ANNEX XXI

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Bycatch of crustacean and fish bottom trawl fisheries from southern Portugal (Algarve)

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SUMMARY: As part of two research projects for analysing bycatch and discards, we quantified catch composition, catch rates, bycatch and discards in two important commercial bottom trawl fisheries (crustacean and fish trawls) off the southern coast of Portugal (Algarve). Stratified sampling by onboard observers took place from February 1999 to March 2001 and data were collected from 165 tows during 52 fishing trips. Commercial target species included crustaceans: blue and red shrimp (*Aristeus antennatus*), deep-water rose shrimp (*Parapenaeus longirostris*), Norway lobster (*Nephrops norvegicus*); and fishes: seabreams (*Diplodus* spp. and *Pagellus* spp.), horse mackerels (*Trachurus* spp.) and European hake (*Merluccius merluccius*). The trawl fisheries are characterised by considerable amounts of bycatch: 59.5% and 80.4% of the overall total catch for crustacean and fish trawlers respectively. A total of 255 species were identified, which belonged to 15 classes of organisms (137 vertebrates, 112 invertebrates and 6 algae). Crustacean trawlers had higher bycatch biodiversity. Bony fish (45.6% and 37.8%) followed by crustaceans (14.6% and 11.5%) were the dominant bycatch components of both crustacean and fish trawlers respectively. The influence of a number of factors (e.g. depth, fishing gear, tow duration and season) on bycatch and discards is discussed.

Keywords: bycatch, trawl fisheries, fish, crustacean, Algarve, Portugal.

RESUMEN: Capturas incidentales de las pesquerías de arrastre de fondo de crustáceos y peces al sur de Portugal (Algarve). – Se ha cuantificado la composición de las capturas, sus tasas, las capturas incidentales y los descartes de dos pesquerías industriales de arrastre de fondo dirigidas a crustáceos y peces del sur del Portugal (Algarve). Se realizó un muestreo estratificado mediante observadores a bordo desde febrero de 1999 hasta marzo de 2001, utilizándose los datos recogidos en 52 embarques y 165 lances. Las especies objetivos de la pesquería comercial fueron: la gamba roja (*Aristeus antennatus*), la gamba blanca (*Parapennaeus longirostris*), la cigala (*Nephrops norvegicus*), varias especies de espáridos de los géneros *Diplodus* y *Pagellus*, jureles (*Trachurus* spp.) y merluza (*Merluccius merluccius*). Estas pesquerías de arrastre de fondo se caracterizaron por la presencia de considerables cantidades de capturas incidentales, que variaron entre un 59.5 y un 80.4% del total de las capturas de crustáceos y peces, respectivamente. Se identificaron 255 especies pertenecientes a 15 clases de organismos (137 vertebrados, 112 invertebrados y 6 algas). Se observó que la mayor biodiversidad se produjo en los arrastreros dirigidos a la captura de crustáceos. El componente dominante de las capturas incidentales en los arrastreros dirigidos a crustáceos y peces fueron los teleósteos (45.6 y 37.8%, respectivamente), seguidos por los crustáceos (14.6 y 11.5%). Se discute la influencia de varios factores (i.e. la profundidad, el tipo de aparejo, la duración del lance o la estación del año) en las capturas incidentales y los descartes.

Palabras clave: capturas incidentales, pesquería de arrastre, peces, crustáceos, Algarve, Portugal.

INTRODUCTION

Although concern about bycatch in commercial and recreational fisheries can be found in the scientific literature from the mid-1970s, it became the most critical fisheries issue in the 1990s (e.g. Alverson *et al.*, 1994; Kennelly, 1995; Alverson and Hughes, 1996; Hall *et al.*, 2000). Given the overfished state of many of the worlds most important stocks (Pauly *et al.*, 2002), there has been great interest in documenting and finding solutions to the economic, political, and ecological implications of bycatch and discarding. The worldwide interest has given rise to a significant number of research papers, reviews and conferences (e.g. Saila, 1983; Alverson and Hughes, 1996; FAO, 1996; Hall, 1996, 1998; Zann, 2000; Sánchez *et al.*, 2004; and many others). Furthermore, there is growing international concern for the conservation of bycatch species (Nakano *et al.*, 1997). The first global estimate of bycatch was approximately 12 million tonnes (Mt), with 3 to 5 Mt a year for the shrimp trawl fisheries alone (Slavin, 1981; Saila, 1983). Later, Alverson *et al.* (1994) estimated an annual shrimp trawl bycatch of around 11.2 Mt worldwide and the global annual commercial fisheries bycatch was estimated to be an average 28.7 Mt per year (FAO, 1996).

Most marine fisheries are mixed fisheries directed at only a few commercial target species; however, a wide variety of bycatch species are captured along with the target species (FAO, 1996; Castriota *et al.*, 2001). Some of these species have economic value and can be retained and commercialised, while others are discarded overboard for a variety of reasons (Saila, 1983; Alverson *et al.*, 1994; Borges *et al.*, 2002; Stobutzki *et al.*, 2003).

Bycatch may include individuals of target species smaller than the legal minimum landing size, juveniles of commercial and/or recreational fisheries species, or individuals of threatened, endangered or protected species (Alverson *et al.*, 1994; Kenelly, 1995; Lewison *et al.*, 2004). Bycatch is by and large regarded as unavoidable, and it is not restricted to any particular gear type or any particular region of the world (Hall *et al.*, 2000). However, non-selective fishing gears such as trawls that catch almost everything in their path, are generally considered to have greater bycatch rates than more selective gears such as longlines and purse seines (FAO, 1996). Indeed, the issue of bycatch in bottom trawl fisheries is of particular concern in tropical shrimp fisheries, where the weight of bycatch can be 5 to 10 times greater than the weight of the target species and may account for 8 to 16 Mt per year as a whole (Andrew and Pepperell, 1992).

The bycatch of commercial fisheries worldwide is of great concern to fisheries managers and environmental and conservation groups as it contributes to biological overfishing and to changing the structure of marine communities and/or ecosystems, with serious implications for marine populations and the overall health and sustainability of ecosystems (Alverson *et al.*, 1994; FAO, 1997; Rebecca *et al.*, 2004).

The first step towards understanding and solving the bycatch problem is to identify and quantify bycatches (Alverson *et al.*, 1994; Kennelly, 1997; Ye *et al.*, 2000; Borges *et al.*, 2002). The most widely used approach for quantifying bycatches in commercial fisheries is to have onboard observers record the required data during normal fishing operations (Saila, 1983; Alverson *et al.*, 1994; Kennelly, 1995; FAO, 1996; Liggins *et al.*, 1996).

In Portugal, the “trawling” category includes fleet components that trawl for both crustaceans and fish (C.E.C., 1993a). The most important fraction of the Portuguese commercial trawl landings comes from the Algarve, with the crustacean trawl fishery constituting a very important part of the fishing fleet in the region (D.R., 1999; Pita *et al.*, 2001).

The present study is based on two research projects that analyse bycatch and discards and focus on the bottom (decapod crustaceans and fish) trawl fisheries of the southern Portuguese coast. We quantify here the composition and catch rates of the target and bycatch species of the fish and crustacean trawl fleets. While previous studies have focused on discards (Borges *et al.*, 1997, 2000, 2001, 2002; Monteiro *et al.*, 2001), this is the first study that specifically addresses the issue of bycatches of crustacean and fish trawlers. This research will increase our knowledge of the impacts of trawling on the area and will provide a useful point of departure and baseline for management and conservation and for present and future work in this field.

MATERIAL AND METHODS

The present study was carried out on commercial fishing vessels operating off the southern coast of Portugal (Algarve) (Fig. 1) from February 1999 to March 2001, during two projects on fisheries bycatch and discards. Sampling was stratified by bottom trawl type (crustacean trawlers and fish trawlers) and season (four) per year. Given the larger bycatch quantities and diversity of crustacean trawlers, the sampling effort was 4 or 5 fishing trips per season for crustacean trawlers compared to 3 fishing trips per season for fish trawlers. Data were collected by onboard observers following the direct collection method, which consists in observers onboard commercial boats asking the skippers to identify the target species at the beginning of each trip.

Onboard the trawlers, observers recorded all the information needed to characterise the fishing vessel, fishing gears and fishing trips (number and duration of trips and tows), catch quantities (total catch, target catch, retained catch, total bycatch, commercial bycatch and discarded bycatch), species composition, and geographical and bathymetric location of the fishing area using onboard electronics. Catch estimates depended on the amounts caught per tow: if large amounts were caught, the size of the catch was estimated by the skipper of the fishing vessel. In the case of small amounts, the total catch was obtained by summing the weight of each commercial (target and bycatch species) species sorted into baskets by the fishermen. Commercial target species as well as bycatch species were measured onboard, with cephalothorax length (mm) and total length (cm) recorded for crustaceans and fish respectively. All data was collected by individual tow per fishing trip and all tows were conducted in a manner that reflected normal commercial practice.

Sampling was concentrated on trawlers based in Portimão and Olhão (Fig. 1), which are the two main fishing ports in the Algarve. The entire Algarve was considered to be a single fishing ground (Borges *et al.*, 2000). Data on the technical characteristics of trawl vessels (year of construction, overall length (in meters), gross registered tonnage (GRT), and engine power in Horsepower, hp, and Kilowatts, kw) and on the number of trawl licences for 1999, 2000 and 2001, were obtained from official archives.

The crustacean trawl fisheries in the Algarve take place on the lower continental shelf and continental slope at depths from 150 m to 800 m, depending on target species (S.E.P., 1984). The most important crustacean trawl target species are the decapod crustaceans, such as blue and red shrimp (*Aristeus antennatus*), deep-water rose shrimp (*Parapenaeus longirostris*), and Norway lobster (*Nephrops norvegicus*). As of 22 November, 2000, the minimum legal mesh size was increased from 55mm to a range of 55 to 59 mm. The total catch of crustacean trawlers that use this mesh size range must consist of a minimum of 30% of target species and a maximum of 30% of bycatch species (fishes and cephalopods) (D.R., 2000).

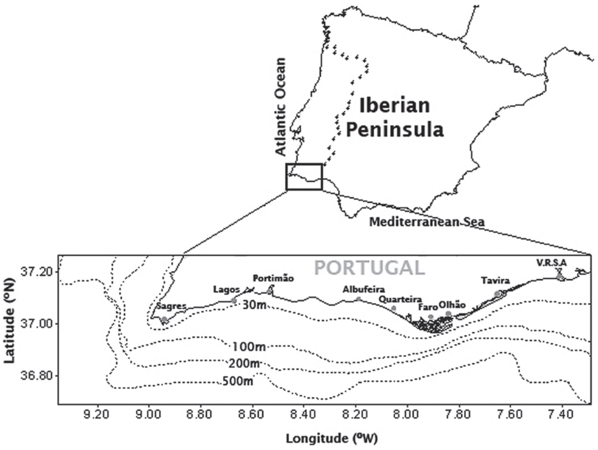

FIG. 1. – Algarve region, showing the main fishing ports in the region.

Fish trawlers operate on the continental shelf and upper continental slope, mainly at depths between 100 and 200 m (Borges *et al.*, 2001; Erzini *et al.*, 2002), and the most important target species are horse mackerel (*Trachurus* spp.), European hake (*Merluccius merluccius*) and sea breams (*Diplodus* spp. and *Pagellus* spp.). Since 2000, the minimum legal mesh size is in the range from 65 to 69 mm, and a minimum of 70% of the catch must consist of the target species. Trawlers using codend mesh sizes greater than 70 mm have no such restrictions regarding target species. However, the crustacean bycatch of fish trawlers must not exceed 20% of the total catch (D.R., 2000). Crustacean and fish trawlers constitute two different fleets with vessels that do not switch between fishing methods.

In this paper we use the following terms and definitions: *total catch* is the quantity of all species brought onboard; *target catch* is the fraction of the total catch which includes the species towards which the fishing effort is directed (target species); *retained (or landed) catch* is the part of the total catch that has economic value (i.e. the quantity of target and bycatch species that can be marketed); and *total bycatch* is the portion of the total catch which includes all the species caught accidentally (non-target species). Total bycatch may be retained if it has commercial value (commercial bycatch) and/or discarded at sea if it is not used for any purpose (discarded bycatch). In order to simplify, "*discarded bycatch*" will be referred to as "*discard(s)*" throughout this paper. It is also necessary to highlight that both the targeted and non-targeted species may be either marketable or discarded at sea.

The means and respective standard deviations of the different catch compositions were calculated according to trip and tow. In order to determine if there

TABLE 1. – Estimates of the total, target and retained catches, bycatch, commercial bycatch and discards, for the number of trips and fishing operations (tows) (* no trips due to fish trawlers strike; **no trips due to bad weather conditions; m=mean; s.d.=standard deviation).

Season	Métier	Boat	Trips	Tow	Catch (kg)					Target Catch (kg)					Retained Catch (kg)				
		(n)	(n)	(n)	Total	m/trip	s.d.	m/tow	s.d.	Total	m/trip	s.d.	m/tow	s.d.	Total	m/trip	s.d.	m/tow	s.d.
Winter 1998	Crustacean trawl	2	4	8	2160	540	88.48	270	101.98	1117	279	54.60	140	105.93	1368	342	58.37	171	118.36
	Fish trawl	2	3	19	27957	9319	1274.09	1471	2097.65	2835	945	56.07	149	167.11	7298	2433	36.49	384	333.64
Spring 1999	Crustacean trawl	2	4	9	1755	439	52.97	195	72.46	540	135	18.96	60	28.41	1166	291	30.85	130	51.09
	Fish trawl*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Summer 1999	Crustacean trawl	3	5	10	2330	466	64.48	233	75.58	1057	211	39.11	106	38.29	1332	266	32.68	133	35.48
	Fish trawl	3	3	18	8720	2907	85.18	484	435.22	2648	883	61.82	147	103.93	4327	1442	62.32	240	136.28
Autumn 1999	Crustacean trawl	2	3	5	1322	441	209.92	264	203.49	336	112	10.21	67	12.83	370	123	23.82	74	21.39
	Fish trawl	3	3	19	8065	2688	101.13	424	341.84	2186	729	19.81	115	141.43	4769	1590	33.73	251	201.99
Winter 1999	Crustacean trawl	3	3	6	1320	440	57.66	220	92.74	682	227	44.33	114	61.30	811	270	59.89	135	71.82
	Fish trawl	2	2	10	3540	1770	18.86	354	191.44	970	485	60.99	97	71.15	2059	1030	87.92	206	81.42
Spring 2000	Crustacean trawl	3	4	7	1485	371	113.07	212	109.69	559	140	34.82	80	35.45	940	235	95.53	134	78.77
	Fish trawl	2	3	12	2970	990	60.09	248	99.01	1347	449	62.23	112	78.80	2109	703	45.84	176	89.04
Summer 2000	Crustacean trawl	2	5	9	1115	223	61.02	124	70.70	370	74	18.35	41	19.92	517	103	26.13	57	26.32
	Fish trawl	2	3	15	4030	1343	219.95	269	331.90	847	282	28.80	56	58.48	1973	658	69.22	132	88.57
Autumn 2000	Crustacean trawl	2	3	8	700	233	60.24	88	70.46	316	105	20.34	40	28.39	385	128	22.12	48	30.81
	Fish trawl**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Winter 2000	Crustacean trawl	1	4	10	2800	700	55.28	280	58.69	1100	275	30.43	110	29.44	1141	285	28.80	114	29.15
	Fish trawl**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	Crustacean trawl	20	35	72	14987	428	100.47	208	83.01	6077	174	43.73	84	55.97	8029	229	57.30	112	67.49
	Fish trawl	14	17	93	55282	3252	708.50	594	1064.04	10833	637	55.06	116	118.84	22535	1326	101.41	242	207.80

Season	Métier	Boat	Trips	Tow	Bycatch (kg)					Commercial Bycatch (kg)					Discards (kg)					Commercial
		(n)	(n)	(n)	Total	m/trip	s.d.	m/tow	s.d.	Total	m/trip	s.d.	m/tow	s.d.	Total	m/trip	s.d.	m/tow	s.d.	bycatch (%)
Winter 1998	Crustacean trawl	2	4	8	1043	261	62.37	130	55.29	251	63	11.38	31	17.76	792	198	56.59	99	56.49	18.3
	Fish trawl	2	3	19	25122	8374	1262.60	1322	2047.60	4463	1488	47.77	235	277.93	20659	6886	1299.93	1087	2040.90	61.2
Spring 1999	Crustacean trawl	2	4	9	1216	304	37.39	135	47.54	627	157	18.02	70	29.01	590	147	31.07	66	34.09	53.7
	Fish trawl*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Summer 1999	Crustacean trawl	3	5	10	1273	255	61.54	127	75.40	275	55	13.28	28	21.48	998	200	55.57	100	69.26	20.6
	Fish trawl	3	3	18	6072	2024	146.13	337	427.81	1679	560	52.30	93	74.46	4393	1464	140.02	244	396.05	38.8
Autumn 1999	Crustacean trawl	2	3	5	986	329	212.00	197	203.82	34	11	14.00	7	11.01	952	317	220.16	190	209.67	9.2
	Fish trawl	3	3	19	5879	1960	86.93	309	276.22	2583	861	50.11	136	93.70	3296	1099	110.48	173	256.80	54.2
Winter 1999	Crustacean trawl	3	3	6	638	213	27.49	106	40.02	129	43	15.60	22	16.22	509	170	29.31	85	40.03	15.9
	Fish trawl	2	2	10	2570	1285	42.13	257	179.99	1089	545	26.93	109	42.62	1481	741	69.06	148	197.88	52.9
Spring 2000	Crustacean trawl	3	4	7	926	232	88.28	132	85.25	381	95	77.99	54	60.44	546	136	57.96	78	65.81	40.5
	Fish trawl	2	3	12	1623	541	6.92	135	63.89	688	229	16.34	57	31.48	935	312	28.25	78	69.74	33.8
Summer 2000	Crustacean trawl	2	5	9	745	149	54.51	83	60.92	147	29	9.39	16	9.89	598	120	48.33	66	53.93	28.4
	Fish trawl	2	3	15	3184	1061	192.98	212	281.81	1127	376	40.99	75	53.17	2057	686	162.04	137	269.27	57.1
Autumn 2000	Crustacean trawl	2	3	8	384	128	40.14	48	43.11	69	23	2.71	9	4.45	315	105	38.97	39	42.15	17.9
	Fish trawl**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Winter 2000	Crustacean trawl	1	4	10	1700	425	31.91	170	52.49	41	10	1.81	4	2.33	1659	415	32.96	166	52.50	3.6
	Fish trawl**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	Crustacean trawl	20	35	72	8911	255	78.91	124	83.01	1941	55	34.92	27	31.54	6958	199	77.69	97	82.54	24.2
	Fish trawl	14	17	93	44450	2615	685.76	478	1028.27	11653	685	70.55	125	148.85	32747	1926	652.35	352	996.40	51.8

are significant differences in the target, total bycatch, commercial bycatch and discard catches between seasons in each trawl type, non-parametric tests that employ the ranks of the measurements instead of using the actual (raw) data, had to be applied since sample sizes were different between the seasons in each year. The two-sample Mann-Whitney test (U) (Zar, 1996), that is analogous to the two-sample t-test, was applied to spring, summer and autumn in the case of crustacean trawls and to all seasons in the case of fish trawls. For testing differences among groups where k (samples) > 2, non-parametric analyses of variance were applied by the means of the Kruskal-Wallis test (H), often known as "analysis of variance by ranks" (Zar, 1996).

