	58	65	56	57	57		1012	12.5 - 93.3
2008	111	79	131	87	94	59	155	33	54	166	66	9	1044	7.3 - 82.8
2009	20	91	198	252	239	55	75	130	221	79	96	39	1495	7.9 - 77.5
2010	107	132	423	208	307	245	171	163	262	246	245		2509	7.5 - 78.9
Total	359	611	1058	1251	941	682	697	506	750	698	611	48	8212	7.3 - 93.3

Table 2. Hake macroscopic maturity stages (ICES, 2007).

MATURITY STAGES	Females	Males
1. Imature/Resting	Small ovaries, with firm consistence and minimal vascularization, transparent or pinkgrey, without opaque or hyaline oocytes.	Small testis, transparent or white, with the shape of a thin ribbon, with no signs of development. Without sperm.
2. Developing/Maturing	Medium or large ovaries, pink or yellow to orange, with vascularization variable, present and obvious. Opaque oocytes present but without hyaline oocytes.	Medium testis, white, with the shape of develop bands. Sperm flows when testis are cut.
3. Spawning	A-Hydrated-Large ovaries, with firm consistence and vascularization, pink or reddish orange. Opaque and hyaline oocytes present.	Large white testis, with the shape of large bands. Sperm flows with pressure on the abdomen.
	B-Partial spawning-Large ovaries, flaccid, with vascularization, pink or reddish orange. With opaque present oocytes but without hyaline oocytes.	
4. Post-spawning	Small or medium ovaries, flaccid, dark pink, orange or purple. Opaque and hyaline oocytes absent or residual.	Large testis, white or light pink, empty and deformed. Sperm absent or residual.

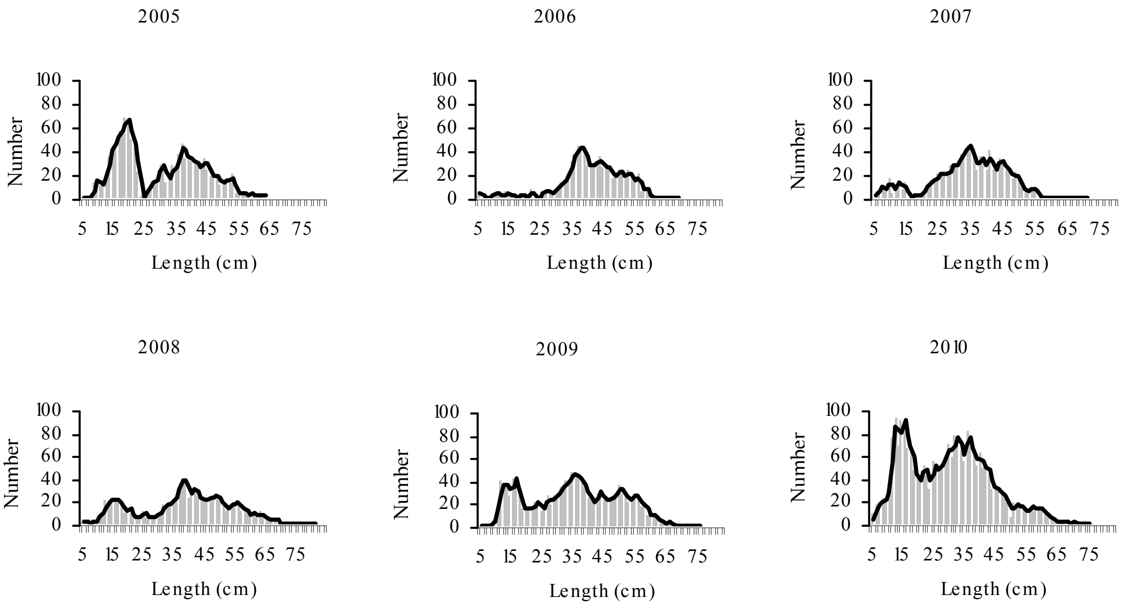


Figure 2. Annual length composition of hake sampled during the period 2005-2010.

g weight) in July. Total length of males ranged from 20.0 cm (with 46.0 g weight) in April to 66.1 cm (with 2057.9 g weight) in May. Fish smaller than 25 cm length, with high numbers in 2005, decreased greatly in the samples of 2006, but from 2007 onwards their abundance raised and in 2010 the number of fish sampled with less than 25 cm was very high. The number of sampled fish bigger than 55 cm length was in general low in all the years.

Fish smaller than 20.0 cm length were not sexed, whatled to a total of 5215 fish macroscopically sexed (3592 females and 1623 males). Individuals whose sex assign ment presented doubts were not considered. Most of the fish sexed belonged to length range 20 - 30 cm (86.8%) and 30 - 40 cm (91.5%), showing a sex ratio close to 1:1 (**Figure 3**). In length classes bigger than 40 cm the proportion of fish sexed was smaller but there was a high predominance of females, in particular among

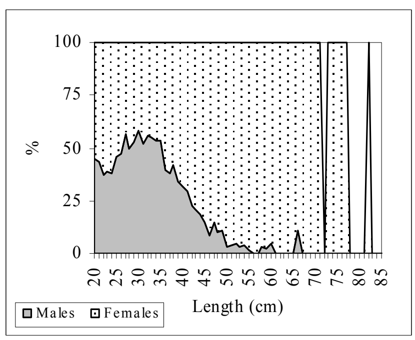


Figure 3. Sex ratio for hake in the Portuguese coast in the period 2005-2010.

the individuals over 50 cm length (97.3%).

3.1. Length-Weight Relationships

The relationships between total length and total weight were determined for both sexes by month in a total of 5471 specimens (1889 males and 3582 females). The estimated parameters of the total length-total weight relationships, the number of fish, length and weight ranges and the correlation coeficients are presented in **Table 3** (years are pooled by month).

The same parameters were estimated for the total length-gutted weight relationships, with a total of 6657 fish, which are presented in **Table 4**. In this table, where

Table 3. Monthly total length-total weight relationships for hake in the Portuguese coast for the period 2005-2010 (years are pooled by month).

