Abundance, biomass and CPUE of deep-water sharks through a five-year deep-water longline survey in the Bay of Biscay (ICES 8c).

Diez, G.,[1]* Arregi, L.,[1] Basterretxea M.,[1] Cuende E.,[1] Oyarzabal, I.[1]

[1]*Marine Research*, *AZTI- BASQUE RESEARCH AND TECHNOLOGY ALLIANCE (BRTA)*, *Txatxarramendi s/n Sukarrieta* 48395, *Bizkaia*, *Spain*

MATERIAL AND METHODS

Data from longline surveys conducted annually on the Basque Coast (ICES 8c) between 2015 and 2019 on a commercial longliner were analyzed. The experimental design was implemented to estimate and assess the inter-annual variation of the abundance and biomass indices of the deep-water ichthyofauna in the area of study. To get homogeneous and comparable data series, the six hauls were carried out every year in the same position and period, covering depths from 650 m to 2400 m. The stratification was based on 400 m intervals following the profile of the canyon valley.

Fishing gear and fishing operations

A modified former commercial bottom longline fishing gear, specific for deep-water sharks, was adapted for the survey. The commercial gear used 6 mother lines with 1800 hooks fishing overnight (soak time = 8 - 9 h), but in order to minimize the mortality of deep-water sharks in the scientific fishing gear, the number of hooks was reduced to 300, and the soak time was set at 4 h (STECF 2013). The vessel was equipped with a specifically designed device for recovering fishing gear from deep waters at a depth of more than 2500 m. Several modifications to the fishing gear were tested during the 2015 pilot survey, and the final design was a double gear divided into two equal main line sections of 1750 m +1750 m, each with 150 hooks. Each hook was baited with a third of Atlantic mackerel (*Scomber scombrus*), and the main line was attached to the bottom by means of a 1.5 kg stone for every five hooks. In order to improve the catch efficiency of species that feed above the sea bottom, the stones of the main line were removed, resulting in two floating sections of 75 hooks. Therefore, the fishing gear consisted of 150 hooks in contact with the bottom, and 150 hooks in the floating sections (Figure 1). The fishing gear was linked to the surface by two head ropes (without hooks) and two marker floats, placed at the beginning and end of the main line. For the continuous recording of depth, temperature and salinity, the longline was monitored every 30 s by means of five small DST CTD and DST centi sensors (www.star-oddi.com), able to withstand 2400-3000 m in depth, respectively. Three of these sensor devices were attached to the beginning, mid-point and end of the main rope, and the remaining two at the top of each of the “floating” sections (Figure 1). To locate and monitor the fishing gear after each haul, two satellite buoys (https://zunibal.com/en/product/zunliner-longline-buoy/) were installed in the marker floats. One haul was accomplished per day; starting at 8 a.m. and ending in the evening after recovering the longline and the hauling data collected by the sensors.