Species diversity for target, bycatch and discard species was calculated in relation to bottom trawl type. Size frequency distributions of the target species of the two types of trawl, as well as of the most important bycatch species captured by fish trawls for which there is legislation concerning legal minimum landing size (LMLS), were prepared. Legal minimum landing sizes for each species are reported following the Portuguese legislation published in the D.R. (2001).

RESULTS

Observers sampled 9 different trawlers of the 27 to 37 that were licensed in the Algarve from 1999 to 2001. Six crustacean trawlers were sampled, ranging in age from 7 to 44 years (mean=19.8) with total lengths ranging from 23 to 30 m (mean=25.8 m). The mean GRT was 144.9 ton (s.d.=29.26) and mean engine power was 441.3 kw (s.d.=80.63). The three fish trawlers that were sampled were older (mean=33.67 years) and slightly larger (mean=30.7 m) than crustacean trawlers. The mean GRT was 172.1 ton (s.d.=2.22) and their engine power mean was somewhat greater, with a mean of 504.7 kw (s.d.=72.17kw).

Crustacean trawlers fished at depths from 117 to 754 m (mean= 463.3 m; s.d.=150.0). Trip duration varied from 45.8 to 94.1 hours (mean=69.5 hours; s.d.= 16.876) and tow duration ranged from 2.25 to 10.22 hours (mean=5.78 h; s.d.=1.89). Fish trawlers normally fished at depths between 100 and 290 meters, but some hauls were as shallow as 41 m (mean= 105.3 m; s.d.=43.95). Fish trawler trip duration varied from 27.5 to 49 hours (mean=43.4 h; s.d.= 7.944) and tow duration ranged from 22.2 minutes to 2.85 hours (mean=1.45 h; s.d.=0.48).

The sampling effort, the quantities caught and retained and the target and bycatch catches according to year and season are shown in Table 1. A total of 52 fishing trips were made (35 in crustacean trawlers and 17 in fish trawlers), during which 72 crustacean trawl tows and 93 fish trawl tows were sampled, which totalled 165 fishing operations. There were less crustacean trawl fishing operations, with a maximum of 3 tows per trip (mean=2.06, s.d.=0.34) and 5 to 10 tows per season (mean=8.00, s.d.=1.73), compared with fish trawls that had a maximum of 8 tows per trip (mean=5.47, s.d.=0.93) and 10 to 19 tows per season (mean=15.50, s.d.=3.83).

From the overall catch composition shown in Figure 2, it can be seen that total bycatch exceeded target catch in both types of bottom trawl, even though it is much higher in fish (80.4% in kg) than in crustacean (59.5% in kg) trawls. Crustacean trawls capture larger amounts of the target species (over 40% in kg) than fish trawls (less than 20% in kg), while quantities of both commercial bycatch and discards are quite similar in the two types of bottom trawls.

During the study period, of the 3 crustacean trawl target species, deep-water rose shrimp accounted for the largest percentage (49.2% in kg) of the target catch, followed by blue and red shrimp (30.1% in kg). Norway lobster accounted for only 20.7% of the target catch in kg (Table 2). There are 14 crustacean trawl commercial bycatch species. We consider 9 of these to be the major bycatch species as they each ac-

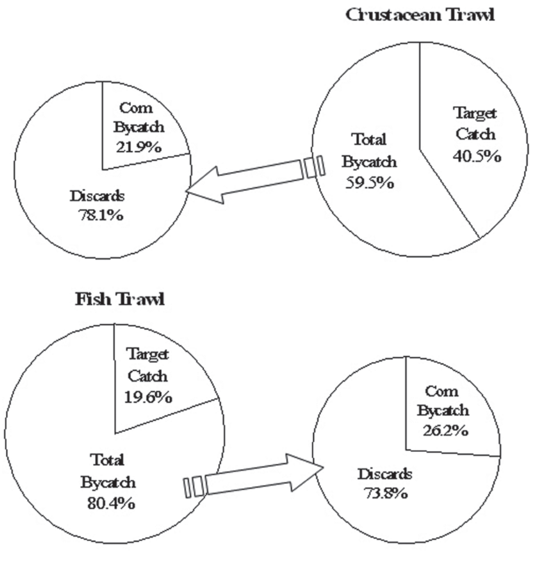

FIG. 2. – Overall catch composition of the crustacean trawl and fish trawl.

TABLE 2. – Target and commercial bycatch species caught by crustacean trawl off southern Portugal from 1999 to 2001(per tow) (s.d.=standard deviation).

Group / Species	Common name	Mean weight (kg)	(s.d.)	(%)
Target:				
Parapenaeus longirostris	Deep-water rose shrimp	60.7	57.59	49.2
Aristeus antennatus	Blue and red shrimp	37.2	32.72	30.1
Nephrops norvegicus	Norway lobster	25.5	32.13	20.7
Total				100.0
Commercial Bycatch:				
Chondrichthyes	Cartilaginous fish	14.3	13.65	21.5
Micromesistius poutassou	Blue whiting	9.7	3.21	14.5
Diverse		6.9	6.08	10.3
Lophius spp.	Angler	6.1	7.65	9.2
Merluccius merluccius	European hake	5.7	4.22	8.6
Phycis spp.	Forkbeard	4.5	2.87	6.7
Lepidopus caudatus	Silver scabbardfish	4.0	-	6.0
Conger conger	European conger	3.6	1.89	5.4
Cephalopoda	Cephalopodes	3.5	2.70	5.2
Maja squinado	Spiny spider crab	2.0	-	3.0
Trachurus spp.	Horse mackerel	2.0	-	3.0
Pagellus spp.	Seabream	2.0	1.41	3.0
Mullus spp.	Red mullet	1.8	1.66	2.6
Helicolenus dactylopterus	Blackbelly rosefish	0.8	0.35	1.1
Total				100.0

TABLE 3. – Target and commercial bycatch species caught by fish trawl off southern Portugal from 1999 to 2001(per tow) (s.d.=standard deviation).

Group / Species	Common name	Mean weight (kg)	(s.d.)	(%)
Target:				
Trachurus picturatus	Blue jack mackerel	142.5	143.96	30.2
Trachurus trachurus	Atlantic horse mackerel	132.3	96.49	28.0
Trachurus spp.	Horse mackerel	84.0	106.25	17.8
Merluccius merluccius	European hake	54.6	54.58	11.6
Pagellus spp.	Seabream	28.4	31.50	6.0
Pagellus acarne	Axillary seabream	15.0	-	3.2
Diplodus spp.	Seabream	10.3	10.94	2.2
Diplodus vulgaris	Common two-banded seabream	5.0	-	1.1
Total				100.0
Commercial Bycatch:				
Scomber japonicus	Chub mackerel	96.9	176.52	19.2
Sardina pilchardus	European pilchard	94.6	98.65	18.7
Scyliorhinus canicula	Small-spotted catshark	50.0	-	9.9
Parapenaeus longirostris	Deep-water rose shrimp	35.9	36.14	7.1
Scomber scombrus	Atlantic mackerel	34.4	38.83	6.8
Boops boops	Bogue	23.5	25.61	4.6
Chondrichthyes	Cartilaginous fish	19.7	16.75	3.9
Cephalopoda	Cephalopodes	19.2	12.02	3.8
Triglidae	Gurnard	14.8	3.02	2.9
Pagrus spp.	Seabream	14.2	5.08	2.8
Diverse		13.7	11.20	2.7
Pagrus pagrus	Common seabream	10.0	-	2.0
Sarpa salpa	Salema	10.0	-	2.0
Xiphias gladius	Swordfish	10.0	-	2.0
Octopus vulgaris	Common octopus	9.8	8.04	1.9
Spondyliosoma cantharus	Black seabream	8.4	5.03	1.7
Serranus cabrilla	Comber	8.0	-	1.6
Zeus faber	John dory	7.8	10.25	1.5
Conger conger	European conger	5.0	-	1.0
Mullus spp.	Red mullet	4.8	3.78	0.9
Pleuronectes platessa	European plaice	4.0	-	0.8
Helicolenus dactylopterus	Blackbelly rosefish	4.0	-	0.8
Solea spp.	Sole	2.0	1.41	0.4
Lophius spp.	Angler	2.0	-	0.4
Trisopterus luscus	Pouting	1.5	-	0.3
Mullus surmuletus	Stripe red mullet	1.0	-	0.2
Phycis spp.	Forkbeard	1.0	-	0.2
Total				100.0

counted for at least 5% of the bycatch (Table 2). Cartilaginous fishes accounted for the largest percentage in kg (21.5%) and blue whiting were the next most important commercial bycatch species (14.5%).

For the fish trawl, horse mackerel accounted for the highest percentage in kg (76%) of the target catch followed by European hake (11.6%) and seabreams (9.2%, for *Pagellus* spp. and 3.3% for *Diplodus* spp.) (Table 3). Fish trawl commercial bycatch species consisted of 27 species, of which 6 are considered to be the major bycatch species, as they each accounted for at least 5% of the bycatch in kg (Table 3). The most important fish trawl commercial bycatch species were chub mackerel (19.2% in kg) and European pilchard (18.8% in kg).

In crustacean trawls (Fig. 3) the target catches account, in kg, for approximately 30 to 40% in spring and autumn and 40 to 46% in summer and winter of the total catch. The target catches were largest in winter (46%) and smallest in autumn (32%). Total bycatch follows the same trends, with approximately 50% in winter and summer and 60 to 68% in spring and autumn, with a minimum of almost 54% in winter and maximum of almost 68% in autumn. The lowest values of commercial bycatch are found in autumn (7.5%) and winter (12.5%), and reach a maximum in spring (47%) but decrease to 20.9% in summer. There were more discards in crustacean trawls in autumn and winter (92.5% and 87.5% respectively) and less in summer, although discards still had relatively high values (79.1%). Only in spring did the amount of discards decrease, reaching a value of a little over 50%.

In all seasons, fish trawl total bycatch is greater than the target catch, especially in winter when it comprises almost 90% of the total catch (Fig. 4). In summer and autumn, both target catch and total bycatch are very similar, approximately 27% and 72% respectively. In spring the target catch reached its highest value (45.4%) which, in turn, decreased the total bycatch (54.6%).

Quantities of commercial bycatch (42% and 43.9%) and discards (58% and 56.1%) were quite similar in spring and autumn respectively. Discards were higher in winter (80%) and in summer (70%) and consequently lower in commercial bycatch (20% and 30.3% respectively).

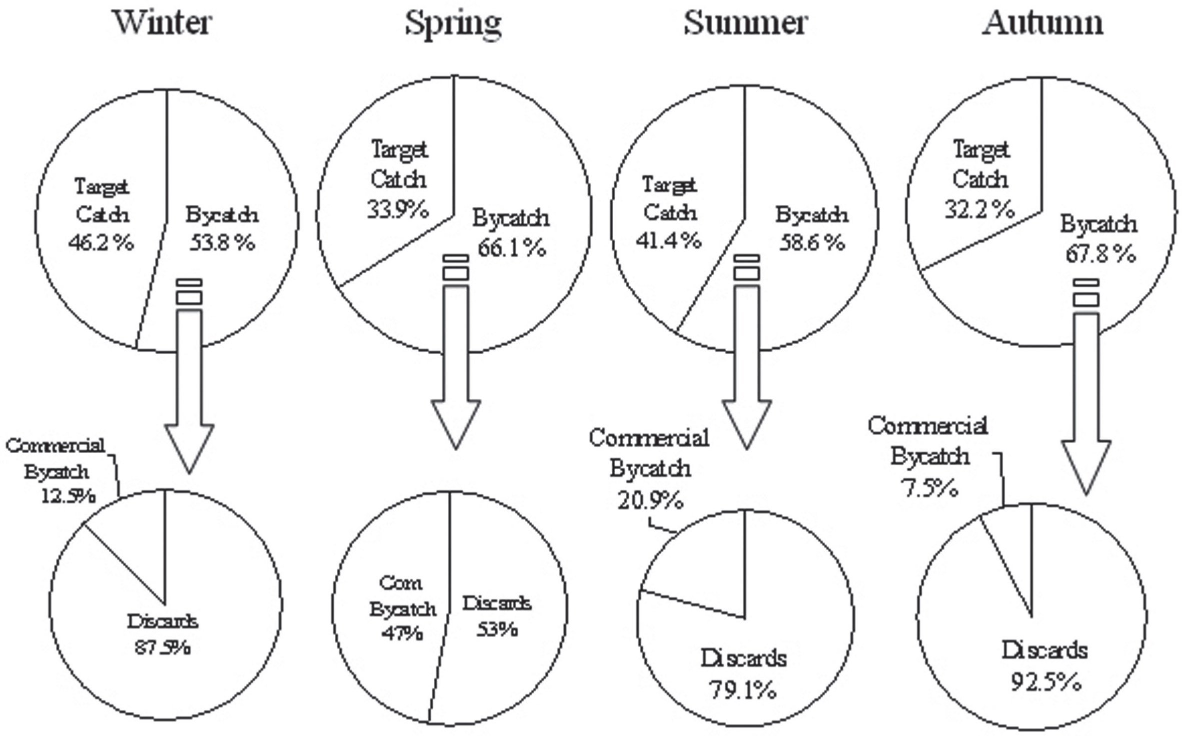

FIG. 3. – Overall catch composition of the crustacean trawl according to season.

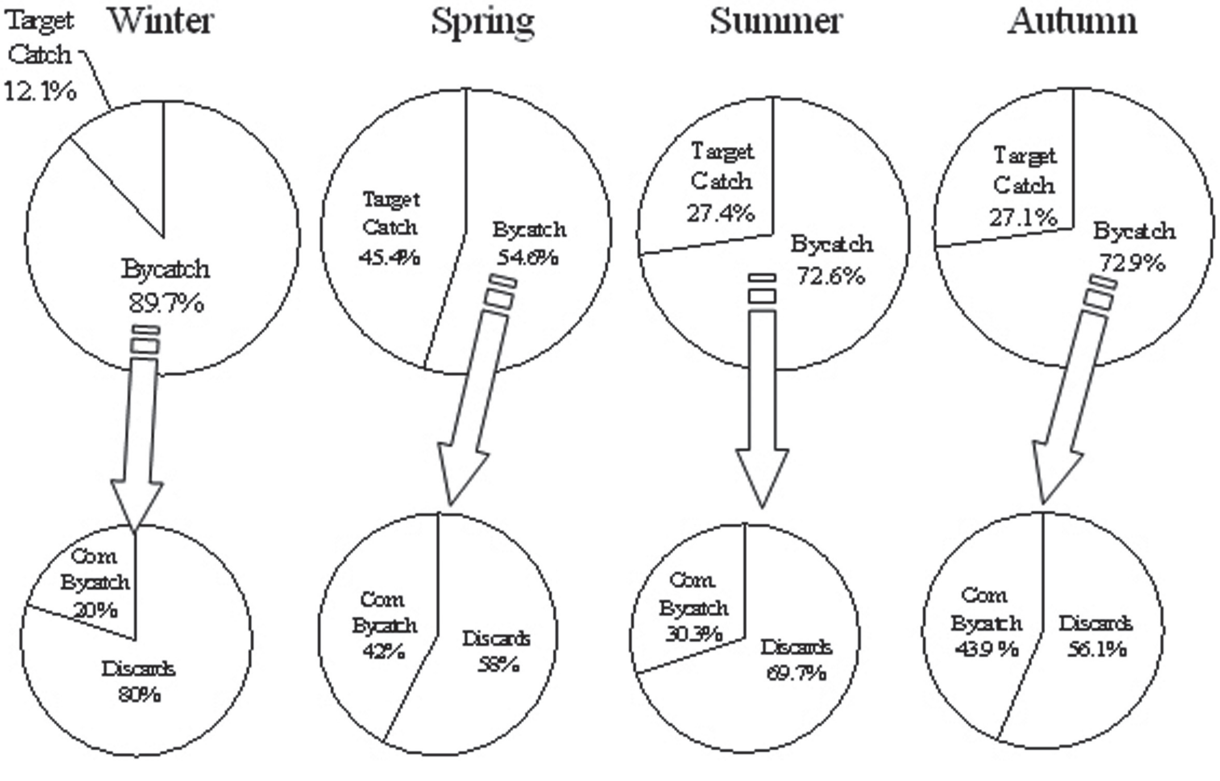

FIG. 4. – Overall catch composition of the fish trawl according to season.

Mann-Whitney tests applied to data from both types of bottom trawls showed significant differences at a significance level (α) of 0.05 only for the target catch in summer. No significant differences were found for the rest of the seasons and the rest of the catch components. The Kruskal-Wallis test ap-

TABLE 4 – Species composition, in number, of the bottom trawl catches off southern Portugal from1999 to 2001. CT, crustacean trawl; FT, fish trawl; C&FT, coincident in both trawls.

