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OBSERVATIONS OF CHONDRICHTHYAN FISHES (SHARKS, RAYS AND CHIMAERAS) IN THE BAY OF BISCAY (NORTH-EASTERN ATLANTIC) FROM SUBMERSIBLES

by

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ABSTRACT. - Forty one manned submersible dives were carried out during 2 cruises in the Bay of Biscay covering a range of depth from about 100 to 2100 m. Chondrichthyan species were observed in most of the dives, some of them were easily identified and their behaviour could be studied. Twenty-two chondrichthyan species (9 sharks, 8 rays and 5 chimaeras) were recorded. Shark species were always seen active except *Scyliorhinus canicula* and *Galeus melastomus*. Some representatives were found motionless on the bottom, sometimes forming groups for the first species. Chimaeras appeared to strongly react to the presence of the submersible. The density of chondrichtyes and their relative frequency in the total fish assemblage were estimated, the results are globally consistent with former knowledge and the differences with results from trawl surveys are discussed. The observations presented here suggest peak of *Chimaera monstrosa* abundance at upper slope depth (200-500 m) that was not documented formerly for that area.

RÉSUMÉ. - Observations de Chondrichtyens (requins, raies et chimères) dans le Golfe de Gascogne (Atlantique Nord-Est), à partir de submersibles.

Quarante et une plongées en submersible habité ont été effectuées lors de 2 campagnes dans le Golfe de Gascogne par des profondeurs de 100 à 2100 m environ. Des Chondrichtyens ont été observés au cours de la plupart des plongées, 22 espèces (9 requins, 8 raies et 5 chimères) ont été identifiées et leurs comportements ont pu être étudiés. Les requins étaient toujours actifs sauf *Scyliorhinus canicula* et *Galeus melastomus* dont certains représentants ont été trouvés immobiles sur le fond, parfois en groupe pour la première espèce. Les chimères se sont montrées très réactives à la présence du submersible. Les densités et fréquences relatives pour l'ensemble des Chondrichtyens ont été estimées, les résultats sont globalement cohérents avec les estimations antérieures; les différences avec les estimations issues de chalutages sont discutées. Les observations présentées ici suggèrent qu'il existe un pic d'abondance de *Chimaera monstrosa* à la profondeur de la pente supérieure (200-500 m). Ce pic n'avait pas été observé précédemment dans cette zone.

Key words. - Chondrichthyans - ANE - Bay of Biscay - Deep-Sea - Submersible.

The chondrichthyan fauna of the Bay of Biscay included about 60 species: 33 sharks, 23 rays and 5 chimaeras (Whitehead *et al.*, 1984), with about 40 on the continental slope. In term of fisheries, chondrichthyan fishes are mainly by-catches of trawl fisheries (Quéro and

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Vayne, 1998; Carpentier, 1999, unpubl. data) and some are target species of longline fisheries. Several fisheries operate in the Bay of Biscay. Some large chondrichthyan fishes are considered as endangered by fishery exploitation in the Bay of Biscay (Quéro and Cendredo, 1996). Due to the extension of fishing activity towards the slope, commercial trawlers exploit the deep-sea sharks of the North-eastern Atlantic for about 10 years. In France, they are marketed skinned under the name "siki" which include several species mainly *Centrophorus squamosus*, *Centroscymnus coelolepis* and *Dalatias licha*, mainly caught off western British Isles. From null in 1993, the landings of "siki" reached about 2400 tons in 1995 (i.e., about 10% of the total catch of chondrichthyan fishes in France), and about 2000 tons in 1997; the evolution of this fishery seems to fit with the "boom and bust" model generally observed for shark fisheries, and the collapse of deep-sea shark fisheries may even be quicker as their populations are limited (Ponroy and Séret, in press).

Beebe (1933) was the first biologist who used a submersible device, the bathysphere, to explore the deep-sea fauna off Bermuda. He observed numerous meso- and bathypelagic fishes but only two sharks. Clarke (1973) made some observations with a submersible off Hawaii, but the seven chondrichthyan species he recorded during the survey were caught in nets and traps. Isaacs and Schwartzlose (1975) used automatic baited cameras to make some observations on deep-sea fishes, including some sharks.

Gilat and Gelman (1984) carried out a photographic survey of deep-sea sharks of the eastern Mediterranean, with "free-fall camera" set between 280 and 1490 m depth off Haifa (Israel) and Cyprus (eastern Mediterranean). They recorded 12 species of sharks and a ray, and they observed the behaviour of three shark species: *Centrophorus granulosus*, *Etmopterus spinax* and *Hexanchus griseus*. They found that gulper shark (*C. granulosus*) made up the bulk of the shark population and that there was good correlation between the estimates made with photographs and those resulting from catches with long lines. The largest biomass, about 89 kg/m^2, was found at 880 m depth.

Clark and Kristof (1990a, 1990b) reported on the results of 71 dives done with seven submersibles between 300 and 4000 m depth off Bermuda, Bahamas, Grand Cayman, California, Suruga Bay (Japan) between 1986 and 1990, in the frame of the Beebe Project. They identified 13 shark species, the most common being the six-gill shark (*Hexanchus griseus*) with about 90 specimens observed, and they found four species of gulper sharks (genus *Centrophorus*). The deepest shark observed during this project was the Pacific sleeper shark (*Somniosus pacificus*) by 1630 m depth. Rays were also observed during this project: two skates and two electric rays.

Séret (1994) analysed the videos taken by the diving saucer "CYANA" during the "CALSUB" cruise carried out off New Caledonia down to 3000 m depth. He recorded six chondrichthyan fishes, five sharks, mainly the kitefin shark *Dalatias licha*, and a skate.