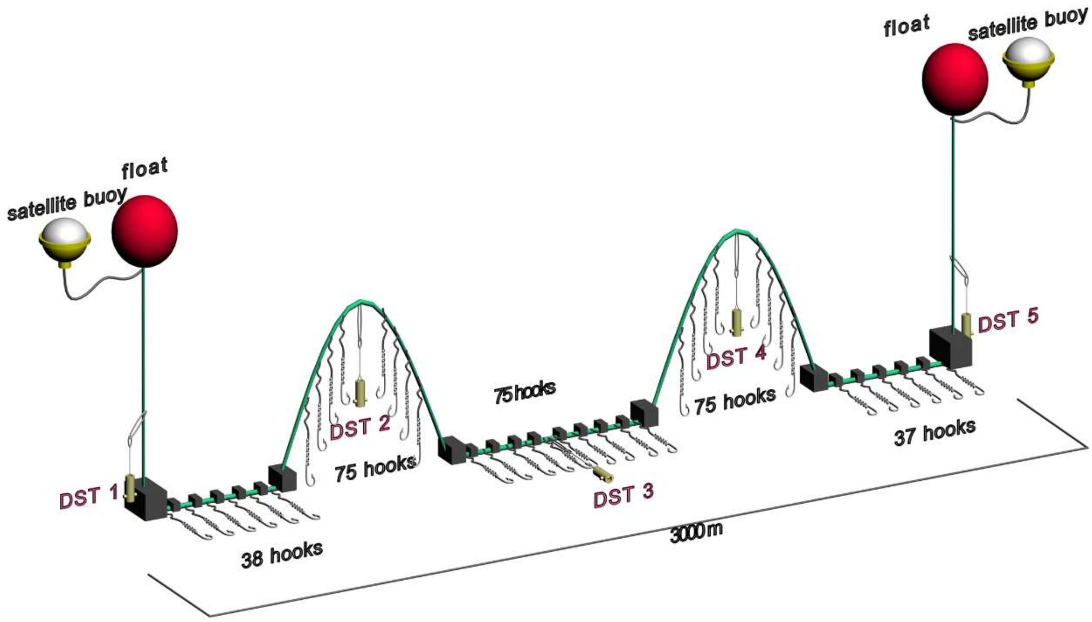

Figure 1. Scheme of the final design of the long-line fishing gear used in the pilot survey. The positions of DST 1, 3 and 5 correspond to the main line sections fishing at the bottom, and DST2 and 4 to the floating sections.

Survey area

The surveys were conducted annually from 2015 to 2019 between the 15th of September and the 15th of October. The sampling stations were located in an area 10.5 km north of Cape Matxitxako in a narrow canyon of about 28 km long that progressively decreases in depth from 500 to 2500 m. The six hauls covered the whole depth range along the canyon valley in four 400 m strata: 650-1050 m, 1051-1450 m, 1451-1850 m and 1851-2250 m (Figure 2).