Class of organisms	Total Species				Target Species				Bycatch Species				Discarded Species			
	CT	FT	C&FT	Total	CT	FT	C&FT	Total	CT	FT	C&FT	Total	CT	FT	C&FT	Total
VERTEBRATES																
Chondrichthyes	18	7	4	21	0	0	0	0	18	7	4	21	13	4	2	15
Osteichthyes	94	65	43	116	0	6	0	6	94	59	43	110	54	23	17	60
INVERTEBRATES																
Malacostraca	33	18	15	36	3	0	0	3	30	18	15	33	28	14	9	33
Cephalopoda	17	18	13	22	0	0	0	0	17	18	13	22	9	9	6	12
Bivalvia	12	10	7	15	0	0	0	0	12	10	7	15	12	10	7	15
Gastropoda	11	15	7	19	0	0	0	0	11	15	7	19	11	15	7	19
Anthozoa	4	4	4	4	0	0	0	0	4	4	4	4	4	4	4	4
Polychaeta	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1
Ophiuroidea	2	3	2	3	0	0	0	0	2	3	2	3	2	3	2	3
Crinoidea	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1
Holothuroidea	1	2	1	2	0	0	0	0	1	2	1	2	1	2	1	2
Asteroidea	2	3	2	3	0	0	0	0	2	3	2	3	2	3	2	3
Echinoidea	5	5	4	6	0	0	0	0	5	5	4	6	5	5	4	6
ALGAE																
Chlorophyceae	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1
Phaeophyceae	4	3	2	5	0	0	0	0	4	3	2	5	4	3	2	5
Total (number)	206	156	107	255	3	6	0	9	203	150	107	246	148	98	66	180

plied to crustacean trawl catches also showed that in winter there are no significant differences in the overall catch compositions.

Of the total number of species (n=255) identified during the present study, 137 (53.7%) are fish, 36 (14.1%) are crustaceans, 56 (22%) are molluscs and 26 (10.2%) are invertebrate species from nine different taxonomic groups (Table 4). Of the total species caught, 80.8% came from crustacean trawlers and 61.2% from fish trawlers, with 42% common to both trawl types. Target species represent a small portion of the total number of species (3.5%), 3.8% and 1.5% respectively for fish and crustacean trawlers. The vast majority of the species are in fact bycatch species: 98.5% for crustacean trawlers, 96.2% for fish trawlers and 96.5% overall for the two types of trawlers. This means that only 27.1% (n=55) and 34.7% (n=52) of bycatch species captured respectively by crustacean and fish trawls have commercial value, and the rest are discarded.

Bottom trawl catches off southern Portugal appear to be very diverse (Fig. 5). Osteichthyes stands out as the dominant group of bycatch species, as it represents almost 46% and slightly less than 38% of crustacean and fish trawl catches respectively.

Size distributions of the target species caught by the two types of bottom trawlers are presented in Figures 6 to 10. Legal minimum landing sizes (LMLS) according to Portuguese legislation are rep-

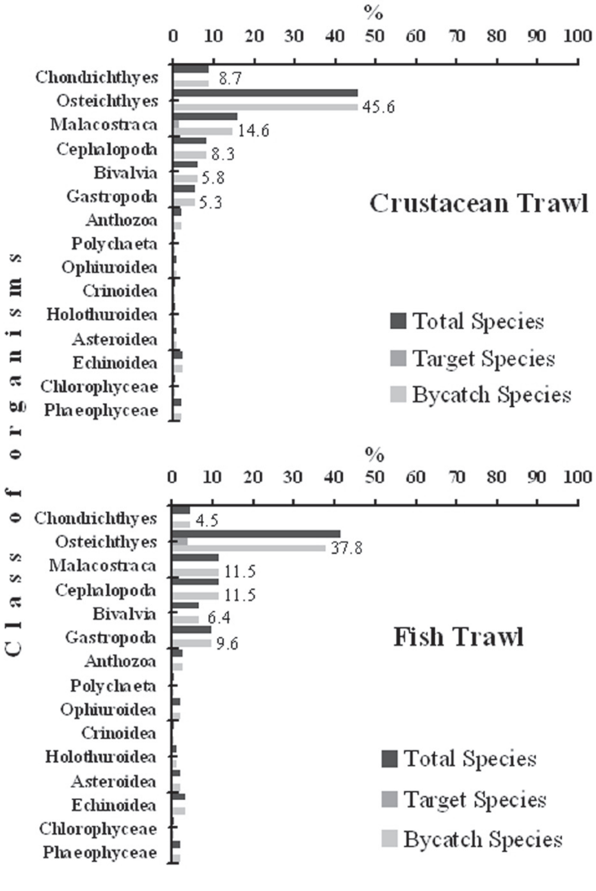

FIG. 5. – Contribution of each class of organisms to the biodiversity of the total, target and bycatch catches in the two types of trawlers. Each bar represents the percentage of the species in that class in relation to the total number of species present.

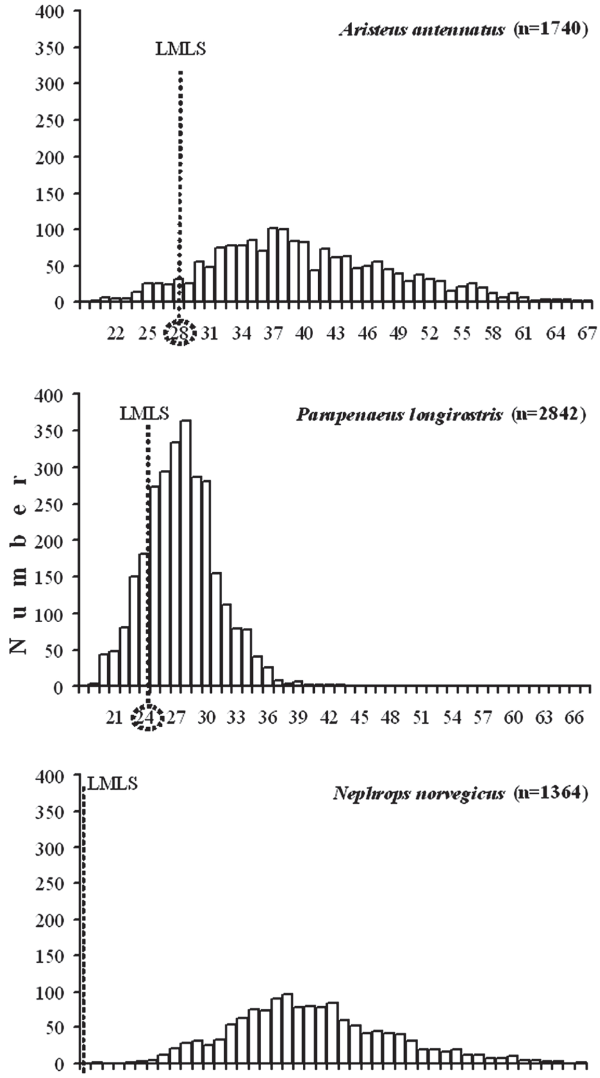

FIG. 6. – Length frequency distribution of the crustacean trawl target species (LMLS=Legal Minimum Landing Size).

resented by a dotted line and individuals under the LMLS were all discarded, mainly due to their small (illegal) size and/or their poor quality.

Size distributions of the three crustacean target species are represented in Figure 6. The majority of blue and red shrimp (92.3%) and deep-water rose shrimp (88.6%) were over the LMLS. All Norway lobster specimens sampled were greater than the LMLS legislated for this species.

Most of the horse mackerel individuals (96.8%) were above the LMLS in both types of trawl (96.4% in crustacean trawl and 96.8% in fish trawl) (Fig. 7). For European hake 68.1% and 57.7% of the individuals caught in crustacean and fish trawls respectively were smaller than the LMLS (Fig. 8). Only 40.4% were large enough to be landed.

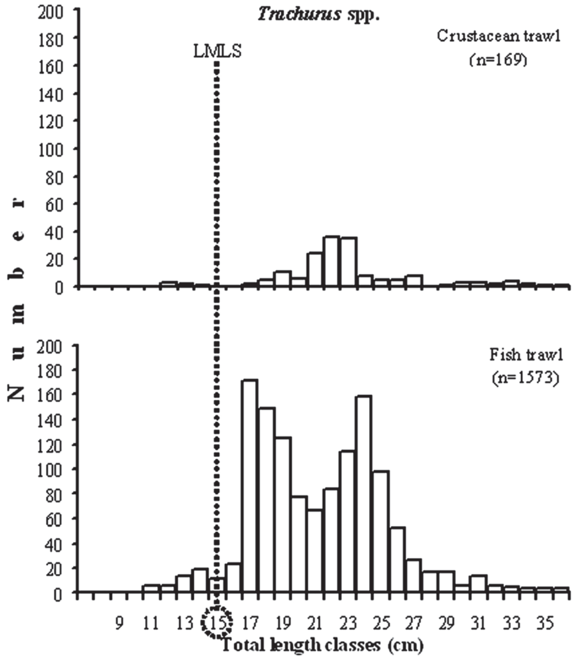

FIG. 7. – Length frequency distribution of the fish trawl target species *Trachurus* spp. (Horse mackerel) (LMLS=Legal Minimum Landing Size).

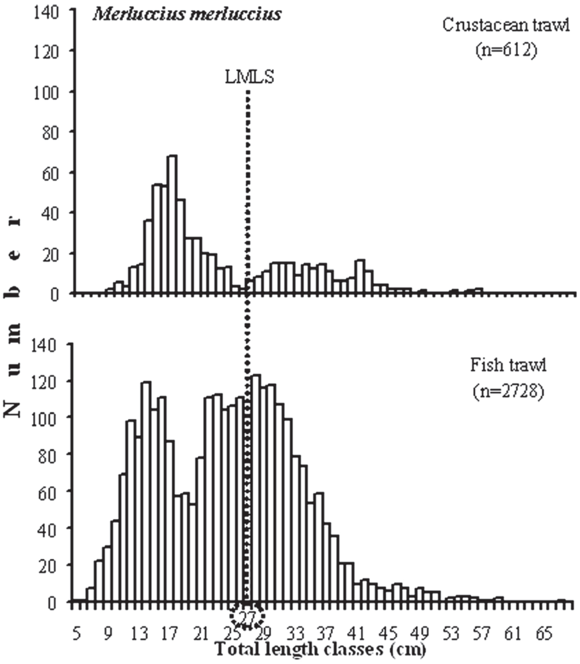

FIG. 8. – Length frequency distribution of the fish trawl target species *Merluccius merluccius* (European hake) (LMLS=Legal Minimum Landing Size).

Figure 9 shows the size composition of the seabream *Pagellus* spp., which is quite similar to that of the European hake, i.e., in the two types of bottom trawls only a few fish (19.3%) were greater than the LMLS of 18 cm (26.7% in crustacean trawls and

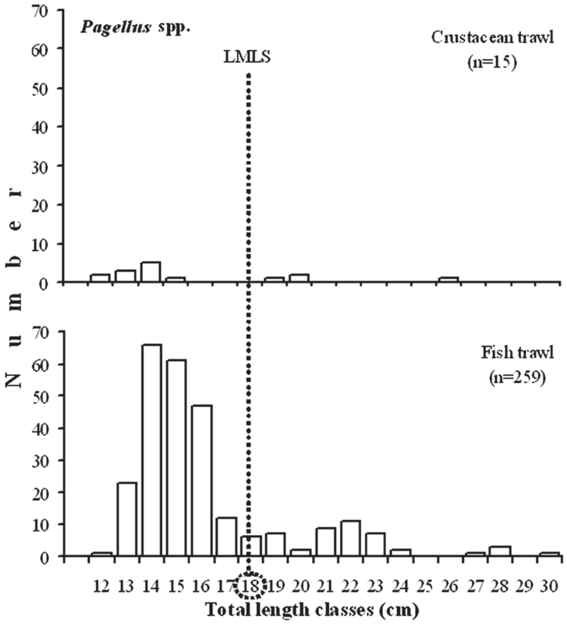

FIG. 9. – Length frequency distribution of the fish trawl target species *Pagellus* spp. (Seabream) (LMLS=Legal Minimum Landing Size).

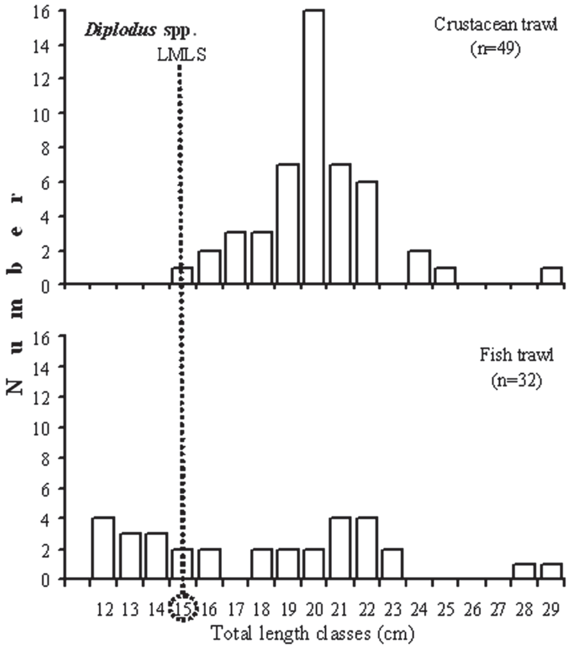

FIG. 10. – Length frequency distribution of the fish trawl target species *Diplodus* spp. (Seabream) (LMLS=Legal Minimum Landing Size).

18.9% in fish trawls) and were landed. For seabreams of the *Diplodus* genus caught both by fish and crustacean trawls the majority were of legal size, with 87.7% of the specimens greater than the LMLS.

The two most important bycatch species captured by fish trawls and for which a LMLS is applicable, are the horse mackerel species (*Scomber japonicus*

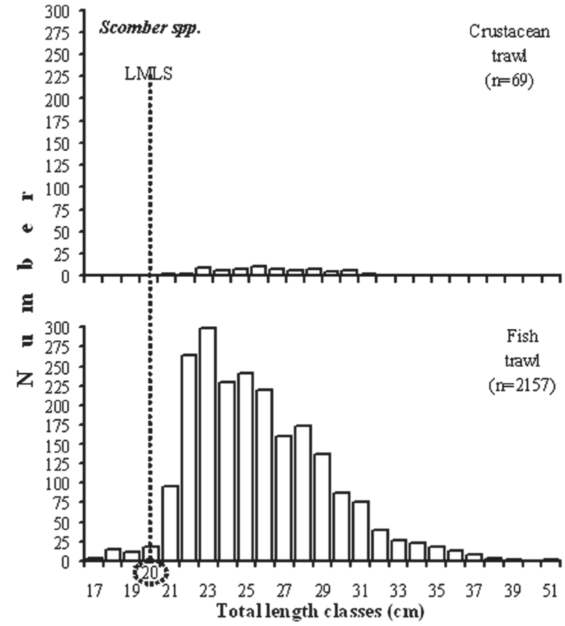

FIG. 11. – Length frequency distribution of the fish trawl target species *Scomber* spp. (Mackerel) (LMLS=Legal Minimum Landing Size).

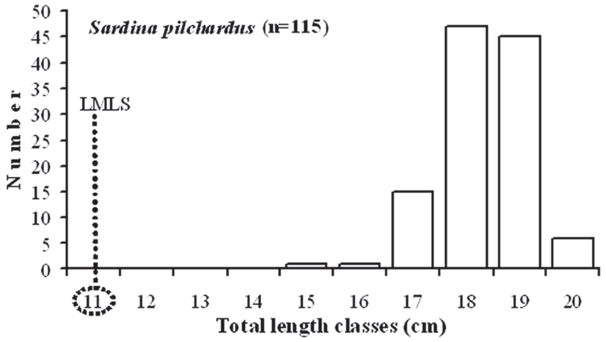

FIG. 12. – Length frequency distribution of the fish trawl target species *Sardina pilchardus* (European pilchard) (LMLS=Legal Minimum Landing Size).

and *Scomber scombrus*, grouped together as *Scomber* spp.) and the European pilchard, *Sardina pilchardus*. These species where chosen because their mean catch and mean catch rates were the highest (94.6 and 58.7 kg; 85.1 and 46.6 Kg/h respectively) of the commercialised bycatch species, and were in fact between those of the two most important fish trawl target species, the horse mackerel and European hake.

Length data and the respective LMLS for horse mackerel and European pilchard bycatch species are presented in Figures 11 and 12 respectively. Almost every horse mackerel specimen sampled (98.7%) was greater than the 20 cm LMLS. Those captured by crustacean trawls were all above the LMLS. All European pilchard specimens sampled were caught by fish trawlers and were greater than the LMLS.

DISCUSSION

Commercial bottom trawling (crustacean and fish trawls) is a very important activity in southern Portuguese waters, with approximately a third of the Portuguese trawl fleet based in the Algarve (D.R., 1999). Bottom trawling off the southern coast of Portugal generates significant amounts of bycatch, with the great majority (80.4% for fish trawlers and 60% for crustacean trawlers) of the total catch captured accidentally (total bycatch). Part of the total bycatch includes non-target species of high commercial value, but a considerable portion consists of non-marketable target species, represented by undersized or poor quality specimens, and bycatch species with low or no commercial value that are discarded at sea in relatively similar proportions in both trawl types (over 70%) (Monteiro *et al.*, 2001). The other fraction of the total catch is made up of target species, and is clearly higher in decapod crustacean trawls (40.5% compared to 20% in fish trawls).

Similar values of bycatch (about 80%) of the total catch were reported for the commercial bottom trawl fishery in the nearby western Mediterranean between 1995 and 1999 (Sartor *et al.*, 2003). The remaining fraction was also composed of target species, which represented a portion between 20% and 46% in all seasons. In contrast to our study, a significant portion of the bycatch consisted of commercial species, with higher values in summer.

Catch composition varies considerably according to a number of factors, including the nature of the fishery stock fished, the type of fishing gear used, gear selectivity, tow duration, target species and their price value, depth of capture, and the time of year (Oliver, 1993; Larson *et al.*, 1996; Merella *et al.*, 1998; Recasens *et al.*, 1998; García-Rodriguez and Esteban, 1999; Rochet *et al.*, 2002). The relatively non-selective nature of trawl nets in itself results in substantial quantities of bycatch (Monteiro *et al.*, 2001). In this study, only the summer target catches of both types of trawl differed significantly from those of the other seasons. This could be due to the fact that fishing effort was comparatively higher than during the other seasons, which leads to greater variability in the catches. Recasens *et al.* (1998) and García-Rodriguez and Esteban (1999), reported that when there are temporal variations in the catches it is important to consider the fluctuations in abundance and size range of the species studied.