Month	Sex	Function	N	R^2 (%)	SE (*b*)	Length range (cm)	Weight range (g)
	Males	$W_t = 0.0039L^{3.153}$	118	97.41	0.048	26.2 - 49.9	127.0 - 760.0
January	Females	$W_t = 0.0076L^{3.005}$	151	95.84	0.051	24.5 - 73.0	107.0 - 2623.0
	Sexes combined	$W_t = 0.0040L^{3.164}$	269	96.04	0.039	24.5 - 73.0	107.0 - 2623.0
	Males	$W_t = 0.0072L^{2.983}$	170	94.50	0.056	20.3 - 45.3	43.8 - 631.0
February	Females	$W_t = 0.0040L^{3.166}$	229	97.57	0.033	20.3 - 77.0	48.5 - 3280.0
	Sexes combined	$W_t = 0.0036L^{3.193}$	399	97.36	0.026	20.3 - 77.0	43.8 - 3280.0
	Males	$W_t = 0.00449L^{3.122}$	251	98.23	0.027	20.0 - 52.0	47.1 - 1035.6
March	Females	$W_t = 0.0039L^{3.164}$	379	98.78	0.018	20.0 - 70.1	44.7 - 2816.0
	Sexes combined	$W_t = 0.0037L^{3.178}$	630	98.78	0.014	20.0 - 70.1	44.7 - 2816.0
	Males	$W_t = 0.0037L^{3.171}$	312	98.70	0.021	20.0 - 53.2	44.0 - 1022.0
April	Females	$W_t = 0.0035L^{3.189}$	683	99.15	0.011	20.0 - 77.5	40.0 - 3236.0
	Sexes combined	$W_t = 0.0034L^{3.196}$	995	99.19	0.009	20.0 - 77.5	40.0 - 3236.0
	Males	$W_t = 0.0049L^{3.093}$	209	98.96	0.022	20.0 - 66.1	45.8 - 2057.9
May	Females	$W_t = 0.0051L^{3.092}$	411	98.74	0.017	20.0 - 74.0	44.4 - 3148.0
	Sexes combined	$W_t = 0.0046L^{3.113}$	620	99.02	0.012	20.0 - 74.0	44.4 - 3148.0
	Males	$W_t = 0.0058L^{3.031}$	142	99.13	0.024	20.0 - 70.4	44.0 - 2172.0
June	Females	$W_t = 0.0040L^{3.161}$	232	98.55	0.025	20.3 - 66.8	45.8 - 2278.0
	Sexes combined	$W_t = 0.0040L^{3.153}$	374	98.86	0.018	20.0 - 70.4	44.0 - 2278.0
	Males	$W_t = 0.0049L^{3.088}$	149	98.26	0.021	20.1 - 50.8	48.0 - 860.0
July	Females	$W_t = 0.0041L^{3.165}$	389	98.79	0.018	20.0 - 82.8	45.0 - 5304.0
	Sexes combined	$W_t = 0.0035L^{3.200}$	538	98.88	0.015	20.0 - 82.8	45.0 - 5304.0
	Males	$W_t = 0.0045L^{3.131}$	109	96.97	0.054	21.1 - 60.7	58.0 - 1504.0
August	Females	$W_t = 0.0065L^{3.045}$	271	98.070	0.026	20.7 - 76.7	52.0 - 3151.0
	Sexes combined	$W_t = 0.0052L^{3.099}$	380	98.07	0.022	20.7 - 76.7	52.0 - 3151.0
	Males	$W_t = 0.0043L^{3.141}$	140	98.01	0.038	20.6 - 46.7	57.6 - 700.0
September	Females	$W_t = 0.0052L^{3.096}$	330	98.45	0.021	20.1 - 67.8	44.3 - 2358.0
	Sexes combined	$W_t = 0.0046L^{3.131}$	470	98.49	0.018	20.1 - 67.8	44.3 - 2358.0
	Males	$W_t = 0.0034L^{3.197}$	94	97.74	0.051	20.1 - 49.0	54.6 - 1050.0
October	Females	$W_t = 0.00376L^{3.190}$	278	97.93	0.028	20.0 - 69.8	42.9 - 2252.0
	Sexes combined	$W_t = 0.0032L^{3.223}$	372	98.20	0.023	20.0 - 69.8	42.9 - 2252.0
	Males	$W_t = 0.0061L^{3.036}$	163	97.38	0.039	21.0 - 54.7	59.9 - 1034.0
November	Females	$W_t = 0.0058L^{3.065}$	222	97.75	0.031	20.4 - 77.0	66.0 - 3332.0
	Sexes combined	$W_t = 0.0052L^{3.091}$	385	97.64	0.025	20.4 - 77.0	59.9 - 3332.0
	Males	$W_t = 0.0016L^{3.418}$	32	92.79	0.174	24.5 - 39.2	102.5 - 438.6
December	Females						
	Sexes combined	$W_t = 0.0007L^{3.665}$	39	93.72	0.156	24.5 - 39.2	102.5 - 500.9

Table 4. Monthly total length-gutted weight relationships for hake in the Portuguese coast for the perid 2005-2010 (years are pooled by month).

Month	Sex	Function	N	R^2 (%)	SE (*b*)	Length range (cm)	Weight range (g)
January	Males	$W_t = 0.0052L^{3.057}$	105	98.29	0.040	26.2 - 49.9	120.0 - 710.0
	Females	$W_t = 0.0090L^{2.924}$	152	97.13	0.041	24.5 - 73.0	102.0 - 2314.0
	Sexes combined	$W_t = 0.00680L^{2.988}$	348	97.93	0.023	24.5 - 73.0	102.0 - 2314.0
February	Males	$W_t = 0.0073L^{2.959}$	169	95.79	0.048	21.0 - 45.3	55.2 - 548.0
	Females	$W_t = 0.0056L^{3.045}$	227	98.09	0.028	20.3 - 77.0	48.2 - 2880.0
	Sexes combined	$W_t = 0.0058L^{3.030}$	546	98.44	0.016	20.3 - 77.0	48.2 - 2880.0
March	Males	$W_t = 0.0053L^{3.047}$	218	98.47	0.026	20.0 - 52.0	45.7 - 941.7
	Females	$W_t = 0.0054L^{3.049}$	365	99.09	0.015	20.0 - 70.1	42.8 - 2256.0
	Sexes combined	$W_t = 0.0052L^{3.054}$	728	99.19	0.010	20.0 - 72.9	42.8 - 2432.0
April	Males	$W_t = 0.0038L^{3.142}$	250	99.03	0.020	20.0 - 53.2	41.9 - 884.0
	Females	$W_t = 0.0045L^{3.091}$	680	99.49	0.008	20.0 - 77.5	37.8 - 2832.0
	Sexes combined	$W_t = 0.0044L^{3.095}$	1010	99.46	0.007	20.0 - 77.5	37.8 - 2832.0
May	Males	$W_t = 0.0059L^{3.017}$	170	99.24	0.020	20.0 - 66.1	42.9 - 1845.7
	Females	$W_t = 0.0063L^{3.004}$	409	99.25	0.013	20.0 - 74.0	42.2 - 2393.0
	Sexes combined	$W_t = 0.00593L^{3.020}$	746	99.38	0.009	20.0 - 74.0	42.2 - 2393.0
June	Males	$W_t = 0.0038L^{3.143}$	75	99.10	0.035	20.0 - 47.2	41.9 - 580.0
	Females	$W_t = 0.0051L^{3.062}$	232	99.09	0.019	20.3 - 66.8	43.4 - 1844.0
	Sexes combined	$W_t = 0.0046L^{3.086}$	452	99.30	0.012	20.0 - 71.1	41.9 - 2200.0
July	Males	$W_t = 0.0055L^{3.034}$	108	98.67	0.034	20.1 - 50.8	46.0 - 810.0
	Females	$W_t = 0.0054L^{3.054}$	388	98.90	0.016	20.2 - 82.8	40.0 - 4787.0
	Sexes combined	$W_t = 0.0051L^{3.063}$	633	98.95	0.013	20.0 - 82.8	40.0 - 4787.0
August	Males	$W_t = 0.0059L^{3.023}$	93	98.40	0.040	21.9 - 60.7	62.0 - 1375.0
	Females	$W_t = 0.0071L^{2.980}$	271	98.820	0.020	20.7 - 76.7	50.0 - 2440.0
	Sexes combined	$W_t = 0.00671L^{2.997}$	492	98.78	0.015	20.7 - 76.7	50.0 - 2440.0
September	Males	$W_t = 0.0051L^{3.062}$	128	98.82	0.030	20.6 - 46.7	49.6 - 650.0
	Females	$W_t = 0.0062L^{3.015}$	326	98.91	0.018	20.1 - 67.8	41.5 - 2023.0
	Sexes combined	$W_t = 0.0063L^{3.007}$	622	98.93	0.013	20.1 - 69.9	41.5 - 2258.0
October	Males	$W_t = 0.0041L^{3.126}$	92	98.48	0.041	20.1 - 49.0	52.1 - 830.0
	Females	$W_t = 0.0051L^{3.071}$	272	98.63	0.022	20.2 - 63.3	41.4 - 1800.0
	Sexes combined	$W_t = 0.0053L^{3.055}$	477	98.89	0.015	20.0 - 66.5	41.4 - 2091.0
November	Males	$W_t = 0.0061L^{3.011}$	160	97.98	0.034	21.0 - 54.7	58.0 - 969.0
	Females	$W_t = 0.0065L^{2.999}$	221	98.11	0.028	20.4 - 77.0	57.8 - 3049.0
	Sexes combined	$W_t = 0.0065L^{2.998}$	555	98.17	0.017	20.4 - 77.0	57.8 - 3049.0
December	Males	$W_t = 0.0035L^{3.168}$	32	97.04	0.101	24.5 - 39.2	96.0 - 380.2
	Females	$W_t = 0.0272L^{2.623}$	21	89.78	0.396	34.4 - 38.8	305.9 - 413.6
	Sexes combined	$W_t = 0.0044L^{3.105}$	48	99.49	0.033	24.5 - 67.8	96.0 - 2122.0