This short account illustrates that direct visual observations of marine ecosystems below the depths accessible to scuba diving have rarely been carried out. No doubt this is related to the technical difficulties and costs to operate submersibles as well as to the worldwide limited availability of such vehicles. Fisheries research commonly relies on three kinds of data: (i) fishery dependant data - catch and effort of the fisheries, biological sampling of the catch, (ii) scientific surveys operating fishing gears or sampling gears derived from fishing gears, and (iii) surveys targeting a particular biological stage of one or a few species in order to estimate population densities and biomass (e.g., egg and larval surveys, acoustics surveys). Although extremely valuable, these investigation methods have their own technical limits. Knowledge about the natural history of species, their behaviour and small-scale species interactions cannot be acquired using these traditional methods of investigation.

Table I. - Number of dives carried out by cruise and objectives (*: dives combined with bottom radials).

	Main objectives	Number of dives		Details
		1996	1998	
1	**Bottom habitat**	14 *	9	Transects over the bottom to count all fixed and mobile organisms
2	**Mid-water habitat**	0	2	Transects in the water column to evaluate the density and the vertical stratification of pelagic fish
3	**Fishing gear technology**	2	5	Observations of: the effects of trawls on the bottom, the setting of pots and nets lines and the possible lost catch when hauling in of static gears
4	**Scientific gear trial**	2	6	Attempts to tag some deep water bony fishes with a chemical dye in order to analyse growth increments deposited while they are kept alive in cages on the bottom
	Invalid dive	1		

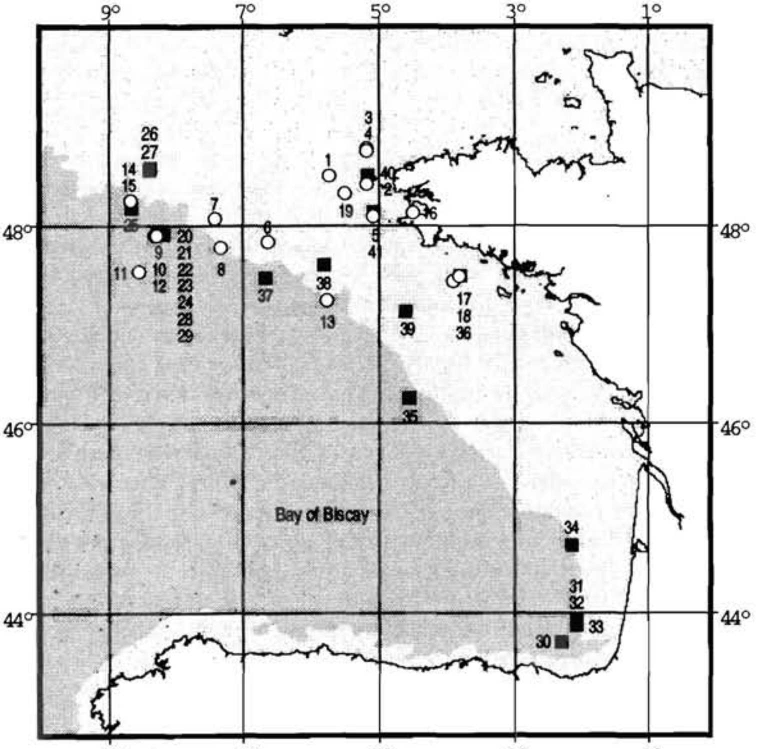

Fig. 1. - Map showing the dive stations in the Bay of Biscay (N.E. Atlantic). O: "OBSERVHAL96" (dives 1 to 19); ■: "OBSERVHAL98" (dives 20 to 41).

In order to assess the possible contribution of submersible observations to fishery science two submersible cruises were carried out in the Bay of Biscay (north west Atlantic). Several objectives were pursued (Table I) the main one being the observation and censusing of all fishes along bottom transects. However, results for chondrichtyes only will be presented here.

Sharks, rays and chimaeras were seen in most of the dives. Some species were easily identified and some behaviour features could be observed. The present paper is an attempt to compare the apparent densities observed to those from trawl surveys and to discuss the possible contribution of submersible observations to the knowledge of chondrichthyan species in terms of distribution, densities, behaviour, which ultimately might lead to improved management of these species.

MATERIAL AND METHOD

The surveys were carried out from 5 to 26 August 1996 with the submersible "CYANA" (OBSERVHAL96) and from 13 May to 7 June 1998 with the submersible "NAUTILE" (OBSERVHAL98).

A total of 40 valid dives could be completed (Table I). Most dives took place to the west of Brittany and some took place in the southern Bay of Biscay when spring tide did not allow operating submersible elsewhere (Fig. 1). The overall depth range of the dives extended from 80 to 2100 m (Tables II, III). It covered continental shelf and slope depth and a variety of types of seabeds.

The duration of a dive was limited to about 5 hours on the bottom by the capacity of the batteries (Latrouite *et al.*, 1999). The locations of the dives were defined in advance. However, the actual route on the bottom depended upon the seabed topography and unpredictable conditions like current strength and direction on the bottom. The speed of the submersible was generally about 1 knot (30 m/min) along transects but several stops occurred for video recording, sampling (stones or organisms) or other operations. The altitude of the submersible above the bottom varied according to the visibility, which depended on turbidity and plankton density. To allow easy observation of benthic megafauna and demersal fishes it was generally between 0.5 and 5 m. The width of the visual scope for the two observers (pilot + scientist) was estimated by the pilot of the submersible. Although the scope within which fish can be seen depends also upon the size and the species of the observed animal (mimetic species, like flatfishes, are less visible than active demersal species), the visual scopes used here apply to all species as no device to estimate distances from the submersible to the fishes observed was available. The swept area per dive was estimated by multiplying the distance travelled with the visual scope. The lengths of the transects were calculated from the navigation system of the support "R/V Suroît" (OBSERVHAL96) or of the submersible "NAUTILE" (OBSERVHAL98); in both cases, the reliability was rather low. Although no confidence interval can be computed, the distance calculated may be wrong of up to 30% for some dives.