Fishing trip duration is one of the most important factors influencing the proportion of the fish bycatch that is commercialised, and the quantity of bycatch landed is inversely related to trip duration (Clucas, 1997). Considering that fish trawler trip duration is significantly shorter (mean=43.4 h) than that of crustacean trawlers (mean=69.5 h), the higher values of commercial bycatch are understandable.

Sbrana *et al.* (2003) considers the variation in tow duration to be the main factor responsible for the seasonal variations in catches of the target species *A. antennatus* and *P. longirostris* in the western Mediterranean. According to Merella *et al.* (1998), tow duration is greatest when the yields are highest or when market prices reach their maximum values. This was observed for the target species *N. norvegicus* (Merella *et al.*, 1998), and for *A. antennatus* and *M. merluccius* (Oliver, 1993) for Mediterranean waters. In our study, an inverse relationship between tow duration and target species catch rates in most cases compounds the non-selectivity of the trawl nets, which leads to more bycatch being captured as well as more undersized individuals of the most valuable species. Seasonal variations in tow duration could be attributed to different species being targeted during certain periods as well as catches being made at different times.

Great diversity in bycatch species composition is a common phenomenon in trawl fisheries (Saila, 1983; Andrew and Pepperell, 1992 in Ye *et al.*, 2000; Stergiou *et al.*, 2003). This was also the case in this study, with a total of 255 species recorded, 246 (96.5%) of which contributed to the total bycatch. The differences between the two types of trawlers can be explained by the fact that crustacean trawlers exploit greater depths that are richer in terms of biodiversity. In addition, longer crustacean trawl tow duration may decrease the size selectivity of the trawl net as the catch accumulates in the codend (Murawski, 1996), thereby increasing the number of species and consequently the bycatch.

The dominant bycatch species captured by both types of trawlers, belong to the class Osteichthyes followed by molluscs (mainly cephalopods) and crustaceans. This is in agreement with the findings of Monteiro *et al.* (2001), also for Algarve coastal waters and in the Mediterranean (Sartor *et al.*, 2003).

Of the crustacean trawl target species, the largest catches are of the deep-water rose shrimp (*P. longirostris*) followed by blue and red shrimp (*A. antennatus*). The deep-water rose shrimp prefers sandy and/or muddy bottoms between 150 and 550 m, while *Aristeus antennatus* (blue and red shrimp) is more common in muddy grounds beyond 500 m and extending to 750 m (Cascalho, 1995; C.E.C., 1993b). The third target species, *Nephrops norvegicus* (Norway lobster), which has an irregular distribution between 170 and 700 m (Ribeiro-Cascalho and Arrobas, 1987; Cascalho, 1995) and is limited primarily by bottom topography and sediment type due to its burrowing behaviour (De Figueiredo and Viriato, 1992), represented only 20.7% of the target catches in the trawls that took place at an average depth of 463 m. Due to the low power of their engines, crustacean trawlers do not often fish at the depths where this species is most abundant (C.E.C. 1993b).

In the demersal fish trawl fishery, horse mackerels (*Trachurus spp.*) followed by European hake (*M. merluccius*) were the main target species with the highest mean catches (76% and 11.6% respectively). Figueiredo *et al.* (1994) also reported European hake as a commercial bycatch species in the crustacean trawl fishery, which accounted for 8.6% of the catch in mean weight. Higher values are referred to by Castriota *et al.* (2001) who found that European hake accounted for 28% for the commercial bycatch in the central Mediterranean and also by Monteiro *et al.* (2001), who reported that the European hake was the most landed bycatch species (91% of occurrence), with horse mackerel contributing only 3% to the commercial bycatch. The most important commercial bycatch species caught by fish trawls are *Scomber japonicus* and *Sardina pilchardus*. Whether these species are marketed or not depends on the total amount caught and on the prices at auction.

Other groups of organisms taken as bycatch can also have some commercial value in fish markets, as is the case of the Chondrichthyes and cephalopods. Chondrichthyes are important only as bycatch and marketable fresh only at large sizes and/or if the fish quota established for the crustacean trawlers allows them to be commercialised. In this study, this group is the dominant component of commercial bycatches in crustacean trawlers, and is composed of 18 species that represent 21.5% in mean weight, which is even greater than that of the target species *A. antennatus* (13%). In fish trawlers, it is the third most important commercial bycatch group, and represents 13.8% in mean weight (7 species caught), of which 9.9% alone is the species *Scyliorhinus canicula*. Some species of cephalopods have high commercial value while others can be commercialised but only if they are caught in significant quantities. Like cartilaginous fishes, the commercial bycatch group of cephalopods is more representative in crustacean trawlers (17 species caught and 5.2% in mean weight) than in fish trawlers (18 species caught and 3.8% in mean weight).

The existence of legal minimum landing sizes (LMLS) for most exploited species leads to proportions of both target and/or commercial bycatch species being discarded. Our results show that this is more significant for fish trawl catches. The clearest cases occur with the European hake and seabreams of the genus *Pagellus* spp. Moranta *et al.* (2000) suggests that this situation could be due, in part, to poor size selectivity in the codend for these species, with potentially important implications in terms of juvenile mortality.

In addition to the LMLS, there are other regulations for conserving fisheries and/or reducing the bycatch in Portugal. These include minimum legal mesh sizes for crustacean and fish trawl nets of 55 to 59 mm and 65 to 69 mm and/or≥70 mm respectively, minimum catch percentages of legal-sized target species of 30% for crustacean trawlers and 70% for fish trawlers, and maximum catch percentages of bycatch species of 30% for crustacean trawlers and 20% for fish trawlers. In this study, the quantities traditionally kept and distributed by fishermen for personal consumption were not taken into account, which probably justifies the higher percentages shown on some occasions.

Other alternatives for reducing bycatch of bottom trawls include research on the development and evaluation of the performance of more selective gear and fishing practices to permit juveniles to escape and to maximise the catch of target species. Research into reducing bycatch has been carried out in Portuguese waters since the 1990s. Experiments using square-mesh codend windows (Fonseca *et al.*, 1998; Campos *et al.*, 2002, 2003; Campos and Fonseca, 2004), diamond mesh codends (Campos *et al.*, 2002, 2003), separator panels (Campos and Fonseca, 2004), and modified Nordmøre grids (Fonseca *et al.*, 2005a,b) were, and still are, being carried out. These studies have demonstrated the varying effectiveness of such sorting devices in reducing the amount of bycatch(and discards) in trawl fisheries, and in allowing a high percentage of undersized specimens and non-commercial bycatch species to escape. However, the use of these devices has not been adopted by commercial fishermen due to the loss of part of the target catch and commercial bycatch species and the cost of implementing and operating such devices.

Knowing that the deep-sea fauna is quite diverse in the Algarve (Borges, 2007), and given the results of this particular study, it can be concluded that bycatch has important economic and ecological implications in this region. Removal of bycatch species by trawling can have a significant impact on marine trophic chains through predator-prey relationships and consequently on the whole ecosystem. This may be one of the reasons for the decrease in target species as well as overfishing.

Considering that both identification and quantification of bycatches are valuable pre-requisites for understanding the lesser known impacts of fishing and solving the problems, more attention should be paid to the bycatch issue in southern Portuguese waters. Efforts should be made to obtain information on the variables that influence the spatial and temporal distribution of bycatch, as well as on the biology of the species, including distribution, growth parameters, reproduction and feeding habits. This is essential for effectively managing this problem, as well as maintaining biodiversity and ecologic stability.

This study highlights the need for new and improved measures for mitigating the bycatch problem in Portuguese trawl fisheries. Although various bycatch reducing devices (BRDs) have been tested in Portuguese waters and size selectivity of both target and bycatch species has been studied (Campos et al. 2002, 2003; Campos and Fonseca 2003, 2004; Fonseca et al., 1998, 2005a,b), there has been little progress in terms of practical applications in the fishery. Indeed, as emphasised by Rawson (1997), the management of fisheries bycatch should consider all approaches for finding solutions that stabilise fish populations and the ecosystem consequences, while taking into account the human requirements for the marine resources.

ACKNOWLEDGEMENTS

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Reproductive biology of the blackmouth catshark, *Galeus melastomus* (Chondrichthyes: Scyliorhinidae) off the south coast of Portugal

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The reproductive biology of 1045 female (9.5–67 cm (total length (TL)) and 1007 male (9.4–64.3 cm TL) blackmouth catsharks, *Galeus melastomus*, was investigated. The sharks were caught off southern Portugal by bottom crustacean trawlers at depths from 209 to 754 m. The sex ratio was 1:1, and this species is sexually dimorphic with males approaching maturity at smaller size than females. Sexual segregation appears to be given for the stock within the study area. Sexual maturity was reached at a total length above 49 cm in males and above 56 cm in females. Mating and egg-deposition take place all year round, with two reproductive peaks of activity, in winter and summer. Egg capsules are, on average, 54 mm long and 21 mm wide, with a maximum of 63×25 mm encountered. Morphometric measurements of claspers, testes, ovaries, and oviducal glands were suitable for determining sexual maturity of blackmouth catshark.

INTRODUCTION

The blackmouth catshark, *Galeus melastomus* Rafinesque, 1810, belongs to the family Scyliorhinidae and is a common deepwater bottom-dwelling shark, not listed in the International Union for the Conservation of Nature and Natural Resources Red list (http://www.fishbase.org; http://www.redlist.org; ICN, 1993). It is found on the continental slope at 200–1200 m (mainly between 200 and 500 m), but occasionally at depths of 55 to 200 m also on the outer shelf. It is distributed in most parts of the north-eastern Atlantic Ocean, northward to the Faeroes and Trondheim (Norway), from the British Isles and Ireland southward to Senegal, in Madeira and Canaries archipelagos and is present throughout the Mediterranean (Cadenat & Blache, 1981; Compagno, 1984b; Quéro, 1984; Sanches, 1986; Pivnička & Černý, 1990; Steel, 1992; Moreno, 1995; Mojetta, 1997; Bannister, 1998; Muus & Nielsen, 1998; http://www.fishbase.org; http://shark-gallery.netfirms.com). This small catshark feeds on bottom-living and midwater invertebrates (cephalopods, crustaceans, gastropods), benthic and also small pelagic bonyfish (e.g. lanternfish) and, occasionally, on other small elasmobranchs. Its mode of reproduction is oviparity, with litters of up to 13–14 depending on the number of eggs present in the oviduct of a female at one time, and with tendril-lacking egg cases measuring 60×30 cm, or smaller in the Mediterranean population (Cadenat & Blache, 1981; Compagno, 1984b; Quéro, 1984; Steel, 1992; Moreno, 1995; Mojetta, 1997; Muus & Nielsen, 1998; http://www.fishbase.org; http://shark-gallery.netfirms.com). Deposition of egg capsules attains a maximum during the hydrologic warm season. In the Mediterranean, egg-deposition occurs throughout the year, with a peak of activity in the spring and the summer (Cadenat & Blache, 1981; Quéro, 1984; Tursi et al., 1993; Moreno, 1995; http://www.fishbase.org; http://shark-gallery. netfirms.com).

The blackmouth catshark is a species of limited interest to fisheries, although in some parts of its distribution it is caught as trawl by-catch at bathyal depths. In the eastern North Atlantic this species is caught in bottom trawls and utilized fresh and dried–salted for human consumption, and for leather (Compagno, 1984b; Quéro, 1984; Tursi et al., 1993; Moreno, 1995; http://www.fishbase.org). According to Tursi et al. (1993), *G. melastomus* abundances and biomasses make this species particularly important to the marine ecosystem.

Galeus melastomus is a very common species off Portugal at depths of 400–800 m, being especially abundant in the Alentejo and Algarve regions (Figueiredo et al., 1995; Moura, 1995; Figueiredo & Correia, 1996) and around Madeira Island, where it is caught mainly between 150 and 500 m depth (Sanches, 1986). In Portugal, the blackmouth catshark is included in the official landing statistics even though only the largest individuals are marketable. There is no minimum legal size set for fisheries (Figueiredo et al., 1994; Moura, 1995).

Like other deepwater shark species, the blackmouth catshark is strongly affected by trawling, being caught as by-catch and largely discarded. The limited fisheries management measures in place do not take into consideration this unaccounted mortality. Regarding this aspect and also because knowledge of the biology of this species is limited in general, with no information regarding sexual maturity in Portuguese waters, this study aims to contribute to the conservation and management of the blackmouth catshark by providing information on its reproductive biology.

Table 1. *Summary data for* Galeus melastomus *examined in each season.*

Season	Trips (N)	Tows (N)	Sex	N	TL range (cm) Range	TL range (cm) Mean	TL range (cm) SD	Tow depth range (m) Min.	Tow depth range (m) Mean	Tow depth range (m) Max.
Winter	7	12	♀	148	13.6–63.5	30.9	15.969	300	567	680
			♂	144	12.0–64.3	26.6	13.009	300	584	680
			♀+♂	292	12.0–64.3	28.8	14.723	300	575	680
Spring	8	15	♀	400	11.2–62.2	19.2	6.365	405	558	754
			♂	353	10.8–59.2	19.3	5.313	350	553	754
			♀+♂	753	10.8–62.2	19.3	5.891		350	555
Summer	8	16	♀	374	9.5–67.0	22.9	10.408	430	587	750
			♂	393	9.4–59.5	22.0	8.719	430	585	750
			♀+♂	767	9.4–67.0	22.5	9.584	430	586	750
Autumn	2	2	♀	123	15.7–59.8	27.4	7.245	610	622	635
			♂	117	15.2–49.5	28.6	7.111	209	618	635
			♀+♂	240	15.2–59.8	28.0	7.191	209	620	635
Total	25	45	♀	1045	9.5–67.0	23.2	10.623	300	577	754
			♂	1007	9.4–64.3	22.5	8.928	209	578	754
			♀+♂	2052	9.4–67.0	22.8	9.831	209	577	754

N, number; Min., minimum; Max., maximum; SD, standard deviation.

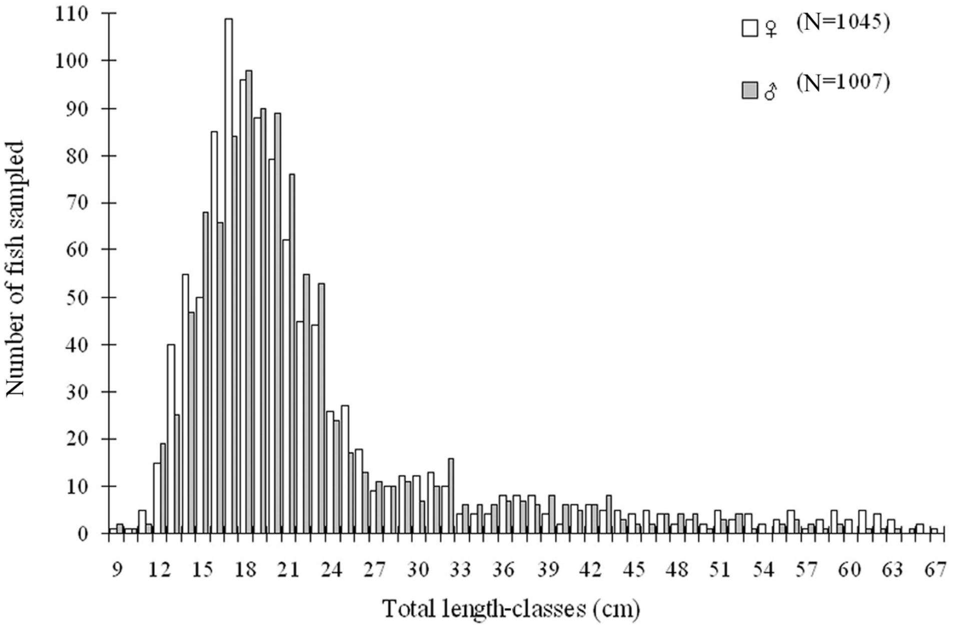

Figure 1. Length distributions of *Galeus melastomus*.

MATERIALS AND METHODS

Sampling

The specimens for this study were collected aboard commercial crustacean bottom trawlers (mesh size of 55 to 65 mm) targeting red shrimp (*Aristeus antennatus*), deep-water pink shrimp (*Parapenaeus longirostris*) and Norway lobster (*Nephrops norvegicus*). Sampling operations were conducted, on a seasonal basis, between February 1999 and March 2001 off the south coast of Portugal (Algarve), during two scientific projects on discards. Blackmouth catshark was captured between 36°41′N–36°56′N and 7°24′W–9°02′W and at depths of 209 to 754 m. Subsamples of the *Galeus melastomus* catch were taken randomly by scientific observers in most cases, but the whole catch was sampled on some occasions.

Measurements

Specimens were taken to the laboratory where they were frozen whole for later study and processed after thawing. Identification was confirmed based on Compagno (1984b), Quéro (1984) and Cadenat & Blache (1981). The following was recorded for each individual:

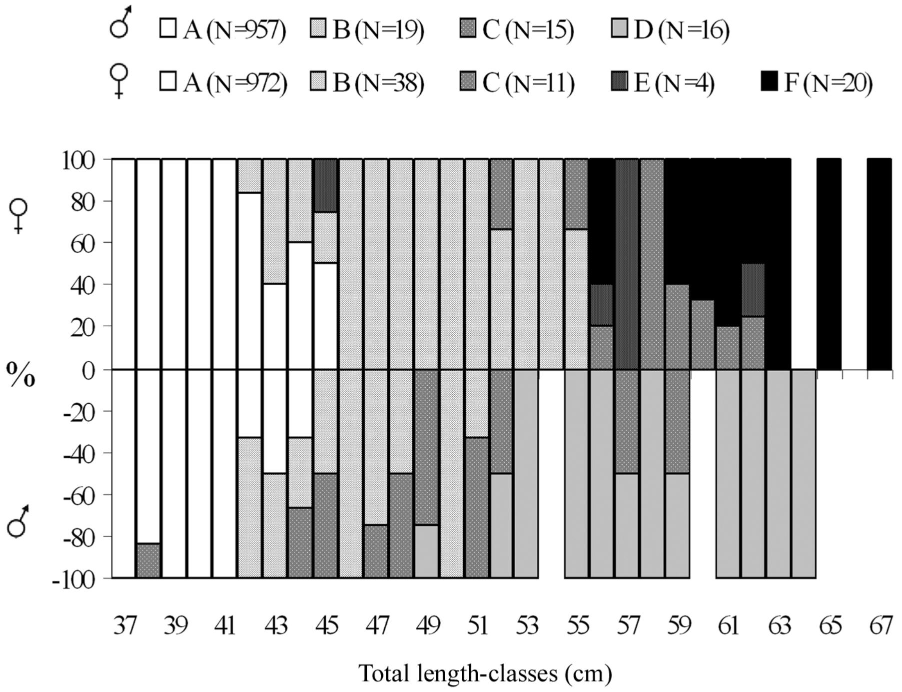

Figure 2. Frequency distributions of *Galeus melastomus* by sex and maturity stages. Specimens between 9 and 36 cm total length (TL) are not represented because they were all immature.