years are pooled by month, the values of sexes combined were obtained not only with the sexed fish but also with the adult fish (over 20 cm length) landed already gutted.

The total length and weights relationships for the total individuals sampled and by sexes are shown in **Tables 5** and **6**.

Length-weight relationships were statistically compared to determine whether there were differences in growth rate between males and females, considering the same length ranges for comparison. The results seem to indicate that the annual growth is similar for males and females (**Table 7**).

In **Table 8** are shown the monthly relationships between total and gutted weights for males, females and sexes combined, the length and weight ranges, number of fish sampled and the correlation coefficient obtained (years are pooled by month).

Grouping together the monthly values of total and gutted weights the relationships found are: $W_t = 7.0261 + 0.892W_g$ for males, $W_t = 16.3313 + 0.845W_g$ for females and $W_t = 15.8112 + 0.848W_g$ for sexes combined.

Considering the same length ranges, total weight- gutted weight relationships were also statistically compared for both sexes, showing that the annual growth is different for total weight and gutted weight (**Table 7**).

According to these results the growth rates of males and females are similar for both sexes although higher when calculated with total weight than with gutted weight.

Conversion factors between gutted and total weights are presented in **Table 9**.

Grouping together the monthly conversion factors between gutted and total weights the values obtained are: 1.0980 for males, 1.1585 for females and 1.1524 for sexes combined.

As seen in the **Figure 4**, and particularly in females, in the length classes over 30 cm viscera represent more than 10% of the total weight and more than 15% in length classes over 60 cm. Considering the mean weight of all length classes viscera account for 13.28% of total weight. The monthly evolution of the visceras weights show for both sexes an increasing trend from January to August, then decreasing until November rising again in December, particularly in females.

3.2. Somatic Condition

Condition factor (Fulton factor) was calculated with total weight (TW) and gutted weight (GW). Mature females (≥38 cm) showed always higher values than immature females (<38 cm) during the entire period, with a similar but smoother oscillation (**Figure 5**).

Both immature (<26 cm) and mature males (≥26 cm) didn't show high variations of this index along the year.

The gonadosomatic index, obtained either with the total weight (TW) or the gutted weight (GW), showed the same general pattern for males and females along the year (**Figure 6**). The values of both indices for females were about 3 times higher of the values of the same indices for males. Immature and mature females showed an opposite variation of GSI during the first semester but in the second half of the year the variation was similar for all the females. Due to the lack of samples this comparison could not be done for males.

The monthly evolution of the hepatosomatic index obtained with the total weight (HSI_t) and the gutted weight (HSI_g) was similar for mature and immature fish, with the HSI_g values slightly higher (**Figure 7**). Females' maximum values of these indices were found in the beginning of the 4th quarter (October) while mature males (≥26 cm) showed a sharp increase in June.

For both sexes the Pearson coefficient (r) shows stronger correlations (Cohen, 1988) [36] between GSI and CF or HSI when using gutted weight (**Table 10**). With total weight those relationships are in general medium and between HSI and CF they are weak, either for males or females.

Table 5. Total length-total weight relationships for hake in the Portuguese coast for the period 2005-2010.

	N	W/L	R^2 (%)	SE (*b*)	Length range (cm)	Weight range (g)
Males	1889	$W_t = 0.0043L^{3.127}$	98.43	0.055	20.0 - 66.1	43.8 - 1400.0
Females	3582	$W_t = 0.0042L^{3.150}$	98.58	0.029	20.0 - 82.8	40.0 - 5304.0
Sexes combined	5471	$W_t = 0.0038L^{3.172}$	98.69	0.022	20.0 - 82.8	40.0 - 5304.0

Table 6. Total length-gutted weight relationships for hake in the Portuguese coast for the period 2005-2010.

	N	W/L	R^2 (%)	SE (*b*)	Length range (cm)	Weight range (g)
Maless	1600	$W_t = 0.0047L^{3.082}$	98.86	0.060	20.0 - 66.1	41.9 - 1845.7
Females	3550	$W_t = 0.0054L^{3.049}$	99.03	0.056	20.0 - 82.8	37.8 - 4787.0
Sexes combined	6657	$W_t = 0.0052L^{3.059}$	99.11	0.043	20.0 - 82.8	37.8 - 1845.7

Table 7. Statitical analysis of the growth rate of Portuguese hake.

Call:				
lm(formula = log(weight) ~ log(length) * type.weight, data = data)				
Residuals:				
Min	1Q	Median	3Q	Max
−0.145038	−0.031178	0.002016	0.031580	0.090341
Coefficients:				
	Estimate	Std. Error	t value	Pr (>|t|)
(Intercept)	−4.99395	0.06133	−81433	<2e−16***
log(length)	2.99168	0.01686	177482	<2e−16***
type. totweight	−0.17133	0.08673	−1975	0.05001
log(length): type. totweight	0.07432	0.02384	3118	0.00218**
Signif. codes:	0'***'	0.001'**'	0.01 '*'	0.05 '.' 0.1 ' ' 1
Residual standard error: 0.04659 on 154 degrees of freedom				
Multiple R-squared: 0.9976,				
F-statistic: 2.159e+04 on 3 and 154 DF			*p*-value: < 2.2e−16	

3.3. Spawning Season

The annual evolution of the maturity stages is a good indicator of the spawning period of a species.

The analysis by sex of the proportion of each maturity stage along the year (**Figure 8**) shows that immature females were present in higher proportions than immature males in every month. In the mature stages (2, 3 and 4) males were in general present at higher proportions, except for maturity stage 3. The months with the highest proportion of mature stages were May for females (74%) and November for males (94%). Considering both sexes May showed the highest proportion of mature stages (76%).

Another indicator of the spawning season is the monthly evolution of the ovary weight (**Figure 9**).