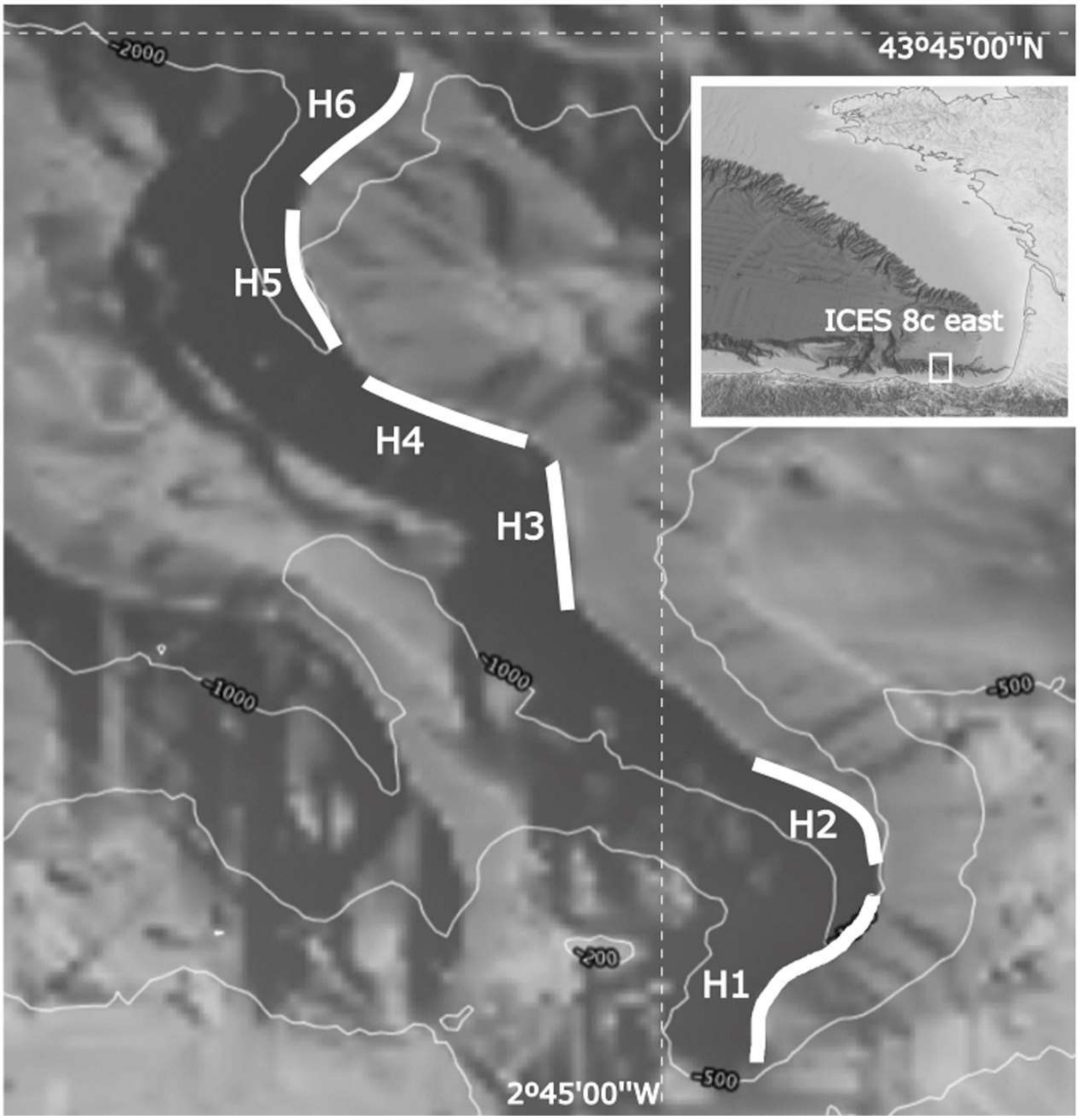

Figure 2. Bathymetric map showing the position of the six hauls in the Matxitxako Canyon in the southeast of the Bay of Biscay (ICES Division 8c). The correspondence of the hauls with the deep strata is: H1 (650-1050 m); H2 (1051-1450 m); H3 (1451-1850 m); H4 (1451-1850 m); H5 (1851-2250 m); H6 (1851-2250 m).

Biomass estimation: catch per unit effort (CPUE)

To calculate fishing effort and CPUEs in each haul, the hooks were classified according to seven categories, both during the hauling and recovery of the longline (Table 1).

During the recovery of the longline, the hooks were numbered from 1 to 300 to identify the position of the catches and to identify whether the catches belonged to the floating or the bottom sections.

Percentage of Ineffective Hooks (PIH) was defined as the number of hooks not able to fish divided by the total number of hooks:

$$PIH: (R + V + N) / (C+E+N+P+R+V).$$

Fishing Gear Catchability (FGC) was defined as the proportion of hooks that had fished (P) divided by the number of hooks able to fish (P + E + C):

$$FGC = P / (P + E + C).$$

Total Catchability (TC) was the proportion of hooks with catch in the total hooks hauled:

$$P / = N + N.O. + E + C + R + V + P$$

Soak time was calculated from the time the first hook reached the bottom (indicated by sensor DST 1) until this hook was hauled back.

Soak time was different in each haul strata, since the time it took for the first hook to reach the bottom became longer as the depth of the bottom increased.

To be able to compare the analysis of catches by haul, Effort and CPUE were standardized to the number of hooks and duration of soak time. Thus, Effort in each stratum (EFFORTst) was estimated as the number of hooks able to fish during the haul (P + E + C), divided by the total of hooks and multiplied by soak time (minutes):

$$EFFORTst: ((P + E + C) / (\text{total hooks}) \times \text{min}$$

Catch per Unit of Effort of each stratum (CPUEs) was calculated as the catch (kg) divided by the EFFORTst:

$$CPUEst = kg / EFFORTst = kg/(\text{hook} \times \text{min})$$

RESULTS

Temporal changes in the biomass, abundance and CPUE of deep-water sharks

CPUE, throughout the five years of the survey of the five main deep-water sharks is shown in the Figure 3.