Table 2. *Internal reproductive organ measurements of* Galeus melastomus *males in each maturity stage.*

	A			B		
Characteristic	Range	Mean	SD	Range	Mean	SD
Inner clasper length (mm)—Right	1.0–29.0 (728)	9.52	5.21	26.0–51.0 (20)	35.98	8.60
Inner clasper length (mm)—Left	1.0–29.0 (728)	9.49	5.18	26.0–51.0 (20)	35.80	8.41
Outer clasper length (mm)—Right	1.0–30.0 (728)	4.65	2.82	13.0–33.0 (20)	20.40	7.38
Outer clasper length (mm)—Left	1.0–30.0 (728)	4.64	2.81	13.0–33.0 (20)	20.40	7.37
Length of testicle (mm)—Right	7.48–61.35 (567)	19.09	9.36	38.77–78.08 (20)	56.73	13.23
Length of testicle (mm)—Left	7.29–52.22 (567)	16.53	7.24	32.75–80.80 (20)	46.68	10.88
Width of testicle (mm)—Right	0.40–6.26 (568)	1.61	1.04	4.37–11.31 (20)	7.57	2.17
Width of testicle (mm)—Left	0.09–5.63 (568)	1.45	0.93	4.32–9.96 (29)	7.21	1.84
Weight of testicle (g)—Right	0.01–0.19 (569)	0.02	0.03	0.14–0.89 (20)	0.47	0.27
Weight of testicle (g)–Left	0.01–0.15 (569)	0.02	0.02	0.12–0.83 (20)	0.40	0.25
Total length of specimens (cm)	9.4–44.0 (730)	21.95	6.59	42.0–51.8 (20)	45.66	2.78
	C			D		
	Range	Mean	SD	Range	Mean	SD
Inner clasper length (mm)—Right	43.3–81.0 (14)	58.44	11.99	65.0–90.0 (16)	76.52	7.29
Inner clasper length (mm)—Left	42.7–81.0 (14)	52.83	16.54	65.0–90.0 (16)	76.58	7.73
Outer clasper length (mm)—Right	27.0–57.0 (14)	38.71	9.58	45.0–67.0 (16)	56.03	7.42
Outer clasper length (mm)—Left	27.0–57.0 (14)	38.34	9.44	43.2–67.0 (16)	55.63	7.69
Length of testicle (mm)—Right	47.1–91.77 (14)	70.46	15.94	59.35–103.86 (16)	74.11	12.39
Length of testicle (mm)—Left	41.8–69.48 (14)	59.09	7.64	32.1–81.54 (16)	67.78	11.66
Width of testicle (mm)—Right	6.96–14.97 (14)	11.21	2.17	10.31–20.22 (16)	14.54	2.83
Width of testicle (mm)—Left	7.13–15.79 (14)	10.69	2.33	10.21–19.86 (16)	14.12	2.96
Weight of testicle (g)—Right	0.57–2.72 (14)	1.42	0.69	0.99–4.46 (16)	2.69	1.03
Weight of testicle (g)—Left	0.56–2.69 (14)	1.29	0.67	1.16–4.14 (16)	2.57	0.90
Total length of specimens (cm)	38.8–59.2 (14)	49.96	5.03	49.2–64.3 (16)	57.23	4.32

N, number of specimens; SD, standard deviation.

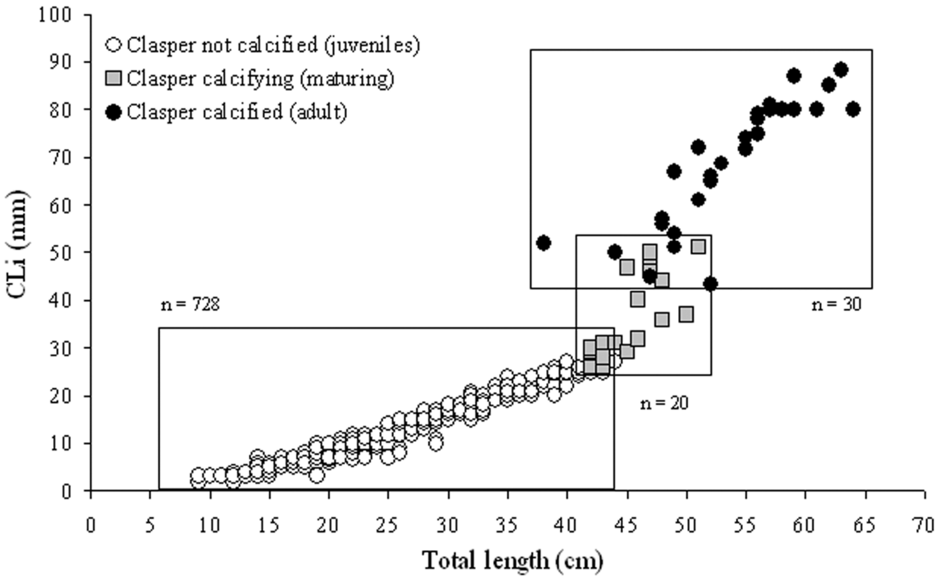

Figure 3. Relationship between total length and inner (left) claspers length (CLi) for males of *Galeus melastomus* across stages of maturity.

total length (TL), to the lowest 0.1 cm; total weight (TW), gonad (left and right testes for males and right ovary for females) weight (GW) and eviscerated weight (EW), to an accuracy of 0.01 g; sex and maturity stage were ascertained macroscopically. The EW was recorded because it is recommended for study of certain aspects of reproduction (Mellinger, 1996 in Peres & Vooren, 1991).

Total length (TL), used throughout this paper, is defined as the length, on a horizontal line, from the snout tip to the posterior tip of the caudal fin, depressed along the anterior–posterior axis of the fish (Compagno, 1984a).

For males, clasper lengths (inner, CLi and outer, CLo) of both left and right claspers and length, width and weight of both left and right testicles were recorded. Inner clasper length was measured from the point of insertion at the cloaca to the distal tip of the clasper and CLo was measured from the point of outside insertion at the pelvic fin to the tip of the clasper (Compagno, 1984a). For females, the following data were collected: maximum length and width of oviducal (nidamental or shell) gland, maximum length and width and total weight of ovary and maximum width of uterus. Reproductive organs were measured to the nearest 0.01 mm using Vernier callipers weighed to the nearest 0.01 g and were recorded in order to examine changes in these structures during the maturation process.

Assessing maturity

Sexual maturity was determined following a scale described for all chondrichthyan species by Stehmann (2002). For males, a four-stage maturity scale (from A or 1 to D or 4) takes into account the size and flexibility or rigidity of claspers, size of testes, width and the occurrence of coiling of sperm ducts (epididymes) and absence or presence of sperm in the seminal vesicle (ampullae ductus deferens). For females, a six-stage maturity scale (from A or 1 to F or 6) is divided in two reproductive activity subcycles: the ovarian and the uterine. In the ovarian stage, size of ovaries, absence or presence and size of oocytes and width of oviducts (uterus) are determinant, while in the uterine stage, presence of large yolk-eggs in fallopian tubes and formation and rigidity of egg capsules are considered.

Sex ratio

The sex ratio (females:males) for the whole sample was analysed considering the variation of sex ratio by seasons, throughout the year. The χ^2 goodness-of-fit test (α=0.05; Zar, 1996) was used to examine the differences between observed sex ratios and the expected ratio of an equal sex ratio.

Maturity stages and egg-deposition period

Distribution of maturity stages for females and males of *G. melastomus*, was analysed according to size, and the egg-deposition period was determined by analysing the seasonal evolution of the maturity stages as percentages by sex.

Size-at-first-maturity

Size-at-first-maturity is usually determined by either analysing the growth of reproductive organs relative to size, or by fitting a maturity ogive. Reproductive organ measurements described above were used for analysing length at first maturity.

Males

One method to determine the size-at-first-maturity for male elasmobranchs is using clasper length measurements

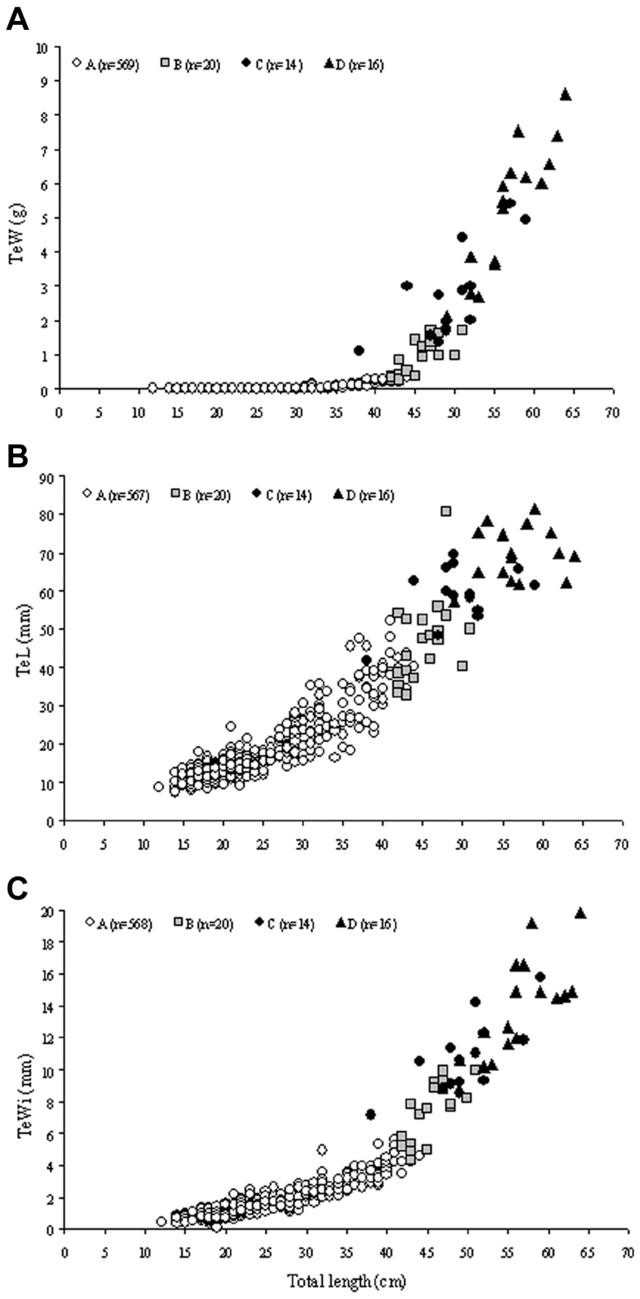

Figure 4. Relationships of total length to (A) testes weight (TeW); (B) testes length (TeL); and (C) testes width (TeWi), in *Galeus melastomus* males, according to maturity stages.

because there is a known correlation between the development of secondary sex characters and the reproductive organs, and maturity (Conrath, 2004). The length of the clasper is plotted against the total length. This usually results in a plot where maturity is indicated by a sharp increase in the slope (Pratt, 1979; Teshima, 1981; Holden & Raitt, 1974 in Natanson & Cailliet, 1986; Yano, 1993). While clasper length is most commonly used, the size or weight of other reproductive structures like the testis and siphon sac are often also used and plotted in the same manner (Teshima, 1981; Yano, 1993). In this study, the length-at-maturity in *G. melastomus* males was estimated by the relation between clasper length and total length, and also from the relations between, testis length, width and weight, and total length.

Females

In females, size of the oviducal gland or other structures of the female reproductive tract are often used to assess the size-at-first-maturity. The size or weight of the ovary, or the size of the oviducal gland, uterus, or other reproductive structures is often plotted against the length of the animal to determine if there is a size-range at which the structure in question begins to develop very quickly before getting thinner again (Yano, 1993; Castro et al., 1988; Wass, 1973 in Conrath, 2004).

As the length-range at which the adolescent part of elasmobranch population matures is determined by a change in the slope of the plot, for the purpose of establishing size at which blackmouth catshark females become mature, we used the length and width of the oviducal gland; length, width and total weight of ovary; and width of uterus vs total length plot, in a similar way to that discussed above for the males.

Size-at-first-maturity for *G. melastomus* males and females (defined as the size at which 50% of all individuals sampled are mature—L_{50}), was also determined through the fitting of maturity ogives. The specimens in Stages A/1 and B/2 were considered as 'immature' and the specimens in other stages were considered as 'mature', as suggested by Conrath (2004).

Once all individuals had been classified, we calculated the proportion of mature specimens by 1 cm size-classes. A maturity curve was determined using the logistic curve, $P_i=1/[1+e^{(a+b*TL)}]$, where P_i is the proportion of mature individuals in length class i and a and b are fitted parameters which can change during the life cycle. A logarithmic transformation was applied to the equation in order to calculate the parameters a and b by means of linear regression and L_{50}, the length at the point of the curve corresponding to 50% often used as an indicator of the size as the specimens mature, could be calculated as $L_{50}=(a/b)$ (Sparre & Venema, 1992).

Reproductive activity

The cyclic manifestations of the reproductive activity in marine fish concerns the evolution of the gonadosomatic indices (GSIs) as an indicator of notable weight variations (Lahaye, 1981). For each sex, the reproductive cycle of blackmouth catshark was analysed in terms of seasonal changes of the GSIs, calculated by using the weight of the gonads as a percentage of the eviscerated body weight. In each index, the means and respective standard deviations were calculated by season.

RESULTS

Length frequency distributions

Length data for *Galeus melastomus* were collected for 2052 specimens in total, captured in 25 trips (45 tows) during the study period (Table 1). The length–frequency distributions for both sexes are shown in Figure 1. Specimens ranged in size from a minimum of 9.5 cm TL (2.62 g TW) to a maximum of 67 cm TL (1013.6 g TW) for

Table 3. *Internal reproductive organ measurements of* Galeus melastomus *females in each maturity stage.*

	A			B			C		
Characteristic	Range (N)	Mean	SD	Range (N)	Mean	SD	Range (N)	Mean	SD
Length of nidamental gland (mm)				8.63–21.11 (21)	13.63	2.86	17.7–31.43 (10)	24.53	4.73
Width of nidamental gland (mm)				3.67–12.24 (21)	6.24	2.66	11.13–19.89 (10)	15.92	2.74
Length of ovary (mm)	6.22–97.08 (612)	26.29	16.50	55.53–108.47 (36)	87.06	10.43	77.10–120.92 (11)	105.49	12.89
Width of ovary (mm)	0.50–13.74 (612)	4.26	2.65	5.73–20.90 (36)	13.56	2.87	15.11–46.76 (11)	30.52	10.51
Weight of ovary (g)	0.01–0.80 (612)	0.04	0.08	0.09–1.68 (36)	0.77	0.32	1.03–27.72 (11)	10.13	8.36
Width of uteri (mm)				2.24–14.30 (22)	5.54	3.26	7.71–19.37 (11)	13.62	3.11
Total length of specimens (cm)	12.7–47.8 (614)	22.87	6.82	43.6–55.1 (36)	49.52	3.57	52.7–62.2 (11)	58.42	2.66

	E			F		
	Range (N)	Mean	SD	Range (N)	Mean	SD
Length of nidamental gland (mm)	21.82–31.15 (4)	25.14	4.33	24.34–35.43 (17)	28.45	2.96
Width of nidamental gland (mm)	12.76–20.06 (4)	17.46	3.28	16.58–25.92 (17)	19.97	2.38
Length of ovary (mm)	73.55–128.74 (4)	101.87	22.60	88.16–155.85 (20)	121.56	19.47
Width of ovary (mm)	26.41–43.81 (4)	37.70	7.96	34.25–59.83 (20)	43.21	6.72
Weight of ovary (g)	9.72–19.5 (4)	13.94	4.17	14.98–45.57 (20)	23.60	8.35
Width of uteri (mm)	14.05–26.02 (4)	19.21	5.24	22.55–28.26 (7)	25.28	2.18
Total length of specimens (cm)	45.5–62.0 (4)	55.23	6.95	56–67.0 (20)	61.42	2.97

N, number of specimens; SD, standard deviation.

females and 9.4 cm TL (1.99 g TW) to 64.3 cm TL (733.2 g TW) for males. Average TL for females is slightly larger (23.2 cm) than for males (22.5 cm). The most frequent sizes, for both sexes, were from 12 to 32 cm TL representing about 87% of the sharks examined.

Sex ratio

Of the total specimens examined, 1045 (51%) were females and 1007 (49%) were males. The overall ratio of females to males was 1.04:1 and χ^2 goodness-of-fit tests showed no significant differences ($\chi^2=0.7$, $P>0.05$) in the proportion of sexes for the whole period analysed. The same result was obtained for the each of the four seasons for both sexes.

Maturity stages and egg-deposition period

The distributions of maturity stages of *G. melastomus* females and males, according to size, are shown in Figure 2. The smallest immature (Stage A) specimens were 9 cm TL, with males reaching 44 cm TL and females 45 cm TL, and representing 95 and 93% of the total, respectively. Both males and females start maturing (Stage B) at 42 cm with females of this stage being larger (55 cm TL) than males (51 cm TL). Males attained maturity (Stage C) sooner (44 cm TL) than females (52 cm TL), reaching a maximum at 59 cm and 62 cm TL, respectively. Males began to become active (Stage D) above 49 cm TL, and no active males were found (Stage D) above 64 cm TL. No active females were found but those that reached the advanced stage (Stage E) attained a size-range from 56 to 62 cm TL, with the exception of one specimen of 45 cm TL. Females start to appear in the extruding phase (Stage F) with sizes above 56 cm to a maximum of 67 cm TL.