In this graphic the 4 peaks of higher ovaries weights (averages) are signalised (sp.) and interpreted as "spawning peaks" and the ascending lines are considered as following recovering periods. Although 2727 ovaries were weighted, the low values observed in December and January are probably due to an insufficient number of individuals sampled (7 and 123, respectively), while in the rest of the year a mean of 260 ovaries were weighted per month.

According to the length class, females spawn mainly three times per year, in January-March, May-June and August, as shown in **Table 11**. These observations seem to indicate that the start of the spawning is independent of fish length, since the spawning peaks occur at the same time for all the fish lengths. The ascending lines shown in the previous figure in October, November and December may represent only false spawning peaks, due to the small number of individuals analysed in those months.

Another fact that can be observed is the increase of the weights of the ovaries with length, which can be explained since normally the gonads are bigger on bigger exemplars.

4. Discussion

One of the most important and exploited fish species in western demersal fisheries is the european hake (*Merluccius merluccius* L., 1758) (Casey and Pereiro, 1995) [37], not only due to its high abundance and large distribution but also because of its role in the food chain. Since 1978 the ICES Working Group on the Assessment of Southern Shelf Demersal Stocks (WGSSDS) distinguishes two hake stocks for assessment purposes: the northern stock and the southern stock (ICES, 1979) [38]. Both stocks are outside safe biological limits and EU has developed in 2006 a recovery plan for the southern stock of this species (EU, 2011) [39]. Taking this into account, the administration authorities need cientific advice to ensure the sustainable management of those species, in order to protect the spawning stock. Therefore, in particular during the spawning season, management measures must be taken, which may consist of seasonal bans, the reduction of fishing effort and the update of the estimation of length at first maturity (L_{50}), since this parameter can change as a result of the fishing intensity or exploitation pattern (BIOSDEF, 1998) [40]. One of the most important management measures for a certain species is the establishment of its minimum landing size, along with the obligation of discarding to the sea all the individuals with smaller sizes. In order to have a biological meaning this minimum size must allow the individuals to reach the size of reproduction, but it must also take into account the characteristics of the fishing gear that captures that species, in other words, its selectivity. The Council Regulation (EC) No. 850/98 of 30 March 1998 established for the european hake the minimum landing size of 27 cm.

Due to the economical importance of hake there are abundante studies about several subjects, such as, biology, maturity, fecundity, reproduction, distribution and growth, not only on the species *Merluccius merluccius* (Biagi *et al.*, 1995 [41]; de Pontual *et al.*, 2006 [42]; Domínguez-Petit *et al.*, 2008 [43]; El Habouz *et al.*, 2011 [44]; Korta *et al.*, 2010 [45]; Murua and Motos, 2006 [46]; Murua *et al.*, 1998 [47]; Piñeiro and Sainza, 2003 [48]; Velasco and Olaso, 1998 [49], among others) as on the other species of *Merluccius* (e.g. Balbontin and Fischer, 1981 [50]; Fernández-Peralta *et al.*, 2011 [51]; Honji *et al.*, 2006 [52]; Relini *et al.*, 2002 [53]). Although in Portugal there has been a directed trawl fishery for white hake for many years and substantial quantities are catch with different fishing gears, biological investigations have been rather limited. Thereby, in the present study some parameters are presented and discussed in order to clarify some characteristics related to the biology of *Merluccius merluccius* that inhabits the waters along the portuguese coast.

Regarding the length distribution of hake along the years, fish smaller than 25 cm, present in 2005, almost desappeared in 2006, increasing again in 2007, what might be explained by the fluctuations of the recruitment indices in those years. The oscillations in hake catches are not a portuguese problem in particular. Since the 1960s (FAO, 2010) [54] European hake catches have been decreasing and the commercial viability of aqua

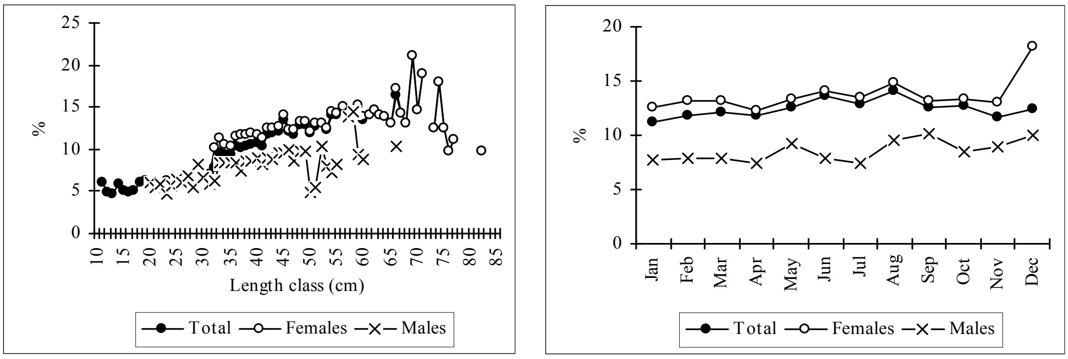


Figure 4. Percentage of viscera weight on the total weight by length class and by month of hake in the Portuguese Coast in the period 2005-2010. Females-length classes 73, 75, 76 e 82 cm with only 1 fish. Males-length classes 55, 57, 59 e 66 cm with only 1 fish.

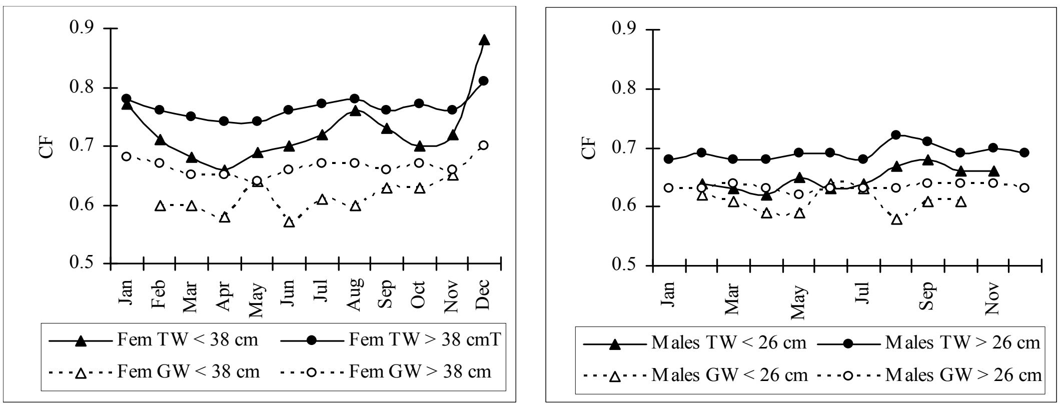


Figure 5. Condition factor monthly evolution using the total and gutted weight for hake in the Portuguese coast in the period 2005-2010.

