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Evidence of a relationship between weight and total length of marine fish in the North-eastern Atlantic Ocean: physiological, spatial and temporal variations

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Abstract :

Weight–Body Length relationships (WLR) of 45 fish species (37 Actinopterygii and eight Elasmobranchii) were investigated. A total of 31,167 individuals were caught and their biological parameters measured during the four quarters from 2013 to 2015, on five scientific surveys sampling the North-eastern Atlantic Ocean from the North Sea to the Bay of Biscay (ICES Divisions IVb, IVc, VIId, VIIe, VIIg, VIIh, VIIj, VIIIa and VIIIb). Among 45 tested species, all showed a significant correlation between total length (L) and total weight (W). The influence of sex on WLR was estimated for 39 species and presented a significant sexual dimorphism for 18 species. Condition factor (K) of females was always higher than for males. Moreover, a spatial effect on the WLR according to five ecoregions (the Bay of Biscay, the Celtic Sea, the Western English Channel, the Eastern English Channel and the North Sea), was significant for 18 species among 38 tested species. The temporal effect was tested according to components (year and quarter/season). The seasonality effect on WLR is more frequently significant than the year especially for the Elasmobranchii species, and can be related to the spawning season. Finally, depressiform species (skates, sharks and flatfish) are characterized by positive allometric growth, whereas there is no such clear pattern regarding roundfishes growth, whatever their body shape is.

Keywords : weight-length relationship, condition factor, Bay of Biscay, Celtic Sea, English Channel, North Sea, sexual dimorphism, seasonality

INTRODUCTION

Biological informations, such as body length and weight, constitute necessary data for assessing population structure, particularly to estimate the biomass from the length frequency distribution and to convert length-at-age by weight-at-age (Froese, 2006). It would be difficult to obtain the weight with a good accuracy during the sampling at sea or from an underwater stereo-video system. Consequently, the characterization of the Weight-Length Relationship (WLR) allows establishing readily from the one known variable, the value of the other variable. Moreover, this relationship is a sustainableproxy for the “fatness” and “general well-being” as the condition factor (Le Cren, 1951; Tesch, 1968; Weatherley, 1972). In fish species, the weight-length relationship is often defined by an exponential function under conditions of isometric growth (regression follows the cube law; Ricker 1958). However, in nature, this relationship depends on the environmental conditions, the physiological state of the fish also has to be considered (Le Cren, 1951; Froese, 2006; Pauly, 2010; Mozsar *et al*., 2015). Growth coefficient (b) varies between 2.5 and 4 (Hile, 1936; Martin, 1949; Pauly & Gayanilo, 1997; Froese, 1998; 2006. In this study, the influence of factors such as sampling year and quarter, geographical area and sex were evaluated through the body length–weight relationships (WLR) which were estimated for 45 species, sampled during five surveys operating from the North Sea to the Bay of Biscay and covering all length range from juveniles to adults.

MATERIALS AND METHODS

Sampling was realized on the research vessels “Thalassa” and “Gwen-Drez” each year from 2013 to 2015, duringfive surveys (Figure 1):

- IBTS survey (International Bottom Trawl Survey), North Sea and Eastern English Channel, January-February
- CGFS survey (Channel Ground Fish Survey), Eastern English Channel, October
- CAMANOC survey (CAmpagne MANche Occidentale), Eastern and Western English Channel, September-October
- EVHOE survey(ÉValuation Halieutique de l’Ouest de l’Europe), the Celtic Sea and the Bay of Biscay, October-November
- LANGOLF (Nephrops Survey), the Bay of Biscay, May

After each haul realized during day-light, all captured fishes and cephalopods were identified, weighed, counted and measured to the nearest inferior centimeter. For this study, 31 167 marine individuals were individually weighed (total weight, W to the nearest gram) and measured (Total length, L to the nearest centimetre) on board. When possible, the sex of *Actinopterygii* and *Elasmobranchii* was determined by macroscopic observation of the gonads. A total of 45 species weredetermined: ***Actinopterygii*** (n=29083) represented by 37 species (28 roundfishes and 9 flatfishes).

Elasmobranchii (n=2084) represented by 8 species. (Table 1; Anonyme, 2016).

Preliminary to the characterization of the W-L relationship, all pairs of data for each species were plotted in order to identify and delete obvious outliers. In order to estimate the parameters of the allometric W-L relationship (Eq. 1), its base-10 logarithm (Eq. 2) was fitted for each species to data using a least squared linear model:

$$W = a\,L^{b} \qquad \text{(Eq. 1)}$$

$$\log W = \log a + b \log L \qquad \text{(Eq. 2)}$$

Where ‘a’ is the intercept or initial growth coefficient and ‘b’ is the slope i.e. the growth coefficient (Le Cren, 1951; Ricker, 1975; Froese, 2006).

To investigate variations of the relationship between body length and weight for each species a completed Generalized Linear Model was performed according to the explanatory variables:

- Geographical area (A): North Sea (ICES divisions IVa & IVb); Eastern English Channel (ICES division VIId), Western English Channel (ICES division VIIe), Celtic Sea (ICES divisions VIIf, VIIg & VIIh) and the Bay of Biscay (ICES divisions VIIIa & VIIIb),
- Sex (S): Female and Male,
- Sampling year (Y): 2013, 2014 and 2015
- Sampling quarter (Q): 1, 2, 3 and 4.

For each species, when data set resulting of explanatory variables was lower than ten, these data were deleted. The individual weight of each species was modeled such as depending on body length as continuous effect and geographical area, sex and sampling year and quarter as factors (Eq. 3):

$$\log \mathrm{W} \sim \log L + A + S + Y + Q + \log L \times A + \log L \times S + \log L \times Y + \log L \times Q \quad \text{(Eq. 3)}$$

With the separate influence of factors A (*log L x A*), S (*log L x S*), Y (*log L x Y*) and Q (*log L x Q*) on the relationship between body length and weight. For each species, the normality of data set was tested by a Quantile-Quantile Plot of the residuals (Zuur *et al*., 2007).