The data were analysed in a quantitative way. Maximum and minimum depth of occurrence of species were recorded, apparent relative densities per taxonomic group (sharks, rays and chimaeras) were calculated based upon observations during all the time on bottom. The relative frequencies of chondrichthyan individuals among all demersal fish were calculated. Pelagic, mesopelagic and small and gregarious species (namely *Trachurus trachurus*, *Scomber scombrus*, *Argentina* sp., *Gadiculus argentatus*, *Micromesistius poutassou*, *Trisopterus minutus*, *Capros aper*), which were encountered sometimes in high numbers, were ignored in these calculations. Depending on the reliability of fish counts, dives devoted to other objectives (Table I) were treated similarly (for example, dive 38, over a pot string, was treated here as a bottom radial) or only short transects carried out during spare time were used. These estimated densities and frequencies were compared to trawl survey data.

In 1998, six dives were carried out at one single location at mid-slope depth (1200 m) for chemical tagging purposes (Latrouite *et al.*, 1999). During these dives fish individuals encountered were recorded, however, as a lot of moves to and from were done the same individual was possibly seen more than once. Furthermore the census cannot be related to a swept area. Hence, the observations from these 6 dives were summed up to provide relative fish frequencies at this location, but no density was calculated.

During 3 dives (1300 m, 1200 m and 1000 m), attempts were made to attract sharks to the submersible using bait. In the first attempt the bait was sepion, in the second tuna and squids and in the third fresh pelagic fish (*Scomber scombrus* and *Trachurus trachurus*). In each case the bait was laid on the ground near the submersible that remained immobile with lights switched off for 30 to 45 min.

RESULTS

Species identification and depth range

In the course of the bottom transects Chondrichthyes were observed during 23 dives among 29 (Tables II, III) and 22 species (9 sharks, 8 rays and 5 chimaeras) were identified (Table IV). Some species were easily identified from their colour patterns. This was the case for most of the rays, *Leucoraja naevus* (Fig. 2A), *L. circularis*, *Raja brachyura*, *R. montagui*, *Neoraja caerulea*, *Torpedo nobiliana*, and for two species of Scyliorhinidae, *Scyliorhinus canicula* and *Galeus melastomus*. The shape of their snout allowed adding the Rhinochimaeridae, *Hariotta raleighana* and *Rhinochimaera atlantica*, to this list of easily identifiable species. Similarly, the single dorsal fin of *Hexanchus griseus*, the concave angle of the anterior margin of the disk in *Dipturus oxyrhinchus* (distinction from *D. nidarosiensis* which could share the same habitat) appeared as typical characteristics usable for visual identification.

Some other species, whose characteristics were less evident, were identified only when individuals could be approached and observed for some time. This was the case for the Chimaeridae family where the colour pattern was of little help. The genus *Chimaera* and *Hydrolagus* could be distinguished from the characteristic separation (*Chimaera*) or continuity (*Hydrolagus*) of anal and caudal fins. Within the genera *Hydrolagus*, species identification was more difficult and could only rely on the long caudal filament of *H. mirabilis*, absent in *H. affinis*. Only one individual of each *Hydrolagus* species was identified with certitude. The deep-water squalids also required a longer examination, and many individuals seen were only identified as sharks. However, some individuals of *Deania calcea* (long snout and characteristic shape), *Dalatias licha* (shape of snout and caudal fin) and *Centroscymnus coelolepis* (combination of a massive body, small dorsal fins and caudal fin with lobes moderately differentiated), were identified. Lastly, some deep-water Scyliorhinidae were also seen, due to the frequency of these species in trawl they should mainly belong to the genus *Apristurus*. As the species of this genus are hard to identify when caught, it is not realistic to identify them from the submersible. However, it is likely that at least two species were encountered as dark and clearer individuals were recorded. According to the area and depth range studied, the black individuals may be *A. microps* and the clearer ones may belong to *A. laurussoni* or to *A. aphyodes*. Another small deep-water Scyliorhinidae had a well visible darker colour at the

Table II. - Chondrichthyan fishes observed during bottom dives, during the cruise "OBSERVHAL96". (*: Some time during transect was spent stopped for video recording or observations; **: Several numbers are minimum as some groups of fishes revealed impossible to count exhaustively).

Dive N°	**1**	**2**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**17**	**18**	**19**
Objective (see table I)	1	1	1	1	1	1	1	4 & 1	4 & 1	1	1	1 & 3	1 & 3	1 & 3	1 & 3	1
Latitude North (median point)	48°30'	48°25'	48°06'	47°51'	48°04'	47°47'	47°55'	47°55'	47°33'	47°54'	47°15'	48°15'	48°15'	47°27'	47°30'	48°20'
Longitude West (median point)	05°44'	09°50'	05°07'	06°38'	07°25'	07°19'	08°17'	08°19'	08°33'	08°17'	05°46'	08°40'	08°38'	03°54'	03°49'	05°30'
Duration on bottom (hh:mm) *	2:22	2:16	4:18	0:52	2:32	4:47	5:39	4:59	4:02	4:22	4:45	2:03	2:46	2:03	2:46	1:58
Minimum depth (m)	119	90	83	83	185	171	1170	1210	2095	1200	172	176	175	95	93	118
Maximum depth (m)	122	94	96	96	186	182	1430	1240	2105	1550	397	184	179	97	97	118
Distance (m)	2 900	2 400	3 700	2 200	1 800	3 800	3 000	2 400	900	4 000	1 200	4 600	5 300	1 500	1 600	1 400
visual scope (m)	6	6	6	4	8	8	15	15	15	10	8	10	10	4	4	6
Swept area (m^2)	17 400	14 400	22 200	8 800	14 400	30 400	45 000	36 000	13 500	40 000	9 600	46 000	53 000	6 000	6 400	8 400
Number observed																
Sharks	32	0	42	1	0	5	2	2	1	20	6	20	18	0	0	6
Rays	0	0	2	0	4	4	0	4	1	1	2	4	8	0	0	1
Chimaeras	0	0	0	0	0	0	8	2	0	7	1	0	0	0	0	0
Demersal bony fishes **	48	> 53	> 84	29	67	> 218	142	90	33	301	> 20	237	> 206	9	68	83
Densities (number per 10 000 m^2)																
Sharks	18.4	0	18.9	1.1	0	1.6	0.4	0.6	0.7	5.0	6.3	4.3	3.4	0	0	7.1
Rays	0	0	0.9	0	2.8	1.3	0	1.1	0.7	0.3	2.1	0.9	1.5	0	0	1.2
Chimaeras	0	0	0	0	0	0	1.8	0.6	0	1.8	1.0	0	0	0	0	0
Demersal bony fishes	27.6	36.8	37.8	33.0	46.5	71.7	31.6	25.0	24.4	75.3	20.8	51.5	38.9	15.0	106.3	98.8
Relative frequencies of Chondrichthyes in the fish assemblage (%)																
Sharks	40.0	0	33	3.3	0	2.2	1.3	2.0	2.9	6.1	20.7	7.7	7.8	0	0	6.7
Rays	0	0	1.6	0	5.6	1.8	0	4.1	2.9	0.3	6.9	1.5	3.4	0	0	1.1
Chimaeras	0	0	0	0	0	0	5.3	2.0	0	2.1	3.4	0	0	0	0	0
Total	40.0	0	34.4	3.3	5.6	4.0	6.6	8.2	5.7	8.5	31.0	9.2	11.2	0	0	7.8