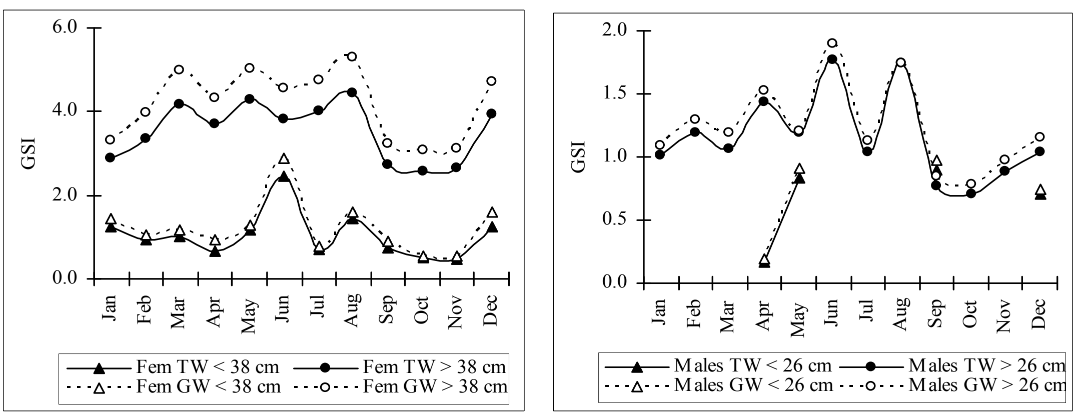


Figure 6. Gonadosomatic index monthly evolution calculated using the total and gutted weight for hake in the Portuguese Coast in the period 2005-2010.

Table 8. Monthly total weight (W_t)-gutted weight (W_g) relationships for hake in the Portuguese coast for the period 2005-2010 (years are pooled by month).

Month	Sex	Function	N	R2 (%)	W_t range (g)	W_g range (g)	Length range (cm)
January	Males	$W_t = 10.8579 + 0.890Wg$	105	98.93	127.00 - 760.00	120.00 - 710.00	26.2 - 49.9
	Females	$W_t = 5.8451 + 0.865Wg$	151	98.90	107.00 - 2623.00	102.00 - 2314.00	24.5 - 73.0
	Sexes combined	$W_t = 14.4329 + 0.860Wg$	269	98.96	107.00 - 2623.00	102.00 - 2314.00	24.5 - 73.0
February	Males	$W_t = 7.7719 + 0.895Wg$	168	96.81	57.58 - 631.00	55.16 - 548.00	21.0 - 45.3
	Females	$W_t = 32.2629 + 0.820Wg$	227	98.54	48.45 - 3280.00	48.20 - 2880.00	20.3 - 77.0
	Sexes combined	$W_t = 25.8547 + 0.833Wg$	395	99.21	48.45 - 3280.00	48.20 - 2880.00	20.3 - 77.0
March	Males	$W_t = 5.8765 + 0.902Wg$	218	98.71	49.31 - 1035.60	45.70 - 941.70	20.0 - 52.0
	Females	$W_t = 23.3082 + 0.837Wg$	367	97.66	44.65 - 2816.00	42.79 - 2256.00	20.0 - 70.1
	Sexes combined	$W_t = 21.6400 + 0.841Wg$	612	98.94	36.20 - 2816.00	35.00 - 2256.00	18.1 - 70.1
April	Males	$W_t = 4.1006 + 0.905Wg$	251	99.45	44.10 - 1022.00	41.90 - 884.00	20.0 - 53.21
	Females	$W_t = 13.8052 + 0.854Wg$	680	99.26	40.00 - 3236.00	37.80 - 2832.00	20.0 - 77.5
	Sexes combined	$W_t = 11.5994 + 0.857Wg$	1073	99.40	6.30 - 3236.00	6.00 - 2832.00	11.0 - 77.5
May	Males	$W_t = 14.3193 + 0.869Wg$	170	99.02	45.80 - 2057.90	42.90 - 1845.70	20.0 - 66.1
	Females	$W_t = 24.0047 + 0.841Wg$	409	98.90	44.38 - 3148.00	42.20 - 2393.00	20.0 - 74.0
	Sexes combined	$W_t = 21.0809 + 0.844Wg$	618	99.12	43.00 - 3148.00	41.00 - 2393.00	18.3 - 74.0
June	Males	$W_t = 0.8239 + 0.917Wg$	75	99.39	44.00 - 640.00	41.90 - 580.00	20.0 - 47.2
	Females	$W_t = 11.7155 + 0.836Wg$	234	98.63	45.82 - 2278.00	43.43 - 1844.00	20.3 - 66.8
	Sexes combined	$W_t = 15.3765 + 0.839Wg$	344	99.01	44.00 - 2278.00	41.90 - 1844.00	20.0 - 66.8
July	Males	$W_t = 3.2517 + 0.912Wg$	108	99.73	48.00 - 860.00	46.00 - 810.00	20.1 - 50.8
	Females	$W_t = 3.4795 + 0.861Wg$	388	99.15	45.00 - 5304.00	40.00 - 4787.00	20.0 - 82.8
	Sexes combined	$W_t = 7.4754 + 0.859Wg$	530	99.27	45.00 - 5304.00	40.00 - 4787.00	19.5 - 82.8
August	Males	$W_t = -4.9365 + 0.916Wg$	93	99.20	64.00 - 1504.00	62.00 - 1375.00	21.9 - 60.7
	Females	$W_t = 22.4510 + 0.828Wg$	271	98.44	52.00 - 3151.00	50.00 - 2440.00	20.7 - 76.7
	Sexes combined	$W_t = 17.1429 + 0.837Wg$	376	98.79	52.00 - 3151.00	50.00 - 2440.00	20.7 - 76.7
September	Males	$W_t = 10.8442 + 0.859Wg$	128	98.16	57.60 - 700.00	49.57 - 650.00	20.6 - 46.7
	Females	$W_t = 12.3124 + 0.848Wg$	326	99.10	44.33 - 2358.00	41.47 - 2023.00	20.1 - 67.8
	Sexes combined	$W_t = 12.3786 + 0.848Wg$	461	99.11	44.33 - 2358.00	41.47 - 2023.00	20.1 - 67.8
October	Males	$W_t = 19.0749 + 0.848Wg$	92	98.78	54.62 - 1050.00	52.10 - 830.00	20.1 - 49.0
	Females	$W_t = 25.0761 + 0.833Wg$	272	98.40	42.90 - 2252.00	41.40 - 1800.00	20.0 - 63.3
	Sexes combined	$W_t = 27.5351 + 0.834Wg$	365	98.67	42.90 - 2252.00	41.40 - 1800.00	20.0 - 63.3
November	Males	$W_t = 1.5425 + 0.909Wg$	159	98.45	59.90 - 1034.00	58.00 - 969.00	21.0 - 54.7
	Females	$W_t = 2.0613 + 0.867Wg$	221	99.05	66.00 - 3332.00	57.80 - 3049.00	20.4 - 77.0
	Sexes combined	$W_t = 11.1763 + 0.864Wg$	381	98.95	59.90 - 3332.00	57.80 - 3049.00	20.4 - 77.0
December	Males	$W_t = 25.0887 + 0.786Wg$	32	95.49	102.50 - 438.60	96.00 - 380.20	24.5 - 39.2
	Females	$W_t = -3.6363 + 0.827Wg$	7	63.84	386.00 - 500.90	305.90 - 413.60	34.4 - 38.8
	Sexes combined	$W_t = 30.0361 + 0.759Wg$	39	96.17	102.50 - 500.90	96.00 - 413.60	24.5 - 39.2