To characterize the difference in the W-L relationship for each species of fish, the condition factor, K, has been employed (Le Cren, 1951, Eq. 4):

$$K=1000.W/L^3 \text{ (Eq. 4)}$$

Fish with a high value of K are heavy for their length, while fish with a low value are light for their length.

All statistical analyses were carried out using the 'CAR' package (Fox & Weisberg, 2011) in the statistical environment R (R Core Team, 2016).

RESULTS

Information relative to each species are presented in Table 1 with the number of measured specimens, the type of body length and the minimum, maximum and mean±standard deviation of length and weight. Measured length and weight ranged respectively from 3 cm (*Chelidonichthys lucerna*) to 220 cm (*Conger conger*) and from 1 g to 45000 g (*Conger conger*) (Table 1). The samples were distributed by sex, sampling year, sampling quarter and by geographical area (Supplementary Table 1). Among the 45 tested species, all showed a significant correlation (P<0.05) between body length and weight. The four explanatory variables presented significant effect on the WLR (Table 2), but only for whiting (*Merlangius merlangus*) and striped red mullet (*Mullus surmuletus*), all the four has been effectively significant in the same time. The influence of sex factor was estimated on the 39 species, for which macroscopic observation allows sex identification. Slopes of W-L relationship were significantly different between males and females on only 18 species (46.1%) of which 14 *Actinopterygii* (*Pleuronectes platessa, Limanda limanda, Microstomus kitt, Dicentrarchus labrax, Merluccius merluccius, Merlangius merlangus, Mullus surmuletus, Platichthys flesus, Solea solea, Trachinus draco, Scophthalmus maximus, Phycis blennoides, Chelidonichthys cuculus, Trisopterus esmarkii*) and 4 *Elasmobranchii* (*Mustelus asterias Scyliorhinus canicula, Raja clavata, Raja montagui*) (Table 1). The effect of the sex factor is more often observed in *Elasmobranchii* (50%) than in *Actinopterygii* (35.1%). Nevertheless, in *Actinopterygii*, this result fluctuated according to the fish shape (66.6% of flatfishes *versus* 21.9% of roundfishes). The geographical factor which was divided in 5 samplings ecoregions from the Bay of Biscay to the North Sea, was significant on W-L relationship of only 18 species among 38 tested species (species occurring in sufficient number in both areas) (47.4%). These species were composed of 17 *Actinopterygii* (*Hyperoplus immaculatus, Limanda limanda, Merlangius merlangus, Chelidonichthys cuculus, Lophius piscatorius, Sardina pilchardus, Gadus morhua, Lophius budegassa, Microstomus kitt, Phycis blennoides, Merluccius merluccius, Melanogrammus aeglefinus, Dicentrarchus labrax, Solea solea, Mullus surmuletus, Pollachius pollachius, Pleuronectes platessa*) and only 1 *Elasmobranchii* (*Raja undulata*) (Table 2). Contrary to the sexual dimorphism, the spatial effect on the body length–weight relationships was measured essentially for the *Actinopterygii*. The temporal effect on the WLR must be divided at two observation scales with the variations inter-years and intra-year (seasonality effect represented by the quarters). Among the 29 tested species with both temporal effects, only five (17.2%, *Gadus morhua, Merlangius merlangus, Lophius piscatorius, Mullus surmuletus, Mustelus asterias*) presented significant variations inter-years and intra-year. Separately, the year effect and the seasonality effect were significant at the level of 32.4% and 35.3% respectively. The seasonality effect (42.8%) was more significant than between years (11.1%) in *Elasmobanchii* (Table 2). The parameters of the body length–weight relationships are given in Supplementary Table 2. The initial growth coefficient ‘a’ varied from $4.2\ 10^{-4} \pm 1.0\ 10^{-5}$ in *Conger conger* to $6.6\ 10^{-2} \pm 4.8\ 10^{-2}$ in *Scophthalmus maximus*, while the growth coefficient ‘b’ ranged from $2.7 \pm 1.2\ 10^{-2}$ in *Hyperoplus immaculatus* to $3.5 \pm 8.2\ 10^{-3}$ in *Conger conger*. The coefficients of the WLR are significantly correlated (Figure 2). Among the 45 tested species, the value of b was under 3 for 14 species (31.1%) with 12 roundfishes and 2 flatfishes (Supplementary Table 2). All elasmobranchii species presented positive allometric growth (coefficient b higher than 3) (Supplementary Table 2; Figure 2). To compare the fatness of each fish species according to geographical area, sex and sampling year and quarter, the condition factor (K) was estimated (Table 3). In the event of significant sexual dimorphism, all condition factors (K) of females were higher than those of males (Table 3). For the others tested factors, the highest values of K were distributed between all sampled years, areas and quarters (Table 3).

DISCUSSION

This study with large sample data (n=31167) showed the allometric W-L relationship and the factors influencing this type of data. According to Hile (1936), Martin (1949), Pauly & Gayanilo (1997) and Froese (1998, 2006), ‘b’ values may range from 2.5 to 3.5 for fish, which is the case for the values estimated in our study. Moreover, the study showed that the coefficients of the WLR were significantly correlated. The growth coefficient (b) reflected firstly the shape and the fatness of the fish species. Consequently, the elasmobranchii (sharks and skates) and the flatfishes presented an only one body shape, as know as depressiform, and consequently the weight growth higher than the length growth (b>3; Figure 2). This result corroborated the results obtained for the elasmobranchii (Pallaoro *et al*., 2005; Yeldan and Avsar, 2007; Yığın and Ismen 2009) and for the soleidae (Torres *et al.*, 2012). Among 28 roundfishes species, the b values were within the range of 2.5-3.5 and there was no observed trend in body shape due to its large range of shapes as fusiform (i.e. *Gadus morhua*), arrow-like (i.e. *Hyperoplus immaculatus*), ribbon-like (*Conger conger*) or laterally flattened (i.e. *Trachurus trachurus*). The difference of shapes could be characterised by the 'form factor' equation ($a_{3,0} = 10^{\log a - S(b-3)}$) of the log a-b relationship (Froese, 2006; Verreycken *et al*., 2011).