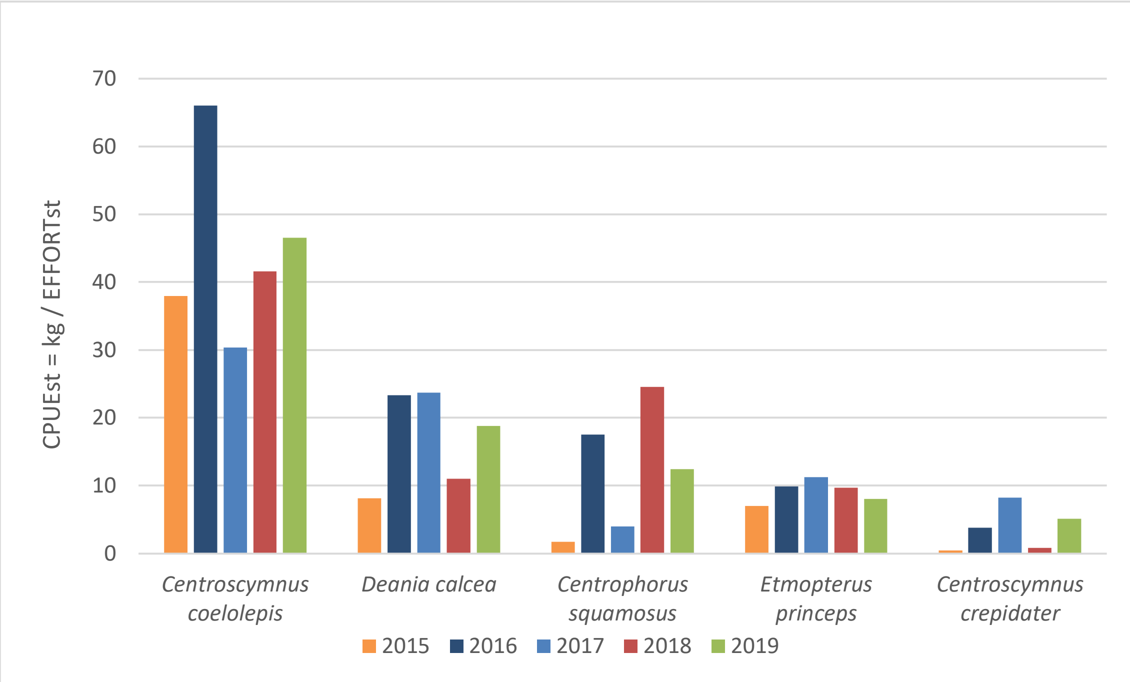

Figure 3. CPUE of the five main deep-water sharks in the period 2015-2019.

The highest abundance and biomass were also recorded in 2016 (146 individuals and 655 kg. Regarding the catches by depth, the highest CPUE and biomass were recorded in 2016 and 2017 at the 1051-1450 m strata, and in 2015, 2018 and 2019 at the 1451-1850 strata (Figure 4, Figure 5).

	CPUEe = kg / EFFORTe				
stratum (m)	**2015**	**2016**	**2017**	**2018**	**2019**
650-1050	0.39	0.55	0.66	0.20	0.29
1051-1450	0.47	1.24	0.77	0.65	0.53
1451-1850	0.64	0.48	0.60	0.92	1.01
1851-2250	0.09	0.60	0.27	0.32	0.27

Figure 4. CPUE (kg/(hook x min) of deep-water sharks by depth stratum and year.

	650-1050	1051-1450	1451-1850	1851-2250
abundance (No)	115	172	236	88
biomass (Kg)	389	765	954	316

Figure 5.. Total abundance (n) and biomass (kg) of deep-water sharks by stratum in the period 2015-2019.

The abundance and biomass of elasmobranch and teleosts on the hooks attached to the bottom were between three and four times higher than in the floating sections, and the percentage of sharks and chimeras caught in the bottom sections was also higher than the percentage registered in the floating sections (Figure 6). The species-specific CPUE showed that the highest values of deep-water sharks were recorded for *C. coelolepis,* especially in 2016 and 2018, with 41.6 and 66.0 kg/(hook x min), respectively. Other species with high values of CPUE were Deania calcea, Centrophorus squamosus and Etmopterus princeps (**¡Error! No se encuentra el origen de la referencia.**).