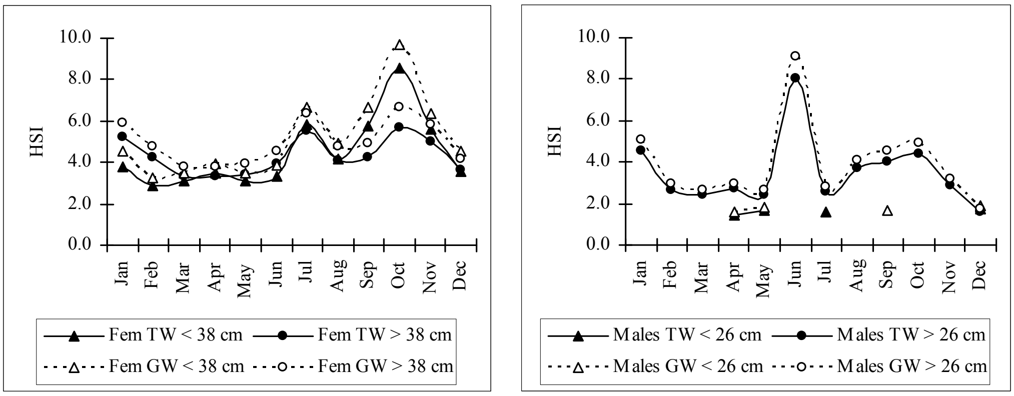
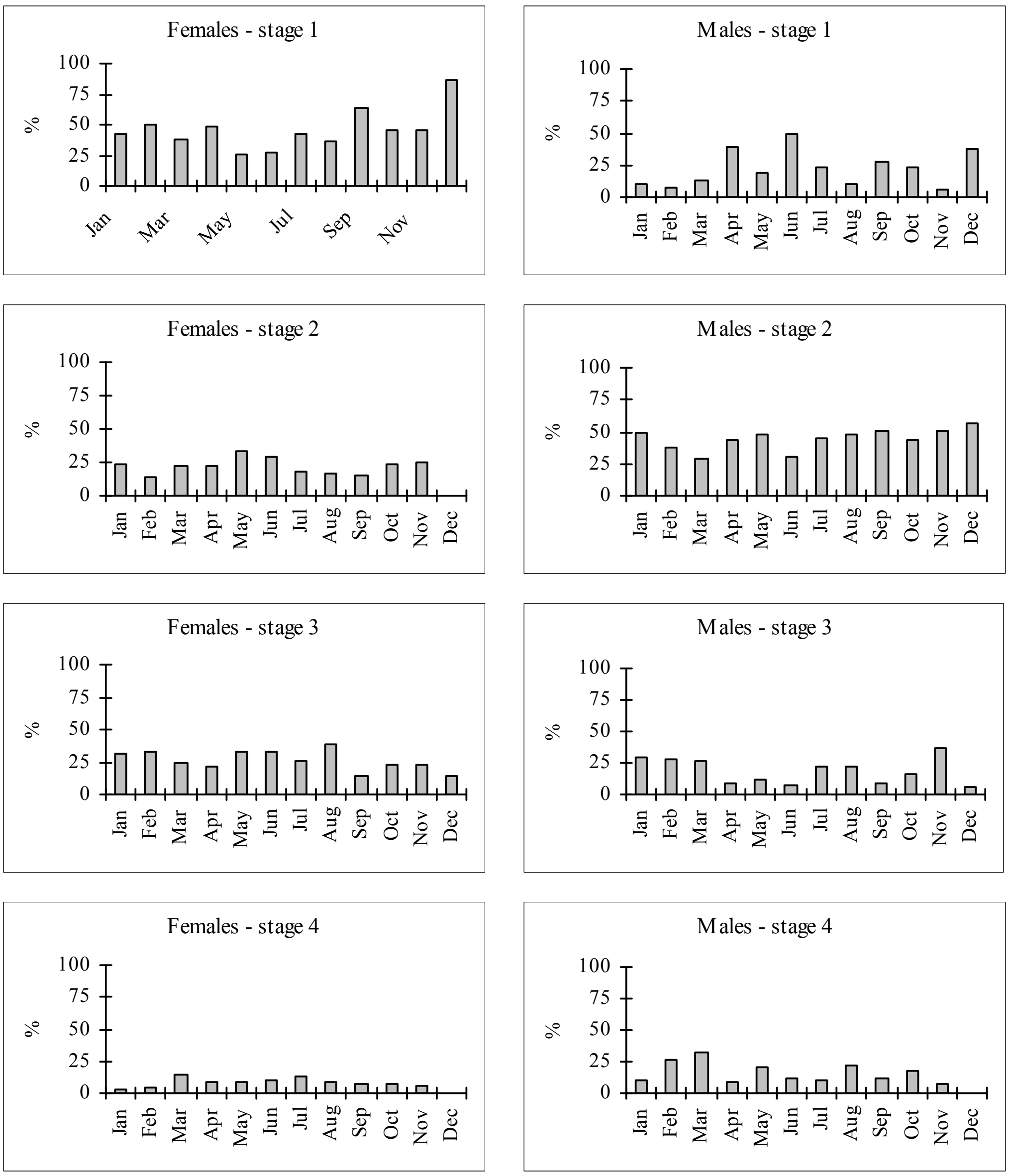


Figure 7. Hepatosomatic index monthly evolution calculated using the total and gutted weight for hake in the Portuguese Coast in the period 2005-2010.



Figue 8. Maturity stages assigned de visu for females (left) and males (right) hake in the Portuguese Coast in the period 2005-2010. Maturity stages: 1) Immature or Resting; 2) Maturing; 3) Spawning; 4) Post-spawning.

Table 9. Conversion factor for gutted weight (Wg) to Total Weight (Wt) by sex and by month for hake in the Portuguese coast in the period 2005-2010 (years are pooled by month).

Month	Sex	Function	N	R2 (%)	Length range (cm)
January	Males	1.0889	105	0.989	26.2 - 49.9
	Females	1.1437	151	0.989	24.5 - 73.0
	Sexes combined	1.1329	269	0.989	24.5 - 73.0
February	Males	1.0860	168	0.968	21.0 - 45.3
	Females	1.1661	227	0.984	20.3 - 77.0
	Sexes combined	1.1505	395	0.990	20.3 - 77.0
March	Males	1.0880	218	0.987	20.0 - 52.0
	Females	1.1584	367	0.987	20.0 - 70.1
	Sexes combined	1.1511	612	0.989	18.1 - 70.1
April	Males	1.0877	251	0.994	20.0 - 53.21
	Females	1.1494	680	0.992	20.0 - 77.5
	Sexes combined	1.1465	1073	0.994	11.0 - 77.5
May	Males	1.1162	170	0.990	20.0 - 66.1
	Females	1.1576	409	0.989	20.0 - 74.0
	Sexes combined	1.1537	618	0.990	18.3 - 74.0
June	Males	1.0852	75	0.994	20.0 - 47.2
	Females	1.1692	234	0.986	20.3 - 66.8
	Sexes combined	1.1661	344	0.990	20.0 - 66.8
July	Males	1.0861	108	0.997	20.1 - 50.8
	Females	1.1538	388	0.992	20.0 - 82.8
	Sexes combined	1.1505	530	0.993	19.5 - 82.8
August	Males	1.0986	93	0.992	21.9 - 60.7
	Females	1.1782	271	0.984	20.7 - 76.7
	Sexes combined	1.1691	376	0.988	20.7 - 76.7
September	Males	1.1212	128	0.981	20.6 - 46.7
	Females	1.1558	326	0.991	20.1 - 67.8
	Sexes combined	1.1529	461	0.991	20.1 - 67.8
October	Males	1.1111	92	0.985	20.1 - 49.0
	Females	1.5530	272	0.983	20.0 - 63.3
	Sexes combined	1.1523	365	0.986	20.0 - 63.3
November	Males	1.0937	159	0.984	21.0 - 54.7
	Females	1.1471	221	0.991	20.4 - 77.0
	Sexes combined	1.1367	381	0.990	20.4 - 77.0
December	Males	1.1226	32	0.949	24.5 - 39.2
	Females	1.2165	7	0.425	34.4 - 38.8
	Sexes combined	1.1586	39	0.954	24.5 - 39.2

Table 10. Pearson correlation coeficient of GSI, HSI and K for hake of the Portuguese coast calculated using the total and gutted weight in the period 2005-2010.