For all 45 species, the body length-weight relationship was significant. Our analyses confirmed those observed in the North-Eastern Atlantic ocean (Dorel, 1986; Coull *et al.*, 1989; Silva *et al.*, 2013; Wilhelms, 2013), in Greek waters (Petrakis & Stergiou, 1995), in Persian Gulf (Naderi *et al.*, 2013), in the Aegean Sea (Moutopoulos & Stergiou, 2002). Consequently, it is possible for these marine species to use W-L relationship to estimate weight from length or *vice versa*. For each species, significant difference nevertheless could be observed according to sex, to the sampled year, seasonality and geographical area. The first tested factor is the sex. The sexual dimorphism influenced significantly the W-L relationship of few species as observed in the Azores islands (Morato *et al.*, 2001). The difference observed between males and females for striped red mullet (*Mullus surmuletus*) corroborated the previous study on this species during 2004 in the Eastern English Channel (Mahé *et al.*, 2013). The results of sexual dimorphism effect on the WLR were similar in the Eastern Adriatic Sea, except for *Mustelus asterias*, but the low number in the Mediterranean Sea for one species with large length range could be one explanation (Pallaoro *et al*., 2005). There was sexual dimorphism according to the value of K, indicated that at the same length, females are heavier than the males. This trend was observed in the actinopterygii and elasmobranchii. This study was realized by five surveys covering all ecoregions, from the Bay of Biscay to the North Sea. Consequently, significant differences in their W-L relationship were observed for many widely distributed species across their distribution area. These difference were a result of many morphotypes within a species or a family. For striped red mullet (*Mullus surmuletus*), there were 2 morphotypes according to the head shape between South and North populations (bay of Biscay/ Eastern English Channel (Mahé *et al.*, 2014)), which could explained the observed difference of condition factors. The head morphological variation, for one species between two geographical areas or habitats, is influenced by feeding behavior (Hyndes *et al.*, 1997; Janhunen *et al.*, 2009). Within a family, values or the trend of condition factors between two similar species could be opposite. This has been observed between *Lophius budegassa* and *Lophius piscastorius* and between *Scophthalmus maximus* and *Scophthalmus rhombus* during the same sampling years and quarters. Seasonal or annual differences in W-L relationships and therefore in condition factor, may be generally related to reproduction (gonad development and spawning period) or feeding activities (food availability and feeding rate) (Bagenal & Tesch, 1978; Weatherley & Gill, 1987; Wootton, 1990) but also attributed to differences in sampling especially length ranges too. Throughout a year, significant difference of the condition factor according to the spawning period for each species (Supplementary Table 3), showed than the specimens were the heaviest just before and during the spawning period. This seasonal oscillation of the WLR and the condition factor could be explained by the environmental factors as the temperature but also by the availability of food and the physiological state of the fish (i.e. degree of gonad development) (Le Cren 1951; Froese, 2006; Pauly, 2010; Mozsar *et al.*, 2015).

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Figure 1. Location of trawling stations from the bay of Biscay to the North Sea (ICES Division IVa, IVb, VIId, VIIe, VIIf, VIIg, VIIh, VIIIa & VIIIb) where the 31 167 individuals used in this study have been sampled.