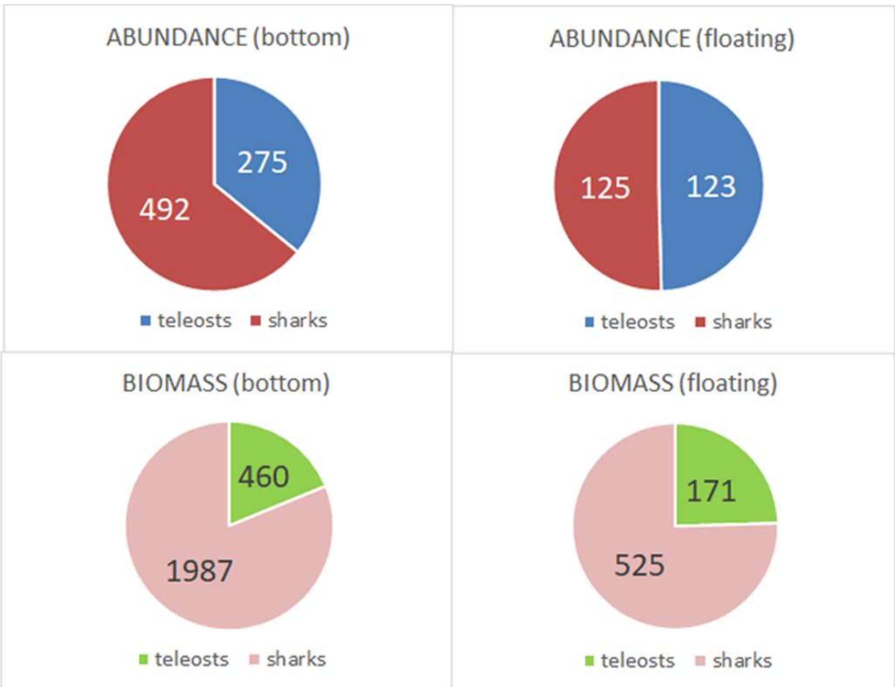

Figure 6. Total abundance (No) and biomass (kg) in the bottom and floating sections in the period 2015-2019.

Table 1. Biomass (kg) of the main deep-water sharks caught in the survey in the period 215-2019 all the depth stratum combined.

species	2015	2016	2017	2018	2019
Centroscymnus coelolepis	228	342	154	202	226
Deania calcea	49	121	120	53	91
Centrophorus squamosus	10	91	20	119	60
Etmopterus princeps	42	51	57	47	39
Centroscymnus crepidater	3	20	42	4	25
Hydrolagus pallidus	13	22	23	20	5

Hexanchus griseus	73				
Galeus melastomus	7	8	24	11	11
Scymnodon ringens	7				21
Centrophorus granulosus	18				5
Dalatias licha			13		
Etmopterus pusillus		2	0	0	4
Deania hystricosa	2				
Pseudotriakis microdon	2				

Table 2. CPUE (kg/(hook x min)) of the main deep-water sharks caught in the survey in the period 215-2019 all the depth stratum combined.

species	2015	2016	2017	2018	2019
Centroscymnus coelolepis	37.96	66.02	30.36	41.57	46.55
Deania calcea	8.11	23.31	23.70	11.01	18.79
Centrophorus squamosus	1.70	17.54	3.98	24.53	12.46
Etmopterus princeps	6.98	9.87	11.29	9.67	8.02
Centroscymnus crepidater	0.45	3.80	8.23	0.82	5.11
Hydrolagus pallidus	2.13	4.21	4.63	4.11	0.99
Hexanchus griseus	12.13	0.00	0.00	0.00	0.00
Galeus melastomus	1.13	1.55	4.69	2.26	2.28
Scymnodon ringens	1.19	0.00	0.00	0.00	4.32
Centrophorus granulosus	2.99	0.00	0.00	0.00	1.07
Dalatias licha	0.00	0.00	2.65	0.00	0.00
Etmopterus pusillus	0.00	0.32	0.06	0.07	0.84
Deania hystricosa	0.39	0.00	0.00	0.00	0.00
Pseudotriakis microdon	0.33	0.00	0.00	0.00	0.00

Biodiversity

During the five years of the survey, 14 different species of sharks, 2 chimaeras and 9 teleosts were caught. The most abundant species were gadiform *M. moro* (230), deep-water sharks *C. coelolepis* (163), *Etmopterus prínceps* (160), *D. calcea* (132), and the black scabbard fish A. carbo (92). Some species like *Pseudotriakis microdon, Deania hystricosa, Hexanchus griseus, Lophius piscatorius, Dalatias licha, Trachyrincus scabrus* and *Alepocephalus bairdii* were scarce in number and were only found in one year of the series. A higher number of different species was found on the hooks in contact with the bottom (24 species) than in the floating section (15 species).