Sex	Correlation factors	Correlation coeficient (*r*)	Correlation type (Cohen, 1988)
Females	GSIt/CFt	−0.3	Medium
	GSIt/HSIt	0.5	Strong
	HSIt/CFt	0.1	Weak
	GSIg/CFg	−0.6	Strong
	GSIg/HSIg	−0.5	Strong
	HSIg/CFg	−0.3	Medium
Males	GSIt/CFt	−0.3	Medium
	GSIt/HSIt	−0.4	Medium
	HSIt/CFt	−0.3	Medium
	GSIg/CFg	−0.6	Strong
	GSIg/HSIg	−0.4	Medium
	HSIg/CFg	−0.2	Weak

Table 11. Peaks of hake spawning in the Portuguese coast in the period 2005-2010.

Classes (cm)	1st peak	2nd peak	3rd peak
Total	Mar.	May	Aug.
20 - 30	Feb.	Jun.	Aug.
31 - 40	Jan.	Jun.	Aug.
41 - 50	Mar.	May	Aug.
51 - 60	Jan.	Mar.	May
>60	Jan.	Jun.	Sep.

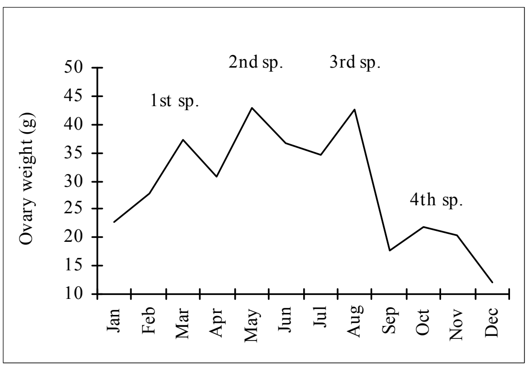


Figure 9. Monthly evolution of average ovarian weight of hake in the Portuguese Coast in the period 2005-2010 considering all the length classes.

culture production has recently increased (Groison, 2010 [55]; Hiney *et al.*, 2002 [56]; Kjesbu *et al.*, 2006 [57]). some researchers have even stated that the hake is one of the most promising new species for marine aquaculture (Engelsen *et al.*, 2004) [58]. Recruitment indices of hake in the portuguese coast have been varying in the last decades, showing a decreasing trend from 1990 to 1995, followed by a strong oscillation from 1995 onwards (Cardador *et al.*, 2009) [59]. Maybe this is responsible for the decreasing catches verified at the middle of the 2000 decade. However, the recovery plan for the southern stock of hake implemented by the E.U. in 2006, as well as the ban on fishing in the portuguese waters between Milfontes and Arrifana, from the 1st of December to the last day of February for the protection of the juveniles, are most likely contributing to the increase of the abundance indices in the most recent years—an increase of 65% in 2007 compared with the previous years. Unlike juveniles, that distribute between 100 and 200 meters depth (Cardador *et al.*, 2009) [59], bigger individuals, living at higher depths, are always caught in smaller numbers. In the present study fish with more than 50 cm total length corresponded to 19% and those with more than 60 cm corresponded to 5% of all the sampled specimens. Yet, these numbers may not reflect the size structure of the exploited population since the discards of the species *Merluccius merluccius* were very high in the years 2004-2005, 18% (Fernandes *et al.*, 2008) [60], while in 2007-2008 the discards of hake, mainly of individuals smaller then 27 cm (the legal minimum length) were higher then the species landings (Cardador *et al.*, 2009) [59].

Similar observations are referred by Lucio *et al.* (1998) [61] for the Bay of Biscay, where only 10% of the captured fish were 45 - 49 cm and less than 5% had more than 60 cm. Piñeiro *et al.* (1998) [62] also mention that very few individuals were caught with more than 60 cm in the ICES Div. VIIIc and IXa.

In the present study sex ratio for the length classes smaller than 40 cm was close to 1:1. In the individuals over 40 cm length females were predominant (1:0.13) while in the classes over 50 cm the abundance of females almost reached the 100% (1:0.03). The several authors that refer the sex ratio of the different hake populations present, in some cases, results different from ours, stating that in length classes under 40 cm males are predominant. Piñeiro *et al.* (1998) [62], Sainza and Pérez (1998) [63] and Lucio *et al.* (1998) [61], studied the biology of demersal fish of the Bay of Biscay and the Cantabrian Sea, within the project BIOSDEF, and refer that in the length classes 25 - 45 cm prevailed the males, while in length classes 45 - 55 cm the proportion of the two sexes was of 1:1. A similar result was observed by Piñeiro and Sainza (2003) [48] in Iberian Atlantic waters corresponding to ICES divisions VIIIc and IXa for the individuals under 45 cm length, but for the bigger classes observations were slightly different, with the males outnumbering the females, after which females predominated and rapidly increased in relative abundance to reach 100% in fish larger than 60 cm. Also El Habouz *et al.* (2011) [44], working with hake from the eastern central Atlantic, refer that the evolution of the sex ratio in the length class interval 17 to 45 cm was close to 1:1 and that only females were found over 45 cm length. Higher number of males for intermediate sizes and higher number of females for larger sizes has been observed by Fariña and Fernández (1986) [64] in the West of Ireland, in the Portuguese coast by Portuguese researchers during five years of surveys (ICES, 1982 [65], 1983 [66], 1986 [67], 1987 [68], 1988 [69]), as well as in the bay of Biscay by Martin (1991) [70] and Lucio *et al.* (1998) [61]. Sarano (1983) [71] states that in the Gulf of Gascony most of the smaller individuals were males, while the bigger fish were predominantly females. Finally, Angelescu *et al.* (1958) [72] show a proportion of 2:1 in favor of the females of the Argentine Sea. Despite these different observations, the results of all the authors indicate, just like ours, that in length classes over 60 cm the percentage of females reaches almost the 100%. This can be due to the differences in the growth rates of the two sexes, the natural mortality rate of old males may be much higher than that of females or to the different behaviour and consequently different acessibility of fish (Piñeiro, 2011) [1]. Likewise, if male grow at a smaller rate, particularly after the start of reproduction the effect of growth and the mortality rate at length would lead to a bigger percentage of females at bigger length (Martin, 1991) [70]. Indeed, a recent study of the growth of European hake using tagging and recapture techniques (Mellon-Duval *et al.*, 2010) [73] shows that from the second year of life, females grow faster than males.