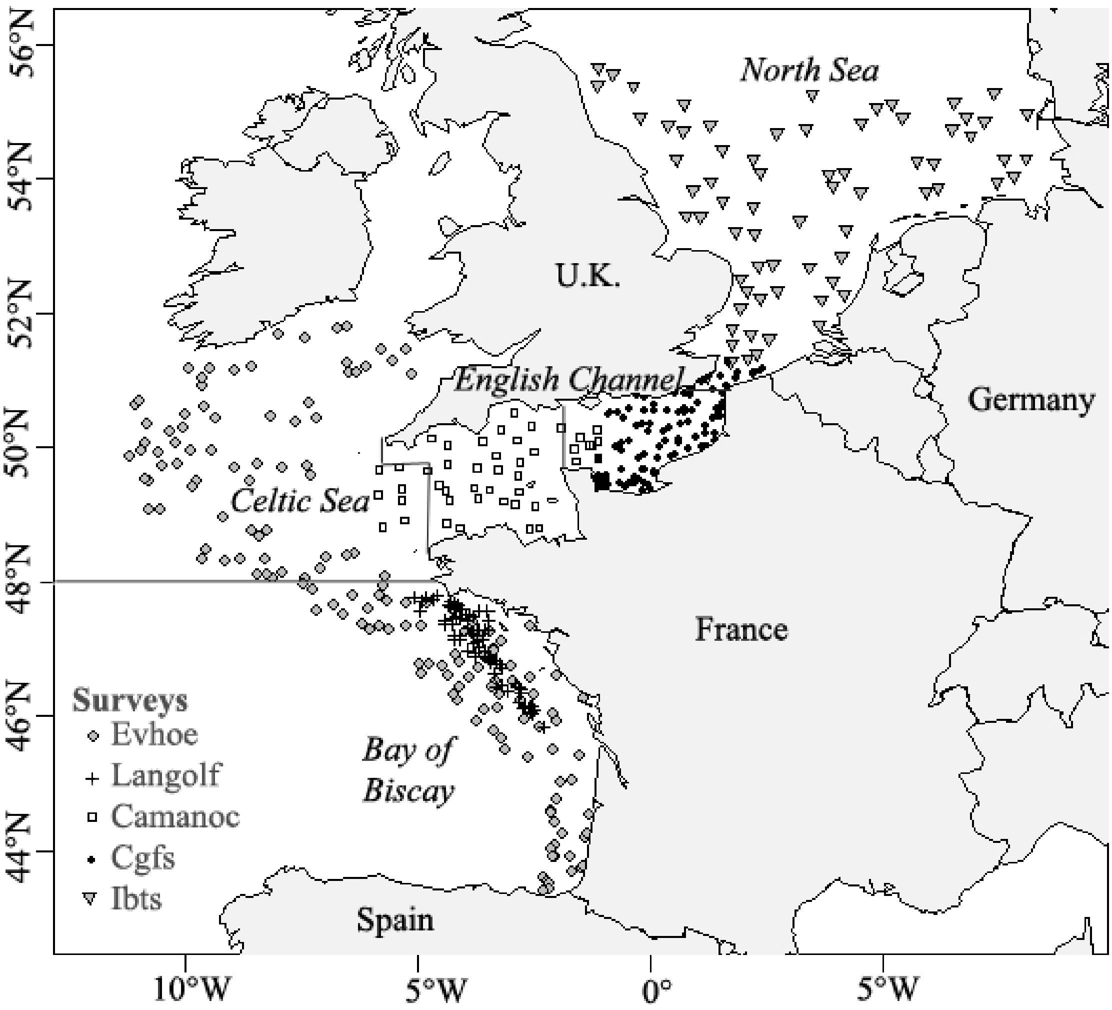

Figure 2. Scatter plot of mean log a (TL) over mean b for 45 fish species by distinguishing the actinopterygii (roundfishes and flatfishes) and the elasmobranchii (sharks and skates) with body shape information (see legend). The regression line was realized from 45 fish species.

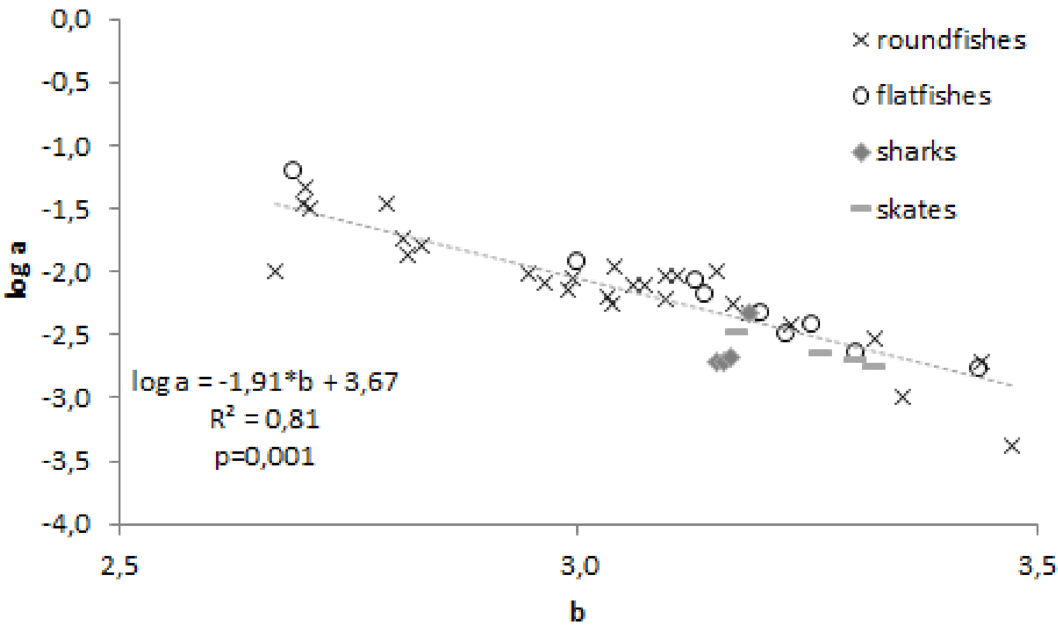

Table 1. Characteristics of the 45 fish species caught from the Bay of Biscay to the North Sea during 2013, 2014 and 2015 years: number of sampled individuals (n), length range (cm), mean length ± standard deviation (cm), weight range (g) and mean weight ± standard deviation (g). Within each class, species are listed in alphabetical order of their family.

Order	Family	Species	n	Mean length ± SD	Length range (cm)	Mean weight ± SD	Weight range (g)
Actinopterygii							
Roundfishes	*Ammodytidae*	*Hyperoplus immaculatus*	139	23,28±3,30	13/36	34,2±12,9	6/90
	Carangidae	*Trachurus trachurus*	244	19,11±8,13	7/39	99,7±101,3	4/540
	Clupeidae	*Clupea harengus*	1342	20,93±5,21	9/34	70,2±51,0	5/292
		Sardina pilchardus	111	18,30±3,31	9/26	53,3±29,7	7/138
		Sprattus sprattus	627	10,81±2,16	5/15	12,4±55,8	1/1 400
	Congridae	*Conger conger*	94	90,50±38,80	32/220	3 279,3±6 185,3	46/45 000
	Engraulidae	*Engraulis encrasicolus*	289	13,62±2,26	8/20	17,6±10,9	1/66
	Gadidae	*Gadus morhua*	1452	45,80±18,43	11/126	1 567,4±2 172,2	15/24 020
		Melanogrammus aeglefinus	1476	36,50±12,66	12/77	698,0±753,7	17/4 900
		Merlangius merlangus	6820	27,28±8,13	8/62	220,0±211,6	1/2 348
		Micromesistius poutassou	52	15,77±2,94	13/27	30,2±25,5	15/149
		Pollachius pollachius	50	54,36±14,16	15/82	1 815,2±1 156,5	38/3 894
		Trisopterus esmarkii	121	14,02±3,60	9/25	3 756,1±7 301,3	5/40 000
		Trisopterus luscus	506	24,79±6,23	9/41	230,1±156,4	8/900
		Trisopterus minutus	164	14,73±3,25	7/20	38,4±19,8	4/88
	Lophiidae	*Lophius budegassa*	489	29,94±14,95	5/82	726,4±1 054,8	2/7 800
		Lophius piscatorius	375	41,61±22,53	9/115	2 007,9±2 878,3	10/19 720
	Merlucciidae	*Merluccius merluccius*	2038	39,37±19,79	6/121	799,4±1 283,4	1/11 100
	Moronidae	*Dicentrarchus labrax*	417	46,11±11,35	16/83	1 221,8±969,1	43/7 140
	Mullidae	*Mullus surmuletus*	904	19,34±5,99	8/39	122,9±111,8	6/880
	Phycidae	*Phycis blennoides*	579	31,43±10,25	13/60	323,7±308,5	14/1 870
	Scombridae	*Scomber scombrus*	43	31,33±4,77	19/43	301,0±174,9	56/830
	Sparidae	*Spondyliosoma cantharus*	209	21,62±10,06	5/48	294,4±353,6	4/2 190
	Trachinidae	*Trachinus draco*	62	33,66±6,74	12/47	291,8±145,6	10/682
	Triglidae	*Eutrigla gurnardus*	266	24,04±6,47	8/38	147,8±109,5	5/480
		Chelidonichthys cuculus	1343	25,5±5,9	7/42	186,1±124,5	10/796
		Chelidonichthys lucerna	176	31,18±8,30	3/64	380,5±422,2	1/3 080
	Zeidae	*Zeus faber*	251	32,55±13,24	4/67	773,3±727,3	3/4 900
Flatfishes	*Scophthalmidae*	*Lepidorhombus whiffiagonis*	977	29,85±10,11	7/58	271,9±277,6	5/1 450
		Scophthalmus maximus	74	39,92±10,99	17/63	1 613,1±1 332,0	92/6 070
		Scophthalmus rhombus	61	36,07±7,23	21/57	741,8±523,2	175/2 750
	Soleidae	*Solea solea*	945	26,14±7,35	9/49	206,5±184,6	4/1 300