Egg-deposition period could be inferred by analysing the seasonal evolution of the percentages of maturity stages (i.e. mature specimens) of *G. melastomus*. Mature males (Stages C and D) are present all year round, occurring most frequently in summer (17.6%) and winter (70.6%), when four active males (Stage D) showed copulating signals, such as opened claspers frequently with sperm. The same seems to happen with mature (Stages C to F) females although less frequently (10.5%) in summer and with much higher percentages (79%) in winter. Throughout the reproductive period, mature and immature (A) stages occurred simultaneously, the latter showing a decrease towards winter. In fact, the smallest individuals (9–12 cm TL) were caught almost exclusively in spring and summer. Females attain first sexual maturity in spring, and neither maturing males nor extruding females appeared in spring.

Size at maturity

Male

The internal reproductive organs' measurements taken of *G. melastomus* males are given in Table 2. The inner clasper length of the left clasper ranged from 1 to 29 mm for juvenile specimens with non-calcified claspers, from 26 to 51 mm for maturing specimens with calcifying claspers and from 42.7 to 90 mm (mean=67.8, SD=13.52, N=30)

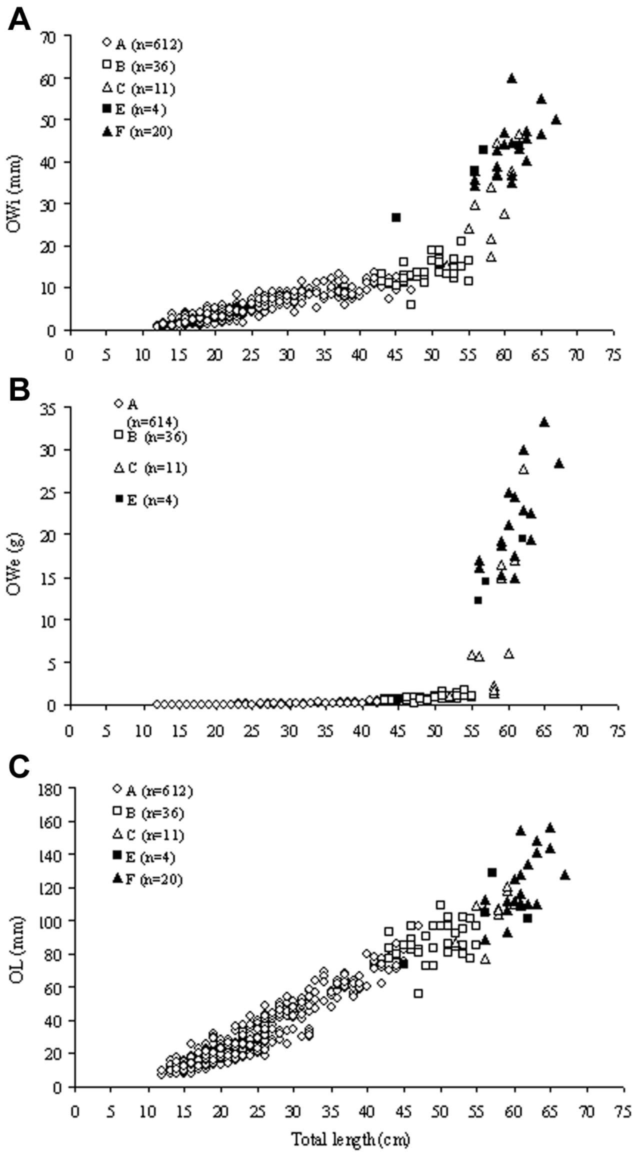

Figure 5. Relationship between total length and (A) ovary width (OWi); (B) ovary weight (OWe); and (C) ovary length (OL), in *Galeus melastomus* females, across stages of maturity.

for adult (Stages C and D) specimens with calcified claspers.

Globally, clasper length (CL) increased with total length and, according to the calcification of the clasper, three groups can be noted (Figure 3). In *G. melastomus*, 778 specimens were analysed and the size of claspers ranged from 1 to 90 mm (mean=12.33, SD=13.00). The first group of CL range corresponds to immature males (93.6%), ranging in size from 9.4 to 44.0 cm TL, with small, non-calcified claspers, of less than 29 mm length. The second range of clasper size corresponds to maturing males (2.6%), ranging in size from 42.0–51.8 cm TL, with claspers attaining larger sizes (26 to 51 mm) and already calcifying, while the third is composed of mature and active males (3.9%) ranging in size from 38.8–64.3 cm TL, with completely developed sexual organs, including fully calcified and rigid claspers (42.7 to 90 mm). When claspers of 42.7 to 54 mm, 58.3% of males are mature and about 83.3% of the male specimens had claspers that were 42.7 to 90 mm long. A noticeable increase in clasper length occurs when specimens attain 49 cm TL, which indicates that male maturation has begun. At this size, claspers are longer than 54 mm and all of the specimens are mature. Following this rapid growth, the claspers continue to grow but at a slower rate.

Like clasper length, left testis weight, length and width also increased with total body length with onset of maturity. With testes weight ranging from 1.13 g (38 cm TL) to 1.97 g (49 cm TL), 46.2% of males are mature. From 49 cm TL onward, testes weight starts to increase and there is a marked further increase (2.04–3.87 g) from 52 cm TL onward, when all of the specimens are mature. Following this rapid growth, the claspers continue to grow at an even higher rate (Figure 4A).

Length of the left testes (Table 2) does not increase with total length as do the other two testes measurements and the data are more disperse (Figure 4B). Even so, testes increased in size more rapidly at a length above 48 cm TL, oscillating between 59.73 to 81.54 mm in length, above which all specimens are mature. As for all other testes measurements, all males greater than 52 cm were mature (Figure 4B).

Testes also started to grow in width rapidly at a total length of 48 cm (11.35 mm) to 51 cm TL (14.23 mm). For testes width ranging from 7.13 mm (38 cm TL) to 10.54 mm (44 cm TL), 36.8% of males are mature, and above 11.35 mm (48 cm TL), all males are mature. No immature or maturing adolescent males less than 52 cm TL were found (Figure 4C).

As clasper length and left testis measurements showed rapid increases with the increment in total length, relationships between clasper length and each of the testis measurements were pooled and plotted against total length, but in this case not considering maturity stages. As expected, the relationship between the clasper length and the total length is very similar to that between the testes weight (TeW), length (TeL) and width (TeWi). An increase in both clasper and testis occurs at approximately 44 cm TL and this may indicate that male *G. melastomus* reaches maturity about this size.

Size-at-first-maturity (L_{50}) for *G. melastomus* males was determined from 31 mature specimens and was estimated to be 49.37 cm TL. The logistic curve was:

$$P_i = 1/[1 + e^{(7.6374+0.1547*TL)}]. \qquad (1)$$

Female

The internal reproductive organ measurements taken on ovaries of *G. melastomus* females are given in Table 3. Ovary width ranged from 0.5 to 13.74 mm for immature (Stage A), from 5.73 to 20.9 mm for maturing (Stage B), and from 15.11 to 59.83 mm (mean=38.59, SD=9.85, N=35) for mature (Stages C, E, F) specimens. Ovary weight ranged from 0.01 to 0.80 g for immature, from 0.09 to 1.68 mm for maturing, and from 1.03 to 45.57 mm (mean=18.26, SD=10.07, N=35) for mature specimens. Ovary length varied from 6.22 to 97.08 mm for immature, from 55.53 to 108.47 mm for maturing and from 77.10 to

Table 4. *Comparison of maximum total length (TL), size at first maturity by sex of* Galeus melastomus *for various geographical subareas.*

		Maximum TL (cm)		Size at maturity	
Author	Maritime sector	♂	♀	♂	♀
Joensen & Taning (1970) in Cadenat & Blache (1981)	Faeroe Archipelago			70–79	
Capapé (1974) in Cadenat & Blache (1981)	Tunisian coasts (Mediterranean)		63	50–70	
Capapé & Zaouali (1977)	Tunisian waters (Mediterranean)	42	47	>42	39–42
Cadenat & Blache (1981)	Mediterranean and Atlantic (occidental coast of Africa)	40 (mean)			
Capapé & Brahim (1984)	Tunisian waters (Mediterranean)	62	66		
Compagno (1984b)	Eastern North Atlantic and Mediterranean	61	90	33–42	38–45
Quéro (1984)	Eastern North Atlantic and Mediterranean	61	90	34–42	39–45
Sanches (1986)	Portuguese coast and Madeira Island	90			
Tursi et al. (1993)	Ionian Sea (Mediterranean)	51	55	45	49
Pivnička & Černý (1990)	European coasts	70			
Figueiredo et al. (1995)	Portuguese south and southern west coasts	80			
Moreno (1995)	Iberian waters, north-eastern Atlantic and Mediterranean	60–70		40	40
Mojetta (1997)	Eastern Atlantic and Mediterranean	90			
Bannister (1998)	Eastern Atlantic	100			
Muus & Nielsen (1998)	Eastern Atlantic and Mediterranean	60	90		
Our data	Portuguese south coast	64	67	49	56–59

155.85 mm (mean=114.26, SD=19.50, N=35) for mature specimens.

In general, width, weight and length of right ovary of *G. melastomus* females also increased with total body length with onset of maturity, as was also the case for males (Figure 5). With an ovary width (OWi) from 15.11 mm (52 cm TL) to 24.15 mm (55 cm TL), only 30.8% of females are mature (Figure 5A). Ovary width in relation to total length increased rapidly from a TL of about 56 cm onward, above which all specimens are mature, varying from a minimum of 27.79 mm to a maximum of 59.83 mm width. Following this rapid growth, the ovary continues to grow in width but at a slower rate. Exceptionally, one female of 45 cm TL was in the advanced stage of maturity, with an ovary width of 26.41 mm. The relationship between total length and ovary weight (OWe) also demonstrates that ovaries started to get noticeably heavier from a total length of 56 cm onward, above which all specimens are mature, varying from 5.74 to 33.28 g (Figure 5B). Following this growth, the ovary continues to grow in weight at an even higher rate. Female specimens from 12 to 55 cm TL were all immature and maturing, with the exception of one mature (Stage C) female of 52 cm TL (OWe=1.03 g) and another one in an advanced stage (E) at 45 cm TL (OWe=0.72 g). Concerning the ovary length (OL), an increase with total length is not as evident as for the other two ovary measurements, with data that are more disperse (Figure 5C). Even so, ovaries seemed to start to grow more rapidly at 59 cm TL, continuing to increase in size with higher total lengths. With ovary lengths ranging from 73.55 mm (45 cm TL) to 108.47 mm (50 cm TL), few females are mature (28.3%) and, similar to other two ovary measurements, females above 56 cm TL are all mature.

Nevertheless, relationships between total length and width and length of oviducal gland and total length and uterus width were explored in order to see if there is an increase in these organ measurements with total body length, with onset of maturity. Both oviducal gland width (OgWi) and length (OgL) in relation to total length, increased rapidly at a TL from about 56 cm onward, above which all specimens are mature. For mature females, OgWi varied from a minimum of 11.88 mm to a maximum of 25.92 mm, and OgL ranged from 17.72 to 35.43 mm. Following this rapid growth, the oviducal gland continues to grow in width but rather gradually, while it seems to continue growing in length but even less gradually. Also, in both kinds of measurements of the oviducal gland, females less than 55 cm are not mature, with the exception of one mature female (Stage C) of 52 cm TL (OgWi=11.13 mm, OgL=17.7 mm) and outstandingly, one female in the advanced stage of maturity (Stage E), measuring 45 cm TL, had a smaller oviducal gland, of 12.76 mm in width and of 21.82 mm in length, being more similar to females in the maturing (B) stage.

Width of uterus (UWi) follows exactly the same pattern as oviducal gland. A rapid increase appears when females attain 56 cm TL, with all females above this size being mature. Nonetheless, after this increment uterus width only grows 2.24 mm more, attaining a maximum of 28.26 mm at 62 cm TL. The rest of the mature females have uteri that range from 11.27 to 26.02 mm in width.

Egg capsules were found in 24 *G. melastomus* females, with three females in advanced stage (E) and 21 females in the extruding stage (F). No marked difference was found in the number of egg capsules between the right and left uterus. The number of egg capsules ranged from 1 to 4 in each uterus (oviducts) and of the 24 litters

Table 5. *Comparison of egg capsules dimensions of* Galeus melastomus *for various geographical subareas.*

Author	Maritime sector	Egg capsules dimension (mm)
Lo Bianco (1909) in Capapé & Zaouali (1977)	Italian seas	45×18
Le Danois (1913) in Capapé & Zaouali (1977)	Manche (eastern Atlantic)	60×30
Tortonese (1956) in Capapé & Zaouali (1977)	Italian seas	45×18
Wheeler (1969) in Capapé & Zaouali (1977)	British Isles (eastern Atlantic)	60×30
Capapé (s/d) in Capapé & Zaouali (1977)	Tunisian waters (Mediterranean)	46×21
Smitt (1893) in Cadenat & Blache (1981)	Occidental coast of Africa	45×18–65×20
Capapé & Zaouali (1977)	Tunisian waters (Mediterranean)	42×18–48×25
Compagno (1984b)	Eastern North Atlantic and Mediterranean	60×29
Quéro (1984)	Eastern North Atlantic and Mediterranean	60×30
Tursi et al. (1993)	Ionian Sea (Mediterranean)	45×17–55×20
Moreno (1995)	Iberian waters, north-eastern Atlantic and Mediterranean	50×20–65×25
Bannister (1998)	Eastern Atlantic	60×30
Our data	Portuguese south coast	35×14–63×25

examined, 18 had equal number of egg capsules in each uterus, one had one more egg capsule on one side or the other and five had only one egg capsule, all in the right uterus. The 100 egg capsules ranged from a minimum of 35×14 mm to a maximum of 63×25 mm in length and width (mean=54×21 mm; SD=4.66×1.78), respectively. Females carrying egg capsules appeared all year round but the majority of them were captured in the winter (70.83%) and in the summer (20.83%). Single females bearing egg capsules were captured in spring and in autumn. Although no relation between female size and the number of eggs was found, larger females seem to have slightly larger egg capsules.

Size-at-first-maturity (L_{50}) for *G. melastomus* females was determined from 35 mature specimens and was estimated to be 69.69 cm TL. The logistic curve was:

$$P_i = 1/[1 + e^{(3.0387+0.0436*TL)}]. \qquad (2)$$

Reproductive activity

The seasonal evolution of the gonadosomatic index (GSI) of *G. melastomus* is similar in both sexes with higher values for females than males. The analysis of GSI shows that gonads reach their maximum weight in winter (egg laying peak) (mean=15.3, SE=2.695, for females and mean=9.6, SE=1.922, for males) and a minimum in the spring (mean=2.7, SE=0.445, for females and mean=3.2, SE=0.233, for males)and autumn (after and before egg-deposition, respectively) (mean=2.2, SE=0.426), in females, and in the autumn (resting period) (mean=1.0, SE=0.08), in males. These findings generally agree with those obtained by the seasonal analysis of maturity stages.

DISCUSSION

The population of *Galeus melastomus* off the south coast of Portugal was found to consist mostly of young individuals. This could be due to the non-selective gear characteristics of crustacean trawlers and/or to overfishing effects at bathyal depths (200 to 800 m) by the fishery targeting valuable species such as *Aristeus antennatus*, *Parapenaeus longirostris* and *Nephrops norvegicus*.

The biological and reproductive aspects of *G. melastomus* from Algarve waters differ only slightly from those of Mediterranean specimens. According to Capapé & Zaouali (1977), Mediterranean blackmouth catshark specimens attain smaller maximum total lengths than those from the Atlantic. The maximum total length of the specimens caught off the south coast of Portugal corroborates this statement, as can be seen in Table 4.

According to Figueiredo & Correia (1996), in Portugal there are no relevant studies on growth of *G. melastomus.* Figueiredo et al. (1994) reported that this species displays a clear increase in size with depth, being well represented in the Algarve at depths from 400 to 800 m, with mean total lengths ranging between 26.12 cm to 56.73 cm. The lack of larger specimens in the present study (mainly females in the last reproductive stages), could be a characteristic of the local population or may be due to the tendency for larger specimens to be found in even deeper waters.

The overall distribution of length-frequencies and maturity stages indicates that the blackmouth catshark presents a sexual dimorphism by size in the studied area, with females growing larger than males and also reaching maturity at a larger size. Capapé & Brahim (1984), in the Mediterranean (Tunisia) also found that females were slightly bigger than males.

No variation in the sex ratio throughout the year was found. Capapé & Zaouali (1977) also found that schools of blackmouth catshark inhabiting bathyal zones in the Ionian Sea were made up of females and males in equal proportion.

The blackmouth catshark has been confirmed as an oviparous species (Cadenat & Blache, 1981; Compagno, 1984b; Quéro, 1984; Moreno, 1995; Mojetta, 1997; http://www.fishbase.org; http://shark-gallery.netfirms.com), with eggs that are enclosed within an egg capsule, without tendrils at the corners, and that are deposited on the bottom. Oviparity in *G. melastomus* is a case of retained oviparity, with multiple egg capsules retained within the oviducts (the same as in the uterus of viviparous sharks), but in which the development proceeds for a longer period before the egg capsules are released into the environment (Compagno, 1988 & Compagno, 1990 in Conrath, 2004).

Wourms (1977) characterized three basic types of reproductive cycle for chondrichthyan fish: (1) reproduction continuously throughout the year; (2) a prolonged and partially defined annual cycle with one or two peaks; and (3) a well defined annual or biennial cycle.

The results of seasonal percentages of males and females by maturity stages, the existence of males that showed copulation signals, the seasonal evolution of the GSI and the correspondence analysis results, suggest that the mating season and egg-deposition period occurs mainly in winter and, to a lesser extent, in summer. The fact that females carrying egg capsules appeared in all seasons could suggest egg-deposition all year round in the studied area. Therefore, *G. melastomus* could have an extended breeding season, reproducing continuously all year round, with eggs continuing to develop throughout the year, but with two reproductive activity peaks occurring during the winter and summer.