The allometry coefficient is expressed by the exponent b of the linear weight-length relationship equation. This relationship reflects an isometric growth when $b = 3$, *i.e.*, when the relative growth of both variables is perfectly identical (Mayrat, 1970 [74]; Ricker, 1973 [31], 1975 [32]). If $b < 3$ we are in presence of a negative allometric growth and if $b > 3$ we have a positive allometric growth (Sokal and Rohlf, 1987) [75]. In general, the estimates of length-weight relationships obtained in this study, based either on the total weight or the gutted weight, are close to those obtained by other authors in previous studies, not only for the portuguese coast but also for the adjacent areas of hake distribution (Cardador, 1988 [8]; Cardenas and Fernández, 1981 [76]; Godinho and Afonso, 1998 [77]; ICES, 1991 [78]; Lucio *et al.*, 1998 [61]; Morey *et al.*, 2003 [79]; Moutopoulos and Stergiou, 2002 [80]; Piñeiro *et al.*, 1998 [62]; Piñeiro and Sainza, 2003 [48]; Santos *et al.*, 2002 [13]). Most of the results reported are related to the relationships between total length and total weight and to both sexes combined. Only few authors present these relationships between total length and gutted weight and with reference to males and females separately (Godinho and Afonso, 1998 [77]; Lucio *et al.*, 1998 [61]; Piñeiro and Sainza, 2003 [48]; Piñeiro *et al.*, 1998 [62]). We also could not find any reference to these relationships on a monthly basis, which we consider to be important since the gonads weights, mainly the ovaries, may vary considerably according to the time of the year, in particular along the spawning season, when the ovaries undergo a high increase in weight. Other factors, such as food availability on fish growth (Mommsen, 1998) [81], spatial variation due to the influence of water quality (Sparre *et al.*, 1989) [82] or feeding rate (Santos *et al.*, 2002 [13]) can also affect the length-weight relationships. However, the parameter *b* is characteristic of the species (Mayrat, 1970) [74] and generally does not vary significantly throughout the year, unlike the parameter *a*, which may very daily, seasonally and/or between different habitats (Bagenal and Tesch, 1978) [83]. So, we conclude that the observed differences with the values reported in other studies can be due to differences in the number of samples at length distribution margins, by the time of the year when sampling took place or to the selective characteristics of fishing gear. The conversion factor between gutted and total weights found in our study is of the same kind of the ones presented by Cardenas and Fernández (1981a) [84] for the ICES Divisions VIIIc and IXa and by Lucio *et al.* (1998) [61] for the Bay of Biscay in particular.

The condition factor gives a general idea of the body condition, in terms of weight, of the fish along the year. The results of the present study, similar to the results presented by other authors (Lucio *et al.*, 1998 [61]; Murua, 2006 [85]; Pérez and Pereiro, 1985 [86]) seem to show that hake condition, considering either the total or the gutted weight, is higher in autumn (November/December), decreasing in winter and reaching its minimum in spring (April). The general pattern observed, similar for both sexes, although for males with less marked fluctuations, maybe due to the fact that in females there is a higher transfer of energy, expressed in terms of weight, to the development of the ovaries.

There are several indicators that, along with the condition factor, allow us to define the spawning season of a certain species, including the indexes of the somatic condition (GSI and HSI), the annual distribution of the maturity stages and the gonads weight. In the present study the distribution of the maturity stages along the year, in particular the occurrence of maturity stages 2 (maturing) and 3 (spawning), as well as the annual distribution of the gonads weight, seem to indicate that spawning lasts from January to August, although with several peaks. Gonadosomatic index expresses the maturity of the gonads and its higher values indicate that the gonads are developing, while its lower values indicate the end of the spawning period (Lahaye, 1972) [87]. During maturation the fat reserves accumulated in the liver during the HSI peaks are mobilized to the ovaries oogenesis and the hepatosomatic index decreases rapidly (Billard, 1979 [88]; Lahaye, 1972 [87]). In the present study, although this observation is not very clear, an increasing trend of the GSI can be seen along the first semester, while HSI showed a decreasing tendency. These observations are in accordance to the fact that the European hake is reproductively active for almost the entire year and spawning females are found all the year round (Murua and Motos, 2006) [46] and so the annual evolution of the two indexes is not as clear as in species with a shorter spawning season (El Habouz *et al.*, 2011) [44].

The analysis of the total results of this study and considering the presence of maturity stage 1 (Immature or Resting), present throughout the year, and the monthly distribution of the weights of the gonads, it seems that the hake of the portuguese coast has a long spawning season, but where three stronger spawning peaks seem to be identified, March, May and August, and a weeker one in October. The same results are presented by Monteiro and Dias (1965) [3], who refer that female hakes from the Portuguese coast spawn all year around, with a higher intensity in Spring and Summer. Similar observations are pointed out by other authors that refer a long spawning season for the species *Merluccius merluccius*, as well as the presence of individuals mature and immature throughout the year (Al-Absawey, 2010 [89]; El Habouz *et al.*, 2011 [44]; Piñeiro and Sainza, 2003 [48]). The winter spawning season has been observed previously in the Moroccan Atlantic (El Habouz, 1995 [90]; Ramos *et al.*, 1990 [91], 1991 [92]), while Maurin (1954) [93] refered for the same area a longer spawning season, from December to the beginning of summer. Two peaks have also been observed in winter and summer in the CECAF area (Cervantes and Goñi, 1986) [94], January-February, and a secondary peak in summer, July-August, while a maximum spawning peak was observed from January to March on the north Atlantic Spanish coast (Perez and Pereiro, 1981 [95]) Piñeiro and Sainza, 2003 [48]) and in the Bay of Biscay (Murua and Motos, 2006 [46]). In the Mediterranean Sea, Bouhlal (1973) [96] observed a maximum spawning peak in winter and two othersmaller peaks in spring and late summer in the Gulf of Tunis, while Álvarez *et al.* (2001) [97] refer for the NE Atlantic that the spawning season extends from February to July. Other studies into the reproductive biology of European hake have indicated that this species spawns from January through July, along the shelf edge from the Bay of Biscay to the southwest of Ireland (Álvarez *et al.*, 2004 [98]; Lucio *et al.*, 2000 [99]; Martin, 1991 [70]). Other species of *Merluccius*, living in other geographical areas, also present long spawning seasons. *M. hubbsi* Marini, 1933, from the Patagonian waters, spawns from December to March, with a peak in January-February (Macchi *et al.*, 2004 [100]); the spawning season of *M. productus* Ayres, 1855, from Canada, extends from February to June (Mason, 1986 [101]), while the results of Payá and Ehrhardt (2005) [102] and Landaeta and Castro (2012) [103] studying *M. gayi gayi* Guichenot, 1848 and *M. australis* Hutton, 1872, from the Chile indicate that the spawning season lasts from late summer to early autumn. In the NW Pacific *M. albidus* Mitchill, 1818, spawns from April to July (Traver *et al.*, 2012 [104]). *M. senegalensis* Cadenat, 1950 and *M. polli* Cadenat, 1950, also called black hakes, are two species which distribution area overlaps with the European hake *M. merluccius* and which spawning season lasts from November to February (Fernández-Peralta *et al.*, 2011 [51]).

This study addresses a set of reliable parameters that can be used to undertake new assessments filling the gap of information available on the reproductive biology of European hake inhabiting the Portuguese coast. After a detailed analysis we did not find significant differences in relation to the results presented by other authors, either for the Iberian Peninsula or the adjacent areas. This work can therefore be the basis for the development of other fields of study, more delimited in space or in time.

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