	Pleuronectidae	*Glyptocephalus cynoglossus*	117	32,42±5,62	18/43	257,1±135,1	30/592
		Limanda limanda	985	20,85±5,10	5/37	114,4±85,2	2/620
		Microstomus kitt	503	25,98±5,27	10/45	238,9±152,3	10/1 175
		Platichthys flesus	98	28,15±5,15	15/39	280,2±175,8	35/960
		Pleuronectes platessa	4684	28,08±7,09	10/57	257,0±209,1	5/1 945
Elasmobranchii							
	Arhynchobatidae	*Raja brachyurops*	45	60,98±20,93	30/103	2 075,6±2 235,1	142/10 650
	Rajidae	*Raja clavata*	608	62,25±17,69	3/112	2 082,7±1 597,0	50/7 340
		Raja montagui	82	47,94±15,23	12/74	943,2±733,3	5/2 700
		Raja undulata	144	68,08±20,51	27/100	2 892,9±2 206,7	200/7 860
	Scyliorhinidae	*Scyliorhinus canicula*	176	50,93±11,12	10/67	504,0±377,1	18/3 900
		Scyliorhinus stellaris	250	70,76±23,84	17/113	2 095,8±1 746,8	48/6 660
	Trakidae	*Galeorhinus galeus*	87	93,14±20,32	48/150	4 116,8±3 163,7	514/17 040
		Mustelus asterias	692	80,78±16,68	33/127	2 328,8±1 552,5	116/8 660

Table 2. P value for the relationship between body length and weight (W-L) and for the influence of sex, geographical area, sampling year and quarter on the W-L relationship (p<0.05 in grey square) of the 45 fish species caught from the Bay of Biscay to the North Sea during 2013, 2014 and 2015 years. If the factor was not tested because there was only one modality, there was no value in the case (-).

Order	Family	Species	W-L	Area	Year	Quarter	Sex
Actinopterygii							
Roundfishes	*Ammodytidae*	*Hyperoplus immaculatus*	< 0,001	< 0,001	-	0,646	-
	Carangidae	*Trachurus trachurus*	< 0,001	0,602	-	0,186	-
	Clupeidae	*Clupea harengus*	< 0,001	0,139	< 0,001	-	0,918
		Sardina pilchardus	< 0,001	< 0,001	0,026	-	0,621
		Sprattus sprattus	< 0,001	0,562	0,174	-	0,099
	Congridae	*Conger conger*	< 0,001	0,092	0,097	0,745	-
	Engraulidae	*Engraulis encrasicolus*	< 0,001	0,322	0,725	0,002	0,778
	Gadidae	*Gadus morhua*	< 0,001	< 0,001	0,092	< 0,001	0,729
		Melanogrammus aeglefinus	< 0,001	0,004	0,191	< 0,001	0,585
		Merlangius merlangus	< 0,001	< 0,001	0,018	< 0,001	0,008
		Micromesistius poutassou	< 0,001	-	-	-	-
		Pollachius pollachius	< 0,001	0,045	0,120	0,443	0,413
		Trisopterus esmarkii	< 0,001	-	< 0,001	-	0,049
		Trisopterus luscus	< 0,001	0,745	< 0,001	0,934	0,225
		Trisopterus minutus	< 0,001	0,616	-	0,053	–
	Lophiidae	*Lophius budegassa*	< 0,001	< 0,001	0,289	0,438	0,764
		Lophius piscatorius	< 0,001	< 0,001	< 0,001	0,039	0,562
	Merlucciidae	*Merluccius merluccius*	< 0,001	0,002	0,392	0,003	0,008
	Moronidae	*Dicentrarchus labrax*	< 0,001	0,005	0,403	0,162	0,002
	Mullidae	*Mullus surmuletus*	< 0,001	0,020	< 0,001	< 0,001	0,047
	Phycidae	*Phycis blennoides*	< 0,001	0,001	0,731	-	0,040
	Scombridae	*Scomber scombrus*	< 0,001	-	-	-	-
	Sparidae	*Spondyliosoma cantharus*	< 0,001	0,123	-	0,586	0,225
	Trachinidae	*Trachinus draco*	< 0,001	-	-	-	0,016
	Triglidae	*Eutrigla gurnardus*	< 0,001	0,600	0,611	0,629	0,233
		Chelidonichthys cuculus	< 0,001	< 0,001	0,001	0,583	0,047
		Chelidonichthys lucerna	< 0,001	0,544	0,327	0,850	0,498
	Zeidae	*Zeus faber*	< 0,001	0,944	0,565	< 0,001	0,585
Flatfishes	*Scophthalmidae*	*Lepidorhombus whiffiagonis*	< 0,001	0,971	< 0,001	0,909	0,867
		Scophthalmus maximus	< 0,001	0,808	0,322	0,446	0,016
		Scophthalmus rhombus	< 0,001	0,280	0,137	0,279	0,288
	Soleidae	*Solea solea*	< 0,001	0,007	0,274	0,119	0,016