Table III. - Chondrichthyan fishes observed during near bottom dives during the cruise "OBSERVHAL98". (*: Addition of 2 short bottom transects at the beginning of dives devoted to mid-water observations; **: Route too tortuous).

Dive N°	22	25	26	30	31/32 *	33	34	35	36	37	38	39	41
Theme (see table I)	1	1	3	1	2	1	1	1	1	1	3	3	1
Latitude North (median point)	47°54'	48°10'	48°04'	43°41'	43°55'	43°51"	44°43"	46°15'	47°30'	47°28'	47°36'	47°08'	48°08'
Longitude West (median point)	08°11'	08°17'	07°25'	02°20'	02°05'	02°04'	02°09'	04°34'	03°50'	06°41'	05°50'	04°37'	05°05'
Time in transect (hh : mm)	4 : 18	5 : 12	1 : 52	4 : 18	1 : 22	5 : 25	4 : 45	4 : 51	3 : 49	4 : 06	3 : 08	0 : 19	2 : 46
Minimum depth (m)	932	245	168	1365	180	200	710	1110	109	434	156	143	100
Maximum depth (m)	1227	408	172	1855	180	496	1580	1560	109	522	158	148	105
Distance (m)	4 800	4 500	3 160	6 070	1 000	6 580	3.750	6 350	**	5 270	4 050	200	4 110
visual scope (m)	15	12	10	10	10	10	20	20	5	15	10	5	10
Swept area (m^2)	72 000	54 000	31 600	60 700	10 000	65 800	75 000	127 000	-	79 100	40 500	1 000	41 100
Number observed													
Sharks	8	0	1	10	0	323	6	62	0	40	21	0	27
Rays	3	0	1	0	0	0	0	11	0	0	0	0	0
Chimaeras	13	3	0	28	0	0	6	13	0	81	0	0	0
Demersal bony fishes	769	62	38	1030	207	119	750	1256	177	316	50	11	38
Densities (number per 10 000 m^2)													
Sharks	1.1	0	0.3	1.6	0	49.1	0.8	4.9	-	5.1	5.2	0	6.6
Rays	0.4	0	0.3	0	0	0	0	0.9	-	0	0	0	0
Chimaeras	1.8	0.6	0	4.6	0	0	0.8	1.0	-	10.2	0	0	0
Demersal bony fishes	106.8	11.5	12.0	169.7	207.0	18.1	100.0	98.9	-	39.9	12.3	110.0	9.2
Relative frequencies of Chondrichthyes in the fish assemblage (%)													
Sharks	1.0	0	2.5	0.9	0	73.1	0.8	4.6	0	9.2	29.6	0	41.5
Rays	0.4	0	2.5	0	0	0	0	0.8	0	0	0	0	0
Chimaerids	1.6	4.6	0	2.6	0	0	0.8	1.0	0	18.5	0	0	0
Total	3.0	4.6	5.0	3.6	0	73.1	1.6	6.4	0	27.7	29.6	0	41.5

Table IV. - List of chondichthyan species, with observed depth ranges compared to literature data.

Family	Species	Depth range (m) observed		Depth range (m). Data from literature		Observed in dives N°	
		Minimum	Maximum	Minimum	Maximum	1996	1998
Scyliorhinidae	*Galeus melastomus* Rafinesque, 1810	276	820	55	1200	-	33, 34, 37
	Galeus murinus	1300	1300	380	1200	12	-
	Scyliorhinus canicula (Linnaeus, 1758)	120	295	0	400	1,5,6,8,13-15,17-19	26, 33, 38, 40, 41
	Apristurus sp.	1286	1490			9, 12	-
Triakidae	*Mustelus asterias* Cloquet, 1821	130	130	0	150	-	40
Hexanchidae	*Hexanchus griseus* (Bonnaterre, 1788)	265	265	0	1875	-	33
Squalidae	*Centroscymnus coelolepis* Bocage & Capello, 1864	945	2100	270	3675	11, 12	-
	Dalatias licha (Bonnaterre, 1788)	932	1140	37	1800	-	22, 28, 34
	Deania calcea (Lowe, 1839)	939	1200	73	1450	-	22, 34
Rajidae	*Dipturus oxyrinchus* (Linnaeus, 1758)	1230	1230	90	900	10	-
	Leucoraja circularis (Couch, 1838)	388	388	70	275	13	-
	Leucoraja naevus (Müller & Henle, 1841)	110	190	20	250	3, 4, 7, 8, 14, 15	-
	Neoraja caerulea (Stehmann, 1976)	1220	1540	600	1260	10	35
	Raja brachyura Lafont, 1873	118	118	0	100	19	-
	Raja montagui Fowler, 1910	90	110	0	100	3, 4, 5	-
	Rajella bigelowi (Stehmann, 1978)	2100	2100	-	-	11	-
Torpedinidae	*Torpedo* sp. cf *nobiliana* Bonaparte, 1835	120	120	10	350	-	40
Chimaeridae	*Chimaera monstrosa* Linnaeus, 1758	395	1380	300	500	9, 10, 12, 13	22, 37
	Hydrolagus affinis (Capello, 1867)	1480	1480	300	2400	12	-
	Hydrolagus mirabilis (Collett, 1904)	1070	1070	450	1200	-	22
Rhinochimaeridae	*Hariotta raleighana* Goode & Bean, 1895	1560	1848	360	2600	-	30, 34
	Rhinochimaera atlantica Holt & Byrne, 1909	1580	1849	500	1500	-	30, 34