Egg-deposition of *G. melastomus* attains a maximum during the hydrologic warm season and, in the Mediterranean, occurs throughout the year, with a peak of activity in the spring and the summer (Capapé & Zaouali, 1977; Quéro, 1984; Tursi et al., 1993; Moreno, 1995; Bannister, 1998). Capapé & Zaouali (1977) reported that vitellogenic activity is constant all year round and that all adult females have numerous oocytes inside their ovary ready to be fertilized in the uterus. Tursi et al. (1993) added that the active reproductive cycle of mature blackmouth catshark occurs at the shallowest depths at which the species is found, whilst juveniles are widely distributed on the bathyal slope (Orsi & Wurtz, 1977), probably due to different feeding requirements compared with those of the adults (Tursi et al., 1993) and, over time, they move successively into shallower depths, reproducing (copulating and fertilizing the eggs) and concluding its life cycle (by gestation, egg-deposition and hatching of the egg-capsules). According to Muñoz-Chápuli (1984), the phenomenon of segregation of deep-sea sharks into aggregations of the same sex and size was already studied by Ford (1921) for the genus *Scyliorhinus*, and by Bullis Jr (in Gilbert, 1967) for *Galeus arae* (Nichols, 1927).

Length of left clasper and measurements of left testis are considered a good measure to define stage of maturity of males, with marked changes in growth rate from 49 to 52 cm TL for clasper length, testis weight, width and length. Size at first maturity (L_{50}) was estimated to be 49.37 cm TL. These results suggest that the size at maturity for males could fall between 48 and 52 cm TL.

Oviducal gland measurements can also be potential indices of maturity, although not so important as the ovary, which is, probably, the best reproductive organ for defining the state of maturity of *G. melastomus* females. On the other hand, uterus width does not seem to be as important for defining female maturity stage. The ovary width and weight increased noticeably at about 56 cm TL (27.79–59.83 mm and 5.74–33.28 g, respectively) and ovary length, although not as clearly as the other two measurements, increased rapidly at 59 cm TL (92.57–120.92 mm). The smallest advanced (Stage E) and extruding (Stage F) females were 56 cm TL. Size-at-first-maturity (L_{50}) was estimated to be 69.69 cm TL. This value is probably overestimated since the sample size of the proportion of mature females used to estimate L_{50} was small. These results suggest that the size-at-first-maturity for females is probably above 56 cm or could fall between 56 and 59 cm TL. Nevertheless, our size at first sexual maturity data is greater than for the Mediterranean, as can be seen in Table 4. Tursi et al. (1993) also found that sexual maturity in *G. melastomus* would be reached around the third or fourth year of life and Capapé (1977) in Capapé & Brahim (1984) states that maximum total lengths and size-at-first-maturity are random in some species of selachians and, notably, that there could be very important variations within the family Scyliorhinidae.

The dimensions of egg capsules vary according to geographic area, with those of specimens from the Atlantic being larger than those from the Mediterranean (Capapé & Zaouali, 1977). Capapé & Zaouali (1977) stated that the reproductive cycle of *G. melastomus* in Mediterranean waters is different from that of other oviparous selachians in certain points: the egg-deposition is permanent all year round and the seasonal fluctuations (egg capsules production was more important in the autumn) are less marked than in *Scyliorhinus canicula* and in Rajidae. The egg capsule dimensions studied off the south coast of Portugal (from 35×14 to 63×25 mm) are, in fact, larger than those of the Mediterranean and, closer to our study are the egg capsule dimensions reported by Moreno (1995) (Table 5).

A relatively small proportion (9%) of *G. melastomus*, off the Algarve, of total lengths greater than 38 cm TL is marketed. If we consider that the size at first sexual maturity for this species is in fact over 38 cm TL, we suggest that a minimum landing size should be established: above 56 cm, for females and above 48 cm, for males.

However, these results should be considered as preliminary and further research into relevant life history characteristics, growth, distribution, spatial segregations of mature individuals and, particularly, gestation period, fecundity studies and histological examinations of the gonads are required in order to carry out an assessment of the G. *melastomus* population off the south coast of Portugal.

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Neoraja iberica n. sp., a new species of pygmy skate (Elasmobranchii, Rajidae) from the southern upper slope of the Iberian Peninsula (Eastern North Atlantic)

by

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ABSTRACT. - *Neoraja iberica* n. sp. is described from the Portuguese and Spanish sector of the Iberian Peninsula south coast slope, based on a series of 50 type specimens representing all sizes of both sexes. This pygmy skate species was found with a maximum total length of 316 mm for females and 327 mm for males. The smallest specimens were a 55 mm neonate female and a 67 mm TL male. This new species is easily distinguished externally from four named congeners *N. stehmanni, N. caerulea, N. africana* and *N. carolinensis* by: upper side ochre to medium greyish-brown and dark greyish in ground colour with a lively ornamentation in smaller specimens of dark brown dots and spots all over disc and posterior pelvic lobes to the extreme margins, plus frequently a few pairs of whitish spots and dots on inner pectorals; 7-8 blackish cross-bars or asymmetrically paired saddle blotches along tail, which pattern fades with growth and becomes reduced in adults to a few pairs of larger dark, pale edged spots, plus mostly 1-2 pairs of the whitish dots, and cross-bars or saddle blotches along tail become less distinct; underside of disc, pelvic-fins and tail white, at most a faint greyish margin to posterior disc and pelvic lobes, but occasionally a cloud of merging brownish spots appears on each pectoral centre. A mature male specimen in poor condition of about 260 mm TL from the southern Bay of Biscay, originally identified by Vaillant (1888) as *Raja fullonica* Linnaeus 1758, is now reallocated to *Neoraja*, based mainly on features of its nearly skeletonised claspers. The similar patchy and limited distributional range of each species all along the Eastern Atlantic from off South Africa to off Scotland is briefly discussed, with four or five species occurring in the Eastern and only one species in the NW Atlantic.

RÉSUMÉ. - *Neoraja iberica* sp. nov., une nouvelle espèce de raie (Elasmobranchii, Rajidae) de la pente continentale méridionale de la péninsule Ibérique (Atlantique nord-est).

Neoraja iberica sp. nov. est décrite des secteurs portugais et espagnol de la côte méridionale de la péninsule Ibérique, à partir d'une série de 50 spécimens-types, représentant toutes les tailles des deux sexes. Les plus grands specimens étaient une femelle de 316 mm et un mâle de 327 mm LT. Les plus petits spécimens étaient un nouveau-né femelle de 55 mm LT et un mâle de 67 mm LT. Cette nouvelle espèce se distingue aisément de ses congénères *N. stehmanni, N. caerulea, N. africana* et *N. carolinensis* par sa coloration générale : la face dorsale du disque est ocre à gris brun moyen, ou bien gris sombre. Chez les plus petits spécimens, l'ornementation est constituée de points et de taches brunes sur tout le disque et les lobes postérieurs des pelviennes jusqu'aux bords extrêmes; de plus, il y a souvent quelques paires de points et de taches blanchâtres au centre des pectorales, 7-8 barres transversales noirâtres ou des paires de taches asymétriques à cheval sur la queue, qui s'estompent avec la croissance et qui sont réduites chez les adultes à quelques paires de grandes taches sombres, bordées d'une auréole claire. Il y a souvent également 1-2 paires de points blanchâtres et des bandes transversales ou des taches en selle sur la queue qui deviennent moins distinctes chez les adultes. La partie ventrale du disque, des pelviennes et de la queue est blanche, avec tout au plus une faible bande grisâtre le long des bords postérieurs du disque et des lobes pelviens ; une zone de taches brunâtres apparaît occasionnellement au centre des pectorales. Un mâle adulte d'environ 260 mm LT provenant du sud du golfe de Gascogne, décrit par Vaillant (1888) comme *Raja fullonica* L., 1758, est maintenant assigné au genre *Neoraja* d'après les caractères du squelette interne des ptérygopodes qui sont presque totalement décharnés du fait du mauvais état de conservation du spécimen. Les distributions similaires, en taches et très limitées, des espèces du genre *Neoraja* le long des côtes atlantiques est, de l'Afrique du Sud à l'Ecosse, est discutée; le genre *Neoraja* comprenant quatre ou cinq espèces en Atlantique est et une seule en Atlantique nord-ouest.

Key words. - Rajidae - *Neoraja iberica* - Skates - ANE - Iberian Peninsula - Gulf of Cadiz - New species.

Bigelow and Schroeder (1948) established the genus *Breviraja* for soft-snouted pygmy skates first found in the Western North Atlantic and assigned their new species *B. colesi* (generotype) and *B. plutonia* (Garman, 1881) to this genus. These authors diagnosed their genus as "Rajidae with a rostral cartilage, but with the latter falling consider-

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ably short of the extremities of the anterior rays of the pectorals and hence short of the tip of the snout; the anterior pectoral rays of the two sides are either close together anteriorly or are farther separated. Characters otherwise as in *Raja*." Six more Western North Atlantic species were subsequently described by Bigelow and Schroeder (1950): *B. cubensis*, *B. atripinna*, *B. sinusmexicanus*, *B. spinosa*, *B. yucatanensis*; and Bigelow and Schroeder (1962): *B. ishiyamai*. Other authors added to this number by describing or assigning further species from other ocean localities to *Breviraja*, based primarily on the soft-snouted rostral condition (e.g., Ishiyama 1958, 1967; Bigelow and Schroeder, 1965; Forster, 1967; Krefft, 1968a), although in external appearance and size most differed considerably from the eight species initially assigned to the genus *Breviraja* by Bigelow and Schroeder (*loc. cit.*).

Ishiyama and Hubbs (1968) compared rostral cartilages and claspers of *Breviraja colesi* with those of soft-snouted Western North Pacific skates described by Ishiyama (1958, 1967) and found considerable differences. Consequently, they rediagnosed *Breviraja* based on its type species *B. colesi* and assigned all species, other than the original eight from the Western North Atlantic, to the genus *Bathyraja* Ishiyama, 1958 by elevating it from subgeneric rank *Breviraja* (*Bathyraja*) to a defined genus. Following this revision, various authors reallocated many species previously assigned to *Breviraja* to *Bathyraja* (e.g. Stehmann, 1970, 1978; Hulley, 1970; Menni, 1972).

Based on the revised diagnosis of *Breviraja* by Ishiyama and Hubbs (1968), further species were described mainly from the Eastern Atlantic: *B. stehmanni* Hulley, 1972, *B. caerulea* Stehmann, 1976b. Stehmann (1976a) also reallocated two Indian Ocean species of *Raja* to *Breviraja*, namely *B. mamillidens* (Alcock, 1889) and *B. sibogae* (Weber, 1913) and commented on a third unnamed one Weber (1913) had collected and assigned to *Raja mamillidens* Alcock, 1889. McEachran and Compagno (1982) analysed and disentangled the interrelationships of and within *Breviraja* with a detailed revision of the 11-12 species resulting in: *Breviraja* Bigelow and Schroeder, 1948 was restricted to two species *B. colesi* and *B. spinosa*, a new genus *Neoraja* was erected with two subgenera *Neoraja* and *Fenestraja*; to the former subgenus were assigned *B. stehmanni*, *B. caerulea* and an unnamed third species, to the latter subgenus the majority of species, i.e. *sinusmexicanus, sibogae, ishiyamai, cubensis, plutonia, atripinna*, and finally was *B. yucatanensis* reallocated to *Raja*.

Three more Western Atlantic species of *Breviraja* were newly described after the genus revision by McEachran and Compagno (1982): *B. claramaculata* McEachran and Matheson, 1985, *B. nigriventralis* McEachran and Matheson, 1985, *B. mouldi* McEachran and Matheson, 1995. A fourth one, *B. marklei* McEachran and Miyake, 1987 from off Nova Scotia, however, is a junior synonym of *Rajella fyllae* (Lütken, 1888).

Appearance of the McEachran and Compagno (1982) revision had overlapped with the manuscript submission by Stehmann and Séret (1983) describing a third Eastern Atlantic species, *Breviraja africana*. McEachran and Stehmann (1984) thus described a fourth species already as *Neoraja carolinensis* from the Western North Atlantic and placed *B. africana* also in *Neoraja* presently comprising three Eastern and only one Western North Atlantic species.

McEachran and Dunn (1998), after a phylogenetic analysis of relevant character complexes, finally elevated all former rajoid subgenera of several genera to generic rank and rediagnosed the genus *Neoraja* for mainly features like: without oronasal pits; individual thorns on nape/shoulder regions, no thorn triangle; median thorns along trunk and tail in a single row; anterior pelvic lobes about 3/4 of length of posterior lobes; tail length distinctly more than 60% of TL; caudal fin with hypochordal lobe; cranium without nasobasal fenestrae, with narrow anterior fontanelle, and feeble rostral shaft almost reaching rostral node; low number of trunk vertebrae, less than 29; clasper tip with external components terminal bridge and dike; clasper skeleton with large dorsal terminal 1 and ventral terminal cartilages which firmly fused distally around axial; accessory terminal 1 cartilage U-shaped and with distal extension.

The present paper describes the fifth species of *Neoraja* and the fourth one from the Eastern Atlantic, based on 50 specimens covering both sexes and all sizes. Stehmann and Séret (1983:921) had discussed this Iberian species briefly in their interspecific comparison of *B. africana*.

MATERIAL AND METHODS

Institutional acronyms follow Leviton *et al.* (1985).

External morphometric measurements were taken from 70% ethanol preserved specimens by dial callipers to 1/10 of a millimetre largely following the scheme of Bigelow and Schroeder (1953), i.e. between perpendiculars, to allow direct comparison with previously described congeners, except for: ventral head length after Ishiyama (1958); nasal curtain and head length (= dorsal HL) measurements after Hubbs and Ishiyama (1968), length of anterior and posterior pelvic lobes according to Stehmann (1985), which all also taken between perpendiculars. Skeletal morphometric measurements of cranium and scapulocoracoid follow McEachran and Compagno (1979) and vertebral counts Krefft (1968b). Skeletal meristics were counted from soft X-rays films: for pectoral radials, the anteriormost propterygium was not counted but only the first laterally attached real radial, as well as on the last metapterygium the last laterally attached one was counted as a radial but not radial-like extension (at times bifurcated) at the rear surface. For pelvic fin (V) radial counts, the thick first one was counted as the first one.

The Portuguese samples were taken during M.E. Costa's research period for her PhD under the auspices of the projects DISCALG (Borges *et al*., 2000), BYDISCARD (Borges *et al*., 2002) and BIOFISH (Borges *et al*., 2007) on board chartered commercial shrimp trawlers using nets specified only by their overall length, with mesh size between 55 and 59 mm.

Two damaged Portuguese paratype specimens, juv. female (ZMH 25427) and juv. male (ZMH 25428), were used for skeletal dissections of crania, scapulocoracoids and pelvic girdles and these elements kept at the Zoological Museum Hamburg University. Alcian blue staining and dissections from underside of snout of another specimen (ZMH 25435) were done to confirm shape of rostral node and its long appendices. In addition, left scapulocoracoids of two more female and male paratypes (MNHN 2007-0124 and MNHN 2007-0125) were dissected in order to confirm variation range found in the two ZMH paratypes specified above and for confirming sexual dimorphism. The holotype male was not at all dissected, only its opened glans clasper with external components is illustrated here, and clasper skeleton was dissected of the mature male paratype ZMH 25429.

Photographs of the original Spanish specimens (1982) of Málaga University, of all new Portuguese and Spanish specimens were taken by the senior author, who also prepared the drawings of figures 5 and 8-12 and 14, and ZMH ichthyology staff assisted with radiographs of all specimens. The map of figure 1 was prepared by João Sendão of the CCMAR, University of the Algarve, Faro. The 50 type specimens have been split and distributed to various European and an U.S. collection as specified in the list of material.

NEORAJA IBERICA N. SP.

(Figs 1-14; Tabs I-V)

Proposed vernacular names: Iberian pygmy skate (En), raie pygmée ibérique (F), raya pigmea ibérica (ES), raia pigméia ibérica (P), Iberischer Zwergrochen (De).

Material examined

Holotype. - MB 4869, mature male 322 mm TL; FV 'Porto Amboim', trawl #1, 3. Jun. 2006; 36º50.7'-36º54.3' N, 07º44.8'-07º39.1' W at 558-531 m depth; 23 m crustacean trawl; collectors Patrícia Calixto and Gonçalo Carvalho.