	Pleuronectidae	*Glyptocephalus cynoglossus*	< 0,001	-	0,650	-	0,542
		Limanda limanda	< 0,001	< 0,001	0,041	0,188	< 0,001
		Microstomus kitt	< 0,001	0,001	< 0,001	0,222	0,001
		Platichthys flesus	< 0,001	0,882	-	-	0,009
		Pleuronectes platessa	< 0,001	0,045	0,127	< 0,001	< 0,001
Elasmobranchii							
	Arhynchobatidae	*Raja brachyurops*	< 0,001	-	0,077	-	0,404
	Rajidae	*Raja clavata*	< 0,001	0,366	0,078	0,584	0,005
		Raja montagui	< 0,001	0,334	0,667	0,171	0,009
		Raja undulata	< 0,001	0,019	0,181	0,020	0,428
	Scyliorhinidae	*Scyliorhinus canicula*	< 0,001	0,180	0,139	< 0,001	< 0,001
		Scyliorhinus stellaris	< 0,001	0,564	0,669	0,592	0,237
	Trakidae	*Galeorhinus galeus*	< 0,001	-	0,406	0,686	0,382
		Mustelus asterias	< 0,001	0,643	0,000	0,011	0,000

Table 3. Mean value of condition factor (K) of the 45 fish species according to each modality of the explanatory factors (Geographical area, Sex, Sampling Year and Quarter) on the relationship between body length and weight. Grey square indicate that a factor appears to have a significant effect ($P < 0.05$) on the W-L relationship. Only the individuals where the sex was determined were tested (F: female; M: male; -1: no sex available information).

		Species	Areas					Sex			Year			Quarter			
Order	Family		8AB	7g,h,j	7E	7D	4	F	M	-1	2013	2014	2015	1	2	3	4
Actinopterygii																	
Roundfishes	*Ammodytidae*	*Hyperoplus immaculatus*			0,25	0,21				0,27		0,27				0,25	0,27
	Carangidae	*Trachurus trachurus*			0,94	0,92				0,93		0,93				0,94	0,91
	Clupeidae	*Clupea harengus*				0,68	0,61	0,63	0,62	0,64	0,64	0,63	0,61	0,62		0,63	0,61
		Sardina pilchardus	0,77			0,88		0,79	0,75	0,78	0,79	0,77	0,85			0,87	0,78
		Sprattus sprattus				0,72	0,70	0,73	0,72	0,74	0,74	0,70	0,69	0,71		0,82	0,87
	Congridae	*Conger conger*	0,21	0,24	0,22	0,25		0,22		0,22	0,22	0,22	0,23			0,23	0,22
	Engraulidae	*Engraulis encrasicolus*	0,61		0,63	0,62		0,62	0,62	0,63	0,61	0,63	0,65			0,64	0,62
	Gadidae	*Gadus morhua*		1,05	1,10	1,03	1,02	1,04	1,03	1,01	1,04	1,02	1,04	1,03		1,01	1,04
		Melanogrammus aeglefinus	1,02	1,03	1,09	1,09	0,90	1,02	1,00	1,03	0,99	1,03	0,98	0,90		1,09	1,03
		Merlangius merlangus	0,79	0,85	0,80	0,83	0,83	0,84	0,82	0,82	0,85	0,83	0,83	0,84		0,80	0,83
		Micromesistius poutassou			0,69					0,69		0,69				0,69	
		Pollachius pollachius			0,93	0,97		0,96	0,94	1,02		0,97	0,94	0,97		0,94	0,97
		Trisopterus esmarkii					0,71	0,75	0,69	0,70	0,75		0,70	0,71			
		Trisopterus luscus			1,26	1,27		1,29	1,27	1,31	1,31	1,31	1,23			1,27	1,30
		Trisopterus minutus			1,12	1,06				1,08		1,08				1,09	1,05
	Lophiidae	*Lophius budegassa*	1,57	1,46				1,55	1,49	1,59	1,52	1,61			1,55		1,53
		Lophius piscatorius	1,28	1,45				1,31	1,31	1,48	1,46	1,02			1,51		1,31
	Merlucciidae	*Merluccius merluccius*	0,71	0,71	0,77			0,71	0,69	0,78	0,73	0,70				0,77	0,71
	Moronidae	*Dicentrarchus labrax*	1,02	1,09	0,90	1,08	0,99	1,08	1,04	1,05	1,07	1,05	1,07	1,04		1,06	1,06
	Mullidae	*Mullus surmuletus*	1,28	1,30	1,32	1,09	1,08	1,31	1,28	1,25	1,29	1,31	1,26	1,11	1,22	1,31	1,33
	Phycidae	*Phycis blennoides*	0,76	0,79				0,80	0,73	0,73	0,75	0,79	0,77				0,77
	Scombridae	*Scomber scombrus*			0,89					0,89		0,89				0,89	0,87
	Sparidae	*Spondyliosoma cantharus*			1,76	1,80		1,75	1,76	1,78	1,80	1,76	1,79			1,77	1,80
	Trachinidae	*Trachinus draco*				0,66		0,68	0,64	0,65	0,64	0,66	0,64			0,65	0,68
	Triglidae	*Eutrigla gurnardus*	0,83	0,84		0,87	0,88	0,88	0,88	0,86	0,85	0,87	0,88	0,88			0,85
		Chelidonichthys cuculus	0,98	0,92	0,93	0,97		0,97	0,92	0,97	0,97	0,94	0,98	0,95		0,95	0,96
		Chelidonichthys lucerna	0,99	0,99		1,00		0,97	0,96	1,09	0,97	1,00	1,00	0,94		1,00	1,00
	Zeidae	*Zeus faber*	1,82	1,89	1,89	1,94		1,78	1,72	1,83	1,72	1,63	1,75			1,51	1,94
Flatfishes	*Scophthalmidae*	*Lepidorhombus whiffiagonis*	0,72	0,73	0,78			0,73	0,70	0,85	0,72	0,77			0,73	0,74	0,73
		Scophthalmus maximus	1,86	1,85	1,89	1,92	1,93	2,00	1,91	2,04	2,00	2,00	1,89	1,99	2,01	1,93	1,99
		Scophthalmus rhombus		1,46		1,43	1,41	1,43	1,36	1,41	1,33	1,41	1,34	1,41		1,40	1,46
	Soleidae	*Solea solea*	0,87	0,99	1,03	0,93	0,94	0,92	0,88	0,91	0,92	0,95	0,97	0,93	0,87	0,88	0,91