In relation to the bathymetric distribution of the species *D. hystricosa, H. griseus, S. ringens* and *D. licha* were only caught in the first strata (650 to 1050 m), while *C. crepidater, E. pusillus,* and *C. squamosus* were found in the entire depth range (Figure 7).

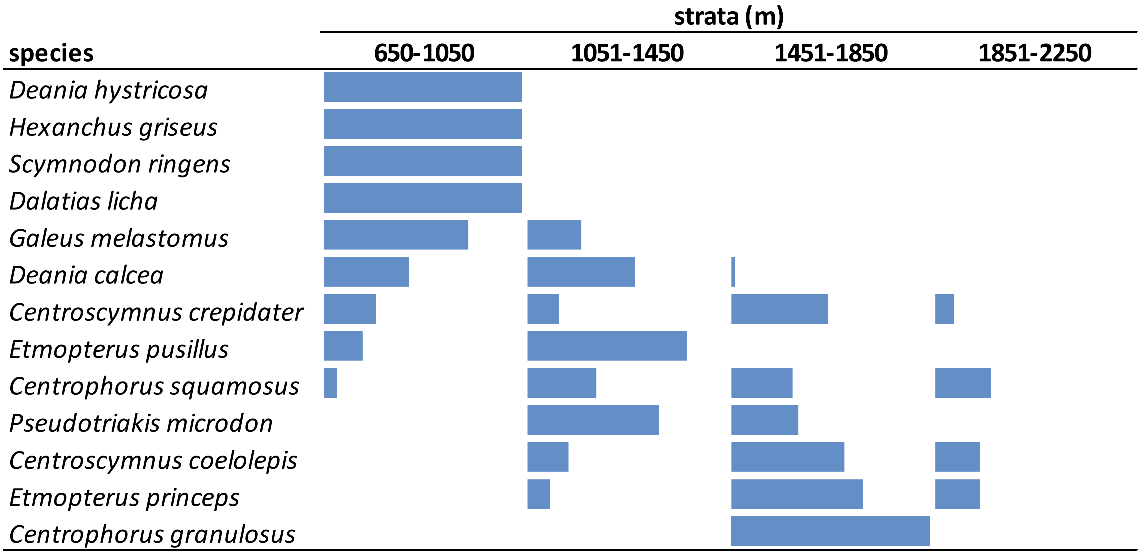

Figure 7. Bathymetric distribution of the deep-water sharks. Bars indicate the percentage of abundance (No) of each species in the entire depth range during period 2015-2019.

Fishing gear parameters: Catchability and soak time

The parameters of the fishing gear catchability in the five years of the survey are shown in Figure 6. Percentage of Ineffective Hooks (PIH) increased in shallowest depths, reaching more than 31% in the 650-1050 m stratum, probably due to hard and rocky bottoms that often resulted in the loss of baits and hooks in some sections of the main line. In this sense, PIH in the bottom section was 36% compared to 9% in the floating hooks. However, despite the higher PIH values registered in the 650-1050 m stratum, the proportion of hooks that had fished (FGC and TC) was also higher in the shallower strata, decreasing in the deepest strata. On average, the soak time in the shallowest stratum was 253 min, and in the deepest one 126 min. Depending on the haul depth, the time it took the first hook (DST 1) to reach the bottom was between 20 and 216 min, with a recorded descent speed of between 7 and 25 m/min.

As a general behaviour, the fishing gear was deployed along the water column in an M-shape like profile because of the difference in weight between floating and ballasted sections. Usually, the first deployed section also arrived at the bottom before the last one, but, in a few hauls, due to the strong currents in the survey area, the first hauled part arrived at the bottom after the last part. In these cases, the estimated soak time could be accurately calculated thanks to the information provided by the DST sensors.