49 paratypes. - Portuguese specimens: MB 4870; adol. female 253 mm TL; FV 'Crustáceo', trawl #2, 8 Jun. 2000; 36°47.8'-36°50.5' N, 07°39.6'-07°48.5' W at 520-620 m; 23.6 m crustacean trawl; collectors M. Esmeralda Costa and Sónia Olim. - MB 4871; juv. male 249 mm TL; FV 'Aurora Boreal', trawl #1, 8 May 2005; 36º48.5' N-07º59.1' W (start position only) at 538 m depth (mean); 26.5 m crustacean trawl; collectors Inês Figueiredo and Jorge Encarnação. - MB 4872; juv. male 244 mm TL; FV 'Aurora Boreal', trawl #1, 9 May 2005; 36º46.9' N-08º10.3' W (start position only) at 531-540 m depth; 26.5 m crustacean trawl, collectors Inês Figueiredo and Jorge Encarnação - MB 4873a-d; adol. female 235 mm (a), juv. female 129 mm (b), juv. male 200 mm (c), juv. male 221 mm TL (d); FV 'Porto Amboim'; trawl #2, 29 May 2006; 36º49.8'-36º51.0' N, 07º39.4'-07º35.0' W; at 529-512 m depth; 23 m crustacean trawl; collectors Patrícia Calixto and Gonçalo Carvalho. - MB 4874, mature female 314 mm TL; FV 'Porto Amboim'; trawl #1, 3 Jun. 2006; 36º50.7'-36º54.3' N, 07º44.8'-07º39.1' W at 558-531 m depth; 23 m crustacean trawl; collectors Patrícia Calixto and Gonçalo Carvalho. - MNCN 259.151; juv. male 216 mm TL; FV 'João Pinto', trawl not numbered, 1 May 1999; no precise locality data, off Faro; 24.5 m crustacean trawl. - MNCN 259.152; juv. female 192 mm TL; data as for MB 4871. - MNCN 259.153; juv. male 167 mm TL; FV 'Porto Amboim', trawl #3, 25 Sep. 2005; 36º57.3'-36º54.1' N, 07º34.3'-07º46.2' W at 172-403 m depth; 23 m crustacean trawl, collectors Gonçalo Carvalho and Jorge Encarnação. - MNHN 2007-0013; juv. female 228 mm TL; FV 'Gamba', trawl #3, 11 May 1999; 36°53.1'-36°45.7' N, 07°42.3'-07°54.2' W at 172-670 m; 30 m crustacean trawl; collectors M. Esmeralda Costa and Sónia Olim. - MNHN 2007-0014; juv. male 270 mm TL; data as for MNCN 259.151 - MNHN 2007-0015; juv. female 239 mm TL; data as for MB 4870. - MNHN 2007-0016; juv. male 183 mm TL; FV 'Aurora Boreal', trawl #1, 10 May 2005; 36º46.9' N-08º10.2' W (start position only) at 530 m depth (mean); 26.5 m crustacean trawl, collectors Inês Figueiredo and Jorge Encarnação. - TCWC 13204.01; juv. female 262 mm TL; data as for MB 4870. - ZMH 25427; juv. female 230 mm TL; FV 'Crustáceo', trawl #1, 8 Jun. 2000; off Faro on the slope, no precise locality data taken) (skeletal parts only), 23

Figure 1. - Atlantic south coast of the Iberian Peninsula from Strait of Gibraltar to Cabo de São Vicente, with 100 m and 500 m continental slope isobathic lines. Rectangles indicate capture areas of the Portuguese *Neoraja iberica* samples off Faro during the 1999-2000 and 2005-2006 project periods and the Spanish samples within the Gulf of Cadiz during 1994-1997, 1999-2000 and 2001-2004 surveys. *[Côte atlantique méridionale de la péninsule Ibérique depuis le détroit de Gibraltar jusqu'au cap Saint Vincent, avec les isobathes 100 et 500 m de la pente continentale. Les rectangles indiquent les zones de capture des exemplaires portugais de* N. iberica *au large de Faro, au cours des campagnes de 1999-2000 et de 2005-2006, et des exemplaires espagnols dans le golfe de Cadix au cours des campagnes de 1994-1997, 1999-2000 et 2001-2004.]*

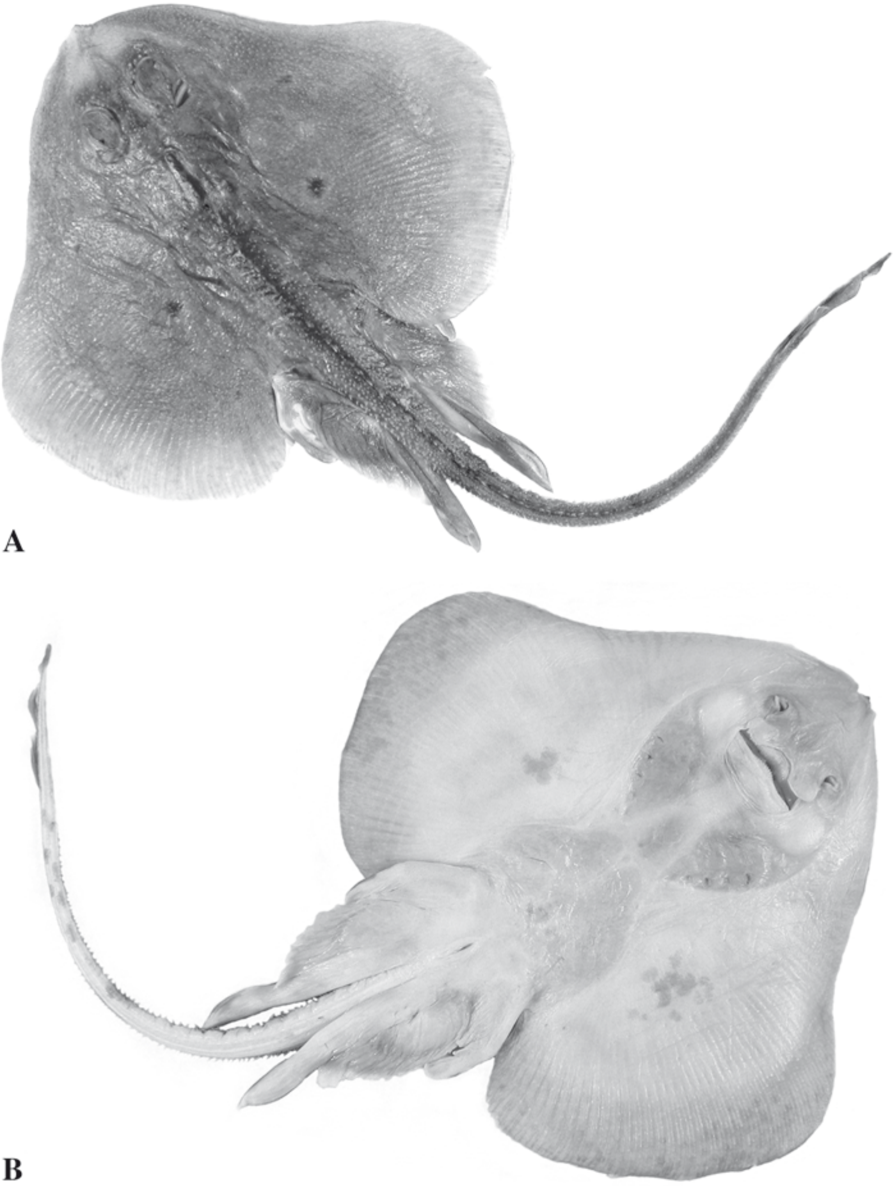

Figure 2. - *Neoraja iberica* n. sp., 322 mm TL mature male holotype, MB 4869, in total dorsal (**A**) and ventral (**B**) views. *[Vue dorsale (**A**) et vue ventrale (**B**).]*

m crustacean trawl; collectors M. Esmeralda Costa and Sónia Olim. - ZMH 25428; juv. male, 252 mm TL (skeletal parts only); data as for MNCN 259.151. - ZMH 25429; mature male 318 mm TL; FV ’Aurora Boreal’, trawl #1, 8 May 2005; 36º48.5’ N -07º59.1’ W (start position only) at 538 m depth (mean); 26.5 m crustacean trawl; collectors Inês Figueiredo and Jorge Encarnação. - ZMH 25430, immature female 200 mm TL; data as for MB 4873a-d. - ZMH 25431, immature female 191 mm TL; data as for MB 4873a-d. - ZMH 25432, immature male 142 mm TL; data as for MB 4873a-d. - ZMH 25433, immature male 209 mm TL; data as for MB 4873a-d. - ZMH 25434, mature female 316 mm TL; data as for MB 4874.

Initial Spanish specimens. - 7 immature females (170.5-206.4 mm TL) and 3 immature males (184.2-187.5 mm TL) taken by commercial trawlers from the Isla Cristina, Gulf of Cadiz, fishing fleet in 1982 by otter trawl on fine and coarse sand bottom within an area delimited by approximately 36°30-45’ N-07°05-20’ W and within a depth range of about 450-600 m; collector J. Baro. - MB 4875, juv. female 170.5 mm TL. - MB 4876, juv. female 170.5 mm TL. - MNCN 259.154, juv. female 202.6 mm TL. - MNCN 259.155, juv. female 206.4 mm TL. - MNCN 259.156, juv. female 192.7 mm TL. - MNCN 259.157, juv. male 187.5 mm TL. - MNHN 2007-0124, juv. female 202 mm TL. - MNHN 2007-0125, juv. male 186.4 mm TL. - ZMH 25435, juv. fem. 203.4 mm TL. - ZMH 25436, juv. male 184.2 mm TL.

New Spanish specimens. - From 1994-2004, collector J. Baro. - MB 4877, mature male 295 mm TL; RV ’Cornide de Saavedra’ cr. ARSA 0302, haul 19, 2 Mar. 2002; 36°21.25’ N-06°54.75’ W, 522 m; ’baka’ bottom trawl. - MB 4878, juv. female 112 mm TL; RV ’CdS’ cr. ARSA 0301, haul 35, 8 Mar. 2001; 36°21.40’ N-07°07.60’ W, 679 m; ’baka’ bottom trawl. - MNCN 259.158, mature female 294 mm; MNCN 259.159, adolescent male 278 mm TL; RV ’CdS’ cr. ARSA 0394, haul 18, 6 Mar. 1994; 36°36.62’ N-07°03.87’ W, 494 m; ’baka’ bottom trawl. - MNCN 259.160, neonate female 55

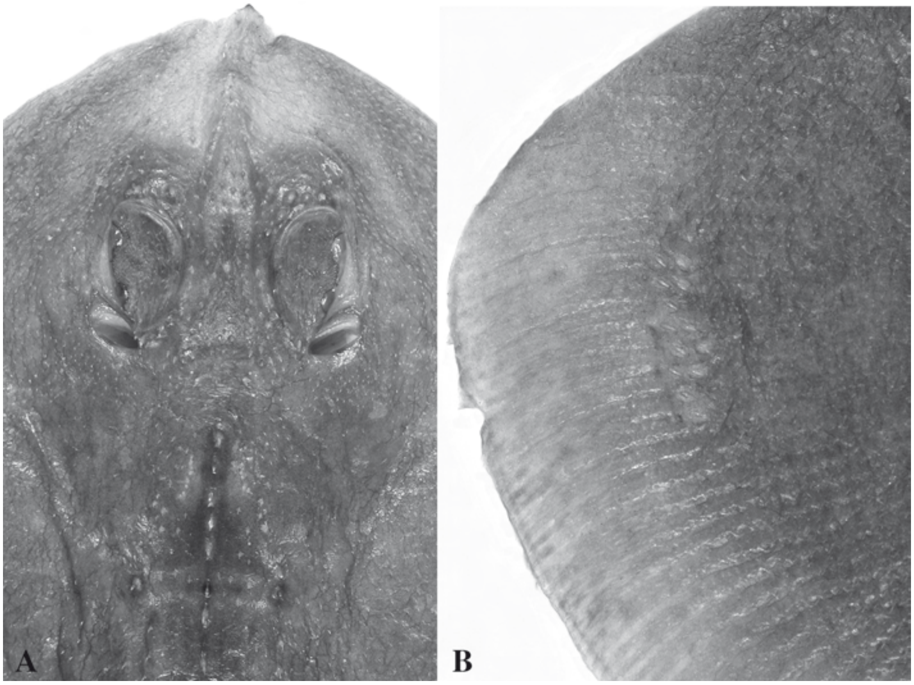

Figure 3. - *Neoraja iberica* n. sp., 322 mm TL mature male holotype, MB 4869, close ups of head dorsally (**A**) and of left wing tip with alar thorn field (**B**). *[Vue détaillée dorsale de la tête (**A**) et du groupe d'épines alaires sur le bord de la pectorale gauche (**B**).]*

mm, MNCN 259.161, juv. female 97 mm; MNCN 259.162, juv. male 202 mm TL; RV 'CdS' cr. ARSA 197, haul 12, 22 Feb. 1997; 36°47.55' N-07°16.80' W, 484 m; 'baka' bottom trawl. - MNCN 259.163, mature male 315 mm TL; RV 'CdS' cr. ARSA 1199, haul 8, 5 Nov. 1999; 36°37.89' N-07°04.26' W, 496 m; 'baka' bottom trawl. - MNCN 259.164, mature male 327 mm TL; RV 'CdS' cr. CALIMA 00, haul 25, 16 Nov. 2000; 36°42.61' N-07°06.89' W, 478 m; 'baka' bottom trawl. - NMHN 2007-0017, mature male 298 mm TL; data as for MB 4877. - MNHN 2007-0018, juv. female 157 mm TL; RV 'CdS' cr. ARSA 0304, haul 37, 13 Mar. 2004; 36°21.35' N-06°55.52' W, 522 m; 'baka' bottom trawl. - MNHN 2007-0019, mature female 299 mm, data as for MNHN 2007-0018 - TCWC 13205.01, mature male 312 mm TL, data as for MNHN 2007-0018. - ZMH 25437, mature male 305 mm TL, data as for MB 4877. - ZMH 25438, juv. male 67 mm TL, data as for MB 4878.

Diagnosis

Disc inverse heart-shaped, with short, triangular projection at snout tip; tail length about 62% (mean) of TL; lateral folds only along posterior half or 1/3 of tail length; caudal fin with hypocordal lobe; anterior pelvic lobes about 3/4 of length of posterior lobes; ochre to greyish-brown or dark greyish disc and posterior pelvic lobes distinctly ornamented dorsally by many dark brown spots and dots and frequently a few paired whitish spots in small and half-grown specimens, all often reduced in larger sized specimens to few pairs of larger symmetrically placed brown, pale edged spots, plus 1-2 pairs of pale spots or dots; tail with 7-8 more or less distinct dark cross-bars or asymmetrically placed saddle blotches; underside of disc and tail white, at most pale greyish margin to pectoral corners and posterior margins, and occasionally a cloud of merged pale brownish spots centrally on each pectoral. Upper side of disc, posterior pelvic lobes and back of tail totally and densely covered with fine dermal denticles, sides of tail with several rows of hooked thornlets. Individual thorns on nape/shoulder regions, no thorn triangle; median thorns along trunk and tail in a single row almost disappearing in posterior half or 1/3 of tail. Dorsal thorns appear irregularly mixed in various stages of development, shape and size in all their locations, resulting particularly in midline thorns (about 60 posterior to shoulder girdle to D1) being set at irregular interspaces. Underside totally smooth, except for extreme edges of tail set with erect dermal denticles which in dorsal and caudal fin section are embedded. Cranium without nasobasal fenestrae, with narrow anterior fontanelle and delicate, thin rostral shaft almost reaching rostral node. Low number of less than 29 trunk vertebrae. Glans clasper with external components terminal bridge, dike and newly defined component ribbon; clasper skeleton with large dorsal terminal 1 and ventral terminal cartilages which firmly fused distally around axial; accessory terminal 1 cartilage U-shaped and with distal extension.

Description of the holotype (Figs 2-5, 11A, 13A)

Detailed morphometric measurements and meristics given in tables I-III and V.

External morphology (Figs 2-4): disc inverse almost heart-shaped, 1.2 times as broad as long, with axis of maximum disc width at about 60% of disc length somewhat posterior to level of shoulder girdle. Anterior disc margins strongly undulated, i.e. concave opposite short projection at snout tip, strongly convex at snout sides to level with eyes, strongly

Figure 4. - *Neoraja iberica* n. sp., 322 mm TL mature male holotype, MB 4869, close ups of mouth/nasal region (**A**), pelvic fins and claspers dorsally (**B**) and enlarged tail section dorsally (**C**) showing transition from regular median thorn row to its becoming irregular and almost disappearing in posterior half of tail. *[Vue détaillée de la région bucco-nasale (**A**), vue dorsale des nageoires pelviennes et des ptérygopodes (**B**), et de la section élargie de la queue (**C**) montrant la transition entre la partie régulière de la rangée médiane d'épines et la partie irrégulière, jusqu'à sa disparition dans la moitié postérieure de la queue.]*

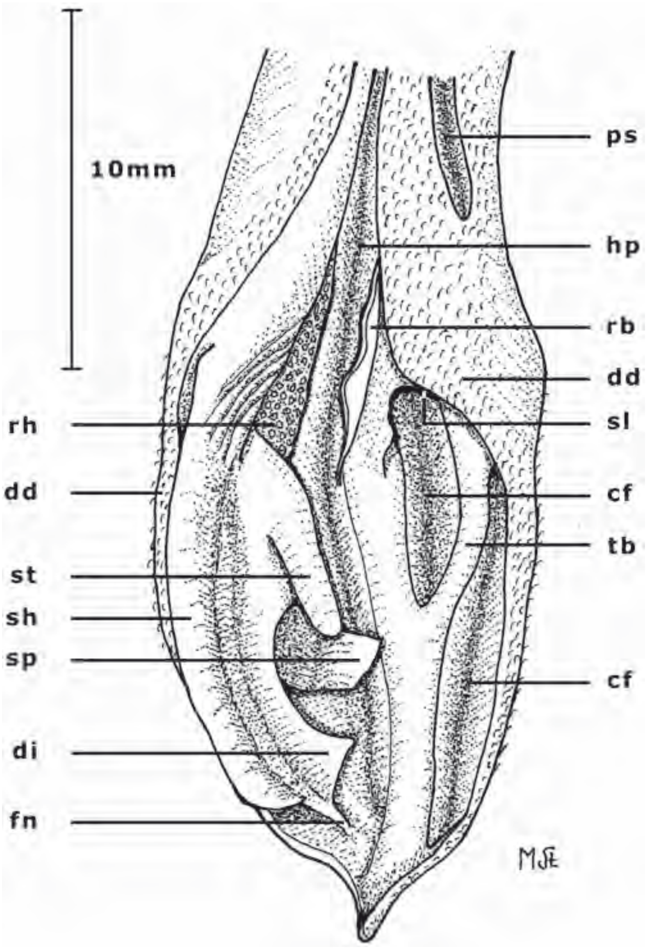

Figure 5. - *Neoraja iberica* n. sp., 322 mm TL mature male holotype, MB 4869, opened left glans clasper showing components and coverage with dermal denticles. Abbreviations: cf = cleft, dd = dermal denticles, di = dike, fn = funnel, hp = hypopyle, ps = pseudosiphon, rb = ribbon, rh = rhipidion, sh = shield, sp = spike, st = sentinel, sl = slit, tb = terminal bridge. *[Extrémité ouverte du ptérygopode gauche montrant les constituants et le revêtement de denticules cutanés. Abréviations: cf = clef, dd = denticules cutanés, di = dike, fn = funnel, hp = hypopyle, ps = pseudosiphon, rb = ribbon, rh = rhipidion, sh = shield, sp = spike, st = sentinel, sl = slit, tb = terminal bridge.]*

concave to level of spiracles and nape, and convex again toward to the broadly rounded outer corners continuous with the evenly convex posterior disc margins. Inner pectoral corners narrowly rounded, with pectoral axils deeply incised to origin of anterior pelvic lobes. Snout bluntly rounded, snout angle 122°, with short triangular projection at tip. Snout very short, preorbital length 3.1 times the very narrow interorbital width and nearly 6 times in disc width. Orbits