Supplementary Table 1. Fish Number of the 45 fish species according to each modality of the explanatory factors (Geographical area, Sex, Sampling Year and Quarter) on the relationship between body length and weight. There are 3 modalities for the sex factor.

Order	Family	Species	Areas					Sex			Year			Quarter			
			8AB	7g,h, j	7E	7D	4	F	M	-1	2013	2014	2015	1	2	3	4
Actinopterygii																	
Roundfishes	*Ammodytidae*	*Hyperoplus immaculatus*			18	121				139		139				18	121
	Carangidae	*Trachurus trachurus*			148	96				244		244				162	82
	Clupeidae	*Clupea harengus*				255	1087	666	662	14	490	360	492	1334			
		Sardina pilchardus	99			12		47	51	13	47	66					104
		Sprattus sprattus				154	473	335	265	27	257	176	194	626			
	Congridae	*Conger conger*	27	30	20	17		27		67	32	62				37	57
	Engraulidae	*Engraulis encrasicolus*	170		23	96		147	108	34	94	195				64	225
	Gadidae	*Gadus morhua*		181	32	776	463	721	634	97	198	721	533	696		181	575
		Melanogrammus aeglefinus	247	677	225	36	291	721	645	110	595	803	78	291		227	958
		Merlangius merlangus	598	1298	409	2174	2341	3766	2685	369	1891	2460	2469	3222		898	2700
		Micromesistius poutassou			52					52		52				52	
		Pollachius pollachius			17	33		23	27			29	21	14		20	16
		Trisopterus esmarkii					121	88	33		54		67	121			
		Trisopterus luscus			98	408		195	243	68		261	245			206	300
		Trisopterus minutus			43	121				164		164				115	49
	Lophiidae	*Lophius budegassa*	330	159				205	175	109	388	101			151		338
		Lophius piscatorius	240	135				152	163	60	274	101			54		321
	Merlucciidae	*Merluccius merluccius*	958	1050	30			922	794	322	991	1047				30	2008
	Moronidae	*Dicentrarchus labrax*	105	23		270	19	183	191	43	143	194	80	46		57	314
	Mullidae	*Mullus surmuletus*	136	108	45	540	75	452	298	154	165	326	413	143	71	226	464
	Phycidae	*Phycis blennoides*	395	184				388	91	100	186	237	156				579
	Scombridae	*Scomber scombrus*			43					43		43				43	
	Sparidae	*Spondyliosoma cantharus*			82	127		22	12	175		209				103	106
	Trachinidae	*Trachinus draco*				62		14	32	16		62					62
	Triglidae	*Eutrigla gurnardus*	13	10		10	233	118	116	32	17	249		233			33
		Chelidonichthys cuculus	242	183	174	744		724	498	121	281	711	351	229		352	762
		Chelidonichthys lucerna	19	49		108		73	37	66	108	49	19	88			88
	Zeidae	*Zeus faber*	20	25	103	103		44	10	197	48	175	28			123	128
Flatfishes	*Scophthalmidae*	*Lepidorhombus whiffiagonis*	683	266	28			579	333	65	605	372			200	28	749
		Scophthalmus maximus		13		47	14	30	21	23	13	28	33	38			36
		Scophthalmus rhombus		10		51		28	12	21		33	28				61
	Soleidae	*Solea solea*	482	35		298	130	503	386	56	403	340	202	219	223	79	424
	Pleuronectidae	*Glyptocephalus cynoglossus*		117				60	57			55	62				117
		Limanda limanda			23	231	731	659	289	37	454	531		923		36	26
		Microstomus kitt	52	199	83	169		254	209	40	101	323	79			120	383
		Platichthys flesus				39	59	29	57	12	98			98			
		Pleuronectes platessa		243	32	2484	1925	2680	1874	130	1346	1325	2013	2887		534	1232
Elasmobranchii																	
	Arhynchobatidae	*Raja brachyurops*				45		22	23			17	28				45

Supplementary Table 2. Parameters 'a' and 'b' with their Standard Error (S.E.) of the relationship ($W = aL^b$) between weight (W; g) and body length (L; cm) for 45 species caught from the Bay of Biscay to the North Sea during 2013, 2014 and 2015 years.