tips of dorsal fins, which is probably a characteristic of *Galeus murinus*, but all this will remain unconfirmed.

Lastly, it is likely that more species could be recognised by a trained observer. It appeared also that, thanks to their external organs, sexing chondrichthyes seen from submersibles is possible.

Habitats

The depth range observed (or the depth at which one single specimen was seen) is most often within the known depth range of the species. The Portuguese shark, *Centroscymnus coelolepis*, observed at 945 and 2100 m depths during "OBSERVHAL" cruises, is the deepest shark, with a bathymetric range of 300-3675 m (Compagno, 1984). The six-gill shark, *Hexanchus griseus*, is mainly a deep-water species, however it occasionally comes to surface, apparently during night without moon light, according to Mediterranean fishermen; during our dives, it was observed at 265 m depth. Several species (*Galeus murinus*, *Dipturus oxyrinchus*, *Neoraja caerulea*, *Chimaera monstrosa* and *Rhinochimaera atlantica*) were observed at greater depths than their known depths ranges (Table IV). However, for these slope species, a lot of new data and records have been collected recently and these depths should not be exceptional for these species.

Densities and relative frequencies

The highest total density of Chondrichthyes was observed at upper slope depths, 200-500 m (about 50 individuals/10 000 m^2, dive 33, see Table III). This figure is due to the large number of lesser spotted catsharks (*Scyliorhinus canicula*) seen during that dive. Other high figures in Chondrichthyes densities were due to the same species on the shelf (dives 1 and 5, see Table II), to the closely related *Galeus melastomus* and to *Chimaera monstrosa* on the upper slope (dive 37, see Table III). Deeper, Chondrichthyes were seen in all dives at densities from 0.8 to 7.0 individuals per 10 000 m^2. Excluding dives 1 and 5, the total density of Chondrichthyes on the shelf ranged from 0 to 8.3 individual per 10 000 m^2, chimaeras being absent (Tables II, III).

In terms of relative frequency of Chondrichthyes in the fish assemblage, the highest proportion was also seen at upper slope depth with a maximum of 71% in dive 33. At greater depths, the proportion varied from 1% to 9%. On the shelf the proportion was more variable from 0 to 34%. At mid-slope (about 1200 m), where more observations were available, the relative frequency was 6% (Table V).

Table V. - Chondrichthyan fishes observed during dives for age validation operations during the cruise "OBSERVHAL98".

Dive N°	**20**	**21**	**23**	**24**	**28**	**29**	**Overall**
Maximum depth	1100	1150	1165	1150	1125	1150	1100
Minimum depth	1220	1190	1190	1190	1195	1190	1220
Sharks	4	0	2	1	1	1	9
Rays	1	1	0	0	5	0	7
Chimaeras	11	5	0	4	6	2	28
Demersal bony fishes	152	84	32	61	244	73	646

Relative frequencies of Chondichthyes in the fish assemblage							
Sharks	2.4	0.0	5.9	1.5	0.4	1.3	1.3
Rays	0.6	1.1	0.0	0.0	2.0	0.0	1.0
Chimaeras	6.5	5.6	0.0	6.1	2.3	2.6	4.1
Total	9.5	6.7	5.9	7.6	4.7	3.9	6.4

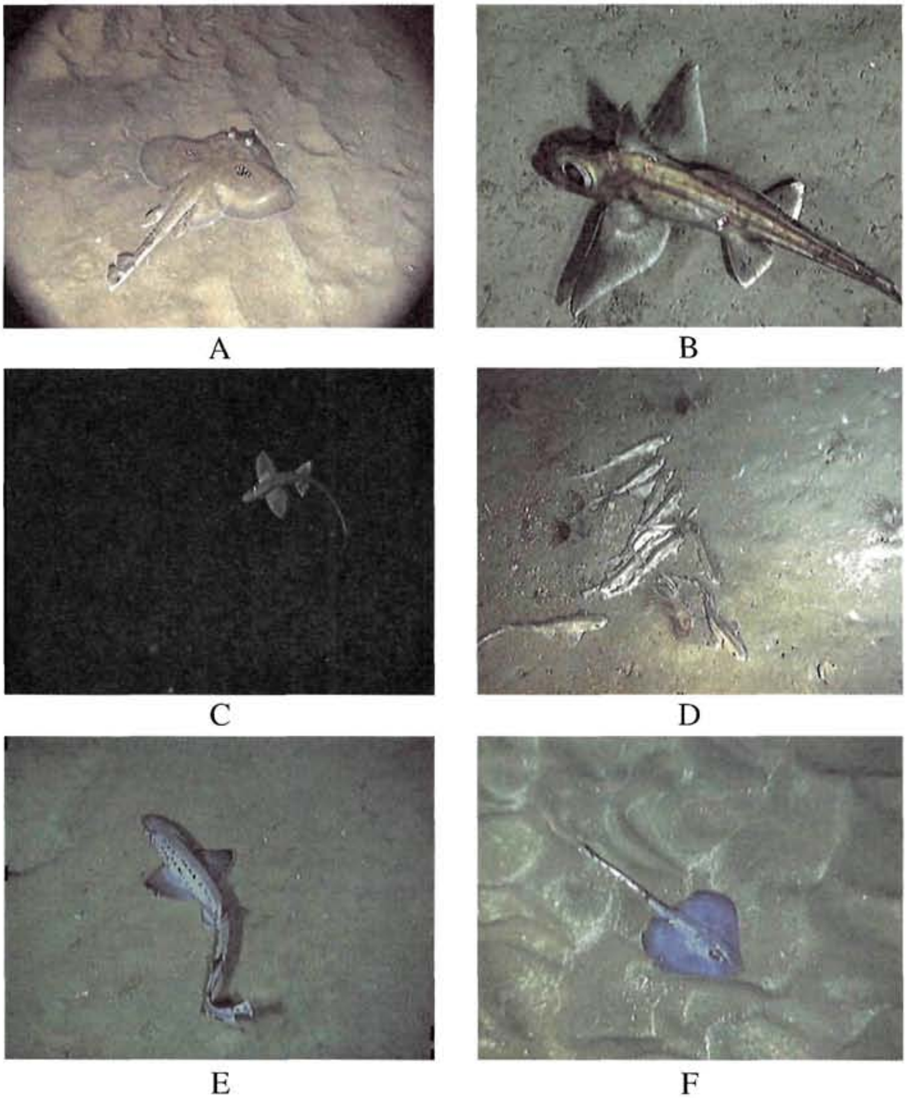

Fig. 2. - Some chondrichthyan fishes observed during the "OBSERVHAL 96" and "OBSERVHAL 98" cruises in the Bay of Biscay (N.E. Atlantic). **A**: Cuckoo ray, *Leucoraja naevus*; **B**: Wounded rabbitfish, *Chimaera monstrosa*; **C**: Rabbitfish looping the loop; **D**: Group of lesser spotted catshark, *Scyliorhinus canicula*; **E**: Blackmouth catshark, *Galeus melastomus*; **F**: Blue ray, *Neoraja caerulea*.

Attraction by bait

None of the three trials carried out attracted any chondrichthyan fish.

Wounded animal

Along the slope, some wounded bony fishes, in particular macrourids having lost their tails, were seen (Latrouite *et al.*, 1999). Amongst Chondrichthyes, several wounded chimaeras were observed (Fig. 2B). These anecdotal observations illustrate the severe predation that prevails at these depths, and from which some chondrichthyan species do not escape.

Behaviour

Chimaeras were always seen very active. Some individuals swam away from the submersible, other went up into the water column, moving actively, sometimes looping the loop (Fig. 2C). Some individuals were also seen knocking against the bottom (probably blinded by the submersible lights). All these behaviours illustrate strong reaction to the submersible.

Sharks did not display such hypersensitive behaviour. They were mainly seen slowly swimming. However, they could not be approached enough to be touched by the submersible arm like some bony fishes. Rays were seen motionless on the bottom, some reacted to the arrival of the submersible.

Scyliorhinus canicula were often seen lying on the bottom; several groups of immobile animals were seen. Up to 12 individuals almost side by side were counted (Fig. 2D). These animals did not react at all to the arrival of the submersible. No other chondrichthyan species was seen forming group.

Galeus melastomus was seen slowly swimming a few centimetres above the bottom or motionless on the bottom as *S. canicula* but not in groups. This swimming behaviour suggested exploitation of ground effect (Fig. 2E). Similarly when they swam away from the submersible all the rays moved just over the bottom. The swimming movements of sharks are different between species, *Galeus melastomus* advances with wide undulations while deep-sea squalids advance by movements restricted to their tail.

One case of possible attraction of *Neoraja caerulea* was observed at dive 35: the ray appeared in the field of vision and approached up to a few meters while the submersible was stopped for topography video recording (Fig. 2F).

At different occasions, over fine sediments, encounter of a chondrichthyan fish was preceded by observation of a sediment perturbation revealing a short running away of the animal, which then stayed in the field of vision.

DISCUSSION

Behaviour

To our knowledge, the literature about the behaviour of chondrichthyan fishes in the open sea is limited, especially for deep-water species. Although this was not the aim of the dives, some observations were collected and may be of interest beyond the scope of animal behaviour.

It is worth noting that deep-water squalids were always seen active while at mid-slope depths several bony fish species were seen lying on the bottom (for example: *Hoplostethus atlanticus, Trachyscorpia cristulata echinata, Bathypterois* sp.) or static (small macrourids, morids). However, it can be difficult to discriminate the usual behaviour of species from their reaction to the submersible, for example rays seen swimming were thought to be reacting to the submersible.

Attraction by baits

In the light of former experiments, carried out in the Bay of Biscay, it is not astonishing that no chondrichthyan species were attracted by baits during "OBSERVHAL" surveys because the stops done were probably shorter than the time required for sharks to arrive on a bait (Isaacs and Schwartzlose, 1975; Mahaut *et al.*, 1990).

Behaviour in relation to the submersible

In the Bay of Biscay, Mahaut *et al.* (1990) studied fish behaviour and population densities. In particular, estimates of fish densities were derived from one transect at 2100 m depth of the unmanned submersible "EPAULARD" which travels at an average 3.5 m above the bottom and takes photos straight down beneath itself. No shark or chimaera was observed in that transect while, during the same series of cruises they were successfully attracted by baited cameras and observed around baits from the submersible "CYANA". As Chondrichthyes attracted by baits were seen swimming close to the bottom and were not frightened by "CYANA", Mahaut *et al.* (1990) thought it unlikely that they would have escaped the field of vision of "EPAULARD" and they concluded that their absence « must have an ethological explanation ». During "OBSERVHAL" cruises, sharks and chimaeras were encountered in all dives along the slope, including at depths similar to that prospected by Mahaut *et al.* (1990). The difference is ascribed to the observation method. The behaviour of chimaeras and deep water sharks, which kept clear enough from the submersible and never stayed beneath it, suggests that they did escape the field of vision of "EPAULARD" during former observations.

Wounded animals, predation, competition

Our observations are very limited and no former analysis of frequency of wounded animal has been found. However, the encounter of a wounded animal is striking and may be useful in terms of predation and competition assessment. This can probably not be done from trawl sampling, as what can be a sign of ethological interactions is lost due to injuries caused by trawling. Censusing of wounded animal over areas where differences in predation/competition intensities are expected to occur (for example in similar ecosystems on unexploited areas and where fishery may have relaxed species interactions) might throw light on this subject as yet very speculative.

Swimming and energy

The suspected use of the ground effect by *G. melastomus* could be an illustration of a strategy for energy saving of dispersed deep-sea fishes as these species live in energetically poor environments. Adaptations for energy conservation of slope fish have often been conjectured, however they remain to be confirmed (Merrett and Haedrich, 1997). Submersible observations may be helpful in the validation of this theory.

Submersibles and assessment of fishery effect

All chondrichthyan species dealt with here are now exploited commercially. Shelf rays and sharks are long-standing components of the catches in the Bay of Biscay and elsewhere (Quéro and Vayne, 1998). Chondrichthyes on the continental slope are of more recent exploitation. Depending on their palatability and market they are either targets, by-catch or discard species (Blasdale and Newton, 1998; Dupouy *et al.*, 1998; Lorance and

Table VI. - Average and ranges of densities and frequencies of chondrichthyan fishes by depth range during "OBSERVHAL" cruises.

	Shelf	**Upper slope**	**Slope**
Depth range (m)	**83 - 186**	**172 - 522**	**710 - 2105**
Densities (number per 10 000 m^2)			
Sharks	4.2 (0 - 18.9)	15.1 (0 - 49.1)	1.9 (0.4 - 5.0)
Rays	0.6 (0 - 2.8)	0.5 (0 - 2.1)	0.4 (0 - 1.1)
Chimaeras	0	3.0 (0 - 10.2)	1.5 (0 - 4.6)
Total	4.5 (0 - 19.8)	18.6 (0.6 - 49.1)	3.9 (1.5 - 7.0)
Relative frequencies of Chondrichthyes in the fish assemblage (%)			
Sharks	10.2 (0 - 41.5)	25.7 (0 - 73.1)	2.5 (0.8 - 6.1)
Rays	1.0 (0 - 5.6)	1.7 (0 - 6.9)	1.1 (0 - 4.1)
Chimaeras	0	6.6 (0 - 18.5)	1.9 (0 - 5.3)
Total	11.3 (0 - 41.5)	34.1 (4.6 - 73.1)	5.4 (1.6 - 8.5)

Dupouy, 1998) In the Bay of Biscay, they are mainly caught by longliners (Piñeiro *et al.*, 1998). Although the French landings as "siki", which reached 2400 t in 1995 (Ponroy and Séret, in press) are mainly caught in the west of the British Isles and not in the Bay of Biscay, they show that these species are of interest for high sea trawlers and may be object of increasing fishing effort in the Bay of Biscay. However, the distribution and total abundance of these species in the Bay of Biscay are not known with sufficient precision for stock assessment.

Table VII. - Densities and relative frequencies of chondichthyan fishes species in the shelf and upper slope demersal fish assemblages of the Bay of Biscay observed from yearly trawl surveys. Shelf corresponds to depths from 60 to 200 m; upper slope to depths from 200 to 500 m. Average densities and frequencies observed over 7 surveys are given together with minimum and maximum annual values. Ratios between mean densities and frequencies from submersible and trawl surveys are calculated.

	Assemblage			
	Shelf (60 - 200 m)		**Upper slope (200 - 500 m)**	
	Density (number per 10 000 m^2)	**Ratio sub./trawl**	**Density (number per 10 000 m^2)**	**Ratio sub./trawl**
Sharks	0.8 (0.3 – 1.4)	5	2.6 (0.8 – 6.1)	6
Rays	0.2 (0.1 - 0.3)	3	0.3 (0.1 – 0.7)	1
Chimaeras	> 0 (0 - > 0)	-	0.3 (0.1 – 0.7)	10
Total	1.0 (0.6 – 1.7)	5	3.2 (1.2 – 7.5)	6
	Relative frequency (%)	**Ratio sub./trawl**	**Relative frequency (%)**	**Ratio sub./trawl**
Sharks	2.3 (1.3 - 3.7)	4	19.0 (9.0 - 28.2)	1
Rays	0.7 (0.3 - 1.3)	1	2.3 (0.9 - 3.4)	1
Chimaeras	> 0 (0 - > 0)	-	2.0 (0.7 - 4.2)	3
Total	3.0 (1.5 - 4.6)	4	23.3 (13.9 - 34.7)	1

Table VIII. - Range of relative frequencies (%) of chondrichthyan fishes species in the fish assemblage to the west of Scotland between 54° and 57° N (data from different types of trawl from SAMS surveys from 1975 to 1987 and IFREMER cruise in 1996).

	Bathymetric zone (m)						
	250	**500**	**750**	**1000**	**1250**	**1500**	**1750**
Sharks	4	1 - 10	0 < - 8	0 < - 4	0 < - 4	0 < - 2	0 < - 4
Rays	0 <	0 <	0 <	0 <	0 <	0	0<
Chimaeras	1	2 - 35	0 < - 9	2 - 5	1 - 3	0 < - 2	0 < - 4
Total	5	4 - 45	1 - 18	5 - 8	1 - 8	1 - 3	1 - 8

Chondrichthyes and, in particular, shark species, are recognised to be sensitive to fishery exploitation due to their k-selected life history strategy. Even species that support major fisheries may only be able to undergo low exploitation rates (Cortés, 1998; Márquez-Farias and Castillo-Geniz, 1998; Rago *et al.*, 1998). Inclusion of some species in the list of internationally protected species is considered (Daves and Nammack, 1998). In the Bay of Biscay, some large species have been depleted due to fishing (Quéro and Cendredo, 1996), suggesting that appropriate fishery management is required for these species. Beyond the continental shelf, the jagged topography restricts the use of trawl sampling to some small terraces. Then, the possibility to estimate population densities from submersibles (or remote operated vehicles) may prove very useful for these species probably susceptible to overfishing.

The mean densities and relative frequencies of Chondrichthyes observed from the submersible in different habitat types (Table VI) can be compared to those estimated from trawl surveys. In the Bay of Biscay, estimates of fish densities, on the shelf and upper slope, were available from a seven years series of trawl surveys, which sampling gear was a 36/47 GOV trawl (Anonyme, 1992). The results are given for two assemblages (shelf and upper slope) which were identified from catch composition analysis (Table VII) and correspond roughly to depths from 60 to 200 m and > 200 m (Poulard, pers. comm.), the deepest tows sampled in these surveys were around 500 m.

For the continental slope, less data were available. The most comprehensive studies of the ecology and biology of slope species, in the North-eastern Atlantic, have been carried out to the west of Scotland from the 70s (Gordon and Duncan, 1985; Gordon, 1986; Gordon and Bergstad, 1992; Gordon *et al.*, 1996, and literature herein). These cruises were carried out with different trawls including large commercial trawls and smaller trawls designed for scientific sampling at great depths. It was shown that the image of the slope fish assemblage from trawl cruises depends upon the kind of trawl used for sampling (Gordon and Duncan, 1985; Gordon, 1986; Merrett *et al.*, 1991; Gordon *et al.*, 1996). A more recent survey was carried out with a larger commercial trawl (Lorance, 1998). The range of relative frequencies of chondrichthyan fishes in the catches from these surveys (Table VIII) was compared to the frequencies derived from submersible observations. The bathymetric zones used in former analysis (Gordon and Bergstad, 1992) were kept.

Comparing these data, it should be kept in mind that the aims of the trawl surveys were different to those of "OBSERVHAL" cruises, resulting in differences in depth ranges covered, geographical distributions and intensity of sampling effort. In other words, comparisons are carried out within a very heterogeneous data set.

The relative frequency of chondrichthyan species along the slope off the west coast of Scotland are comparable to those calculated from "OBSERVHAL" cruises and peak frequencies of sharks and chimaeras at upper slope depths are seen in both (Tables VI, VIII).

Within the Bay of Biscay, the densities of Chondrichthyes calculated from submersible cruises were higher than those calculated from trawling, the relative frequencies of Chondrichthyes in the demersal fish assemblage were more similar (Tables VI, VII).

The higher densities calculated from "OBSERVHAL" may suggest that swept areas were underestimated. Indeed, no device to estimate the visual scope was available on the submersible, so that the field of vision within which these large animals were visible may have been underestimated. The better consistency of the relative frequencies makes this underestimation of the visual scopes probable. However, the higher densities of Chondrichthyes obtained from "OBSERVHAL" may also come from their behaviour and/or the geographical distribution of dives (several dives were carried out over not trawlable grounds or areas of relatively low fishing intensity, where the density of large predators like Chondrichthyes could be higher).

It is worth noting that chimaeras reacted strongest to the submersible, which could mean that they avoid trawls. Along the slope the relative frequency of chimaeras estimated from submersible is 3 times higher than the estimate obtained from trawling while the frequencies of sharks and rays are similar from the submersible and in trawl catches (Table VII). However, the trawlable grounds in the Bay of Biscay are restricted, which means that the sampling of the fish density from trawl may be biased, in particular the depth distribution of the trawl hauls within the depth range 200 to 500 m during trawling cruises may be uneven.

The higher density of chimaeras observed at upper slope depth is due to one species: *Chimaera monstrosa*, other chimaeras have a deeper distribution. This peak of abundance was also found to the west of British Isles from 50° to 60° North (Bridger, 1978; Ehrich, 1983; Gordon and Duncan, 1985; Gordon and Bergstad, 1992) but it seemed less marked further south at Porcupine Seabight - to the south west of Ireland - (Gordon *et al.*, 1996). In the Bay of Biscay area, Ehrich (1983), indicated that *C. monstrosa* was present from 200 to 1200 m at low densities and interpreted the difference with the west of the British Isles as due to hydrological conditions.

On the shelf, the ability of the submersible to sample not trawlable bottom may also explain that densities and frequencies of sharks higher than those derived from trawl surveys were estimated. Most of the sharks seen were *Scyliorhinus canicula*, which motionless attitude suggests a greater vulnerability to trawling than for chimaeras. However, on the shelf, the estimates derived from trawling surveys are based upon a much larger number of stations.

CONCLUSION

The frequency of Chondrichthyes in the slope fishes assemblage from the present study are consistent with trawl data from the west coast of Scotland. In shallower waters, on the upper slope and on the shelf, there are differences between trawl and submersible estimates. These could be due to bias in estimates, species behaviour and the geographical distribution of the sampling stations. No single sampling method is suited to estimate densities and frequencies of all species. There is currently no reason to believe that densities or frequencies derived from trawl sampling are more realistic than those from submersibles. The range of the densities of Chondrichthyes obtained from yearly trawl surveys illustrate that they do not provide very accurate estimates for these species and underwater visual observation may become a useful complement to collect data on these species. Trawl sampling allows identifying all specimens to species level while from the submersible this identification proved difficult for some chondrichthyan species. On the other hand, the submersible provides observations from not trawlable grounds like most of the continental slope of the Bay of Biscay where some shark species are exploited by longliners. This also includes rough bottom with blocs, steep areas as well as sea floor with fine sediment where trawl gear quickly bury with not chance of recovery. Moreover, the submersible allows not destructive studies.

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