Order	Family	Species	a		b	
			mean	SE	mean	SE
Actinopterygii						
Roundfishes	*Ammodytidae*	*Hyperoplus immaculatus*	0,010	0,008	2,671	0,012
	Carangidae	*Trachurus trachurus*	0,016	0,003	2,830	0,054
	Clupeidae	*Clupea harengus*	0,006	0,000	3,037	0,026
		Sardina pilchardus	0,003	0,001	3,322	0,093
		Sprattus sprattus	0,006	0,002	3,032	0,098
	Congridae	*Conger conger*	0,000	0,000	3,472	0,008
	Engraulidae	*Engraulis encrasicolus*	0,001	0,000	3,353	0,050
	Gadidae	*Gadus morhua*	0,005	0,000	3,185	0,023
		Melanogrammus aeglefinus	0,008	0,001	3,073	0,017
		Merlangius merlangus	0,006	0,000	3,095	0,007
		Micromesistius poutassou	0,007	0,001	2,988	0,043
		Pollachius pollachius	0,032	0,014	2,709	0,108
		Trisopterus esmarkii	0,004	0,001	3,232	0,073
		Trisopterus luscus	0,009	0,001	3,096	0,034
		Trisopterus minutus	0,018	0,003	2,810	0,053
	Lophiidae	*Lophius budegassa*	0,046	0,008	2,704	0,042
		Lophius piscatorius	0,011	0,003	3,039	0,068
	Merlucciidae	*Merluccius merluccius*	0,008	0,001	2,964	0,015
	Moronidae	*Dicentrarchus labrax*	0,034	0,006	2,701	0,045
	Mullidae	*Mullus surmuletus*	0,009	0,001	3,109	0,018
	Phycidae	*Phycis blennoides*	0,010	0,001	2,946	0,028
	Scombridae	*Scomber scombrus*	0,002	0,000	3,439	0,066
	Sparidae	*Spondyliosoma cantharus*	0,010	0,002	3,152	0,043
	Trachinidae	*Trachinus draco*	0,013	0,006	2,814	0,116
	Triglidae	*Eutrigla gurnardus*	0,009	0,002	2,994	0,058
		Chelidonichthys cuculus	0,008	0,000	3,059	0,018
		Chelidonichthys lucerna	0,006	0,001	3,168	0,027
	Zeidae	*Zeus faber*	0,035	0,004	2,793	0,046
Flatfishes	*Scophthalmidae*	*Lepidorhombus whiffiagonis*	0,003	0,000	3,223	0,023
		Scophthalmus maximus	0,066	0,048	2,688	0,185
		Scophthalmus rhombus	0,009	0,002	3,124	0,073
	Soleidae	*Solea solea*	0,004	0,000	3,251	0,026
	Pleuronectidae	*Glyptocephalus cynoglossus*	0,002	0,001	3,299	0,064
		Limanda limanda	0,007	0,001	3,136	0,021
		Microstomus kitt	0,012	0,001	2,995	0,033
		Platichthys flesus	0,002	0,001	3,433	0,132
		Pleuronectes platessa	0,005	0,000	3,195	0,012
Elasmobranchii						
	Arhynchobatidae	*Raja brachyurops*	0,002	0,002	3,303	0,231

	Rajidae	*Raja clavata*	0,003	0,001	3,174	0,055
		Raja montagui	0,002	0,001	3,263	0,154
		Raja undulata	0,002	0,001	3,321	0,127
	Scyliorhinidae	*Scyliorhinus canicula*	0,002	0,001	3,151	0,100
		Scyliorhinus stellaris	0,002	0,001	3,167	0,092
	Trakidae	*Galeorhinus galeus*	0,005	0,000	3,185	0,023
		Mustelus asterias	0,002	0,001	3,159	0,043

Supplementary Table 3. Reproduction period of the 45 fish species with sampled geographical area and the reference in FishBase. Grey Squares with one star are the reproduction months by each species.

Family	Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Area	Reference
tinopterygii															
mmodytidae	*Hyperoplus immaculatus*	*	*											Eastern Atlantic	1
Carangidae	*Trachurus trachurus*				*	*	*	*						Celtic Sea	2
Clupeidae	*Clupea harengus*	*	*	*							*	*	*	Celtic Sea	3
	Sardina pilchardus				*									English Channel	4
	Sprattus sprattus		*	*	*	*	*	*						Scotland coasts	5
Congridae	*Conger conger*						*	*	*					Portugal	6
Engraulidae	*Engraulis encrasicolus*				*	*	*	*	*					Bay of Biscay	7
Gadidae	*Gadus morhua*	*	*	*	*	*								Irish Sea	8
	Melanogrammus aeglefinus		*	*	*									Celtic Sea	9
	Merlangius merlangus	*	*	*	*	*	*	*	*	*				Between British Isles and Bay of Biscay	10
	Micromesistius poutassou		*	*										British isles	11
	Pollachius pollachius	*	*	*	*	*								Northeast Atlantic	12
	Trisopterus esmarkii	*	*	*										Scotland coasts	11
	Trisopterus luscus	*	*	*	*								*	Atlantic	10
	Trisopterus minutus		*	*										English Channel	10
Lophiidae	*Lophius budegassa*	*	*									*	*	Atlantic Iberian Coast	13
	Lophius piscatorius			*	*	*	*							British isles	11
Merlucciidae	*Merluccius merluccius*	*	*	*	*	*								North Sea	11
Moronidae	*Dicentrarchus labrax*		*	*	*	*	*							British isles	14
Mullidae	*Mullus surmuletus*					*	*	*						North Sea	15
Phycidae	*Phycis blennoides*			*	*	*	*	*						North Atlantic	10
Scombridae	*Scomber scombrus*					*	*							British isles	11
Sparidae	*Spondyliosoma cantharus*				*	*								British isles	19
Trachinidae	*Trachinus draco*	-	-	-	-	-	-	-	-	-	-	-	-		
Triglidae	*Eutrigla gurnardus*				*	*	*	*	*					North Sea	11
	Chelidonichthys cuculus	*	*	*	*	*	*	*						Northeast Atlantic	21
	Chelidonichthys lucerna	*	*	*	*						*	*	*	Tunisia	22
Zeidae	*Zeus faber*	*	*	*	*									British isles	11
cophthalmidae	*Lepidorhombus whiffiagonis*			*	*	*	*							Northeast Atlantic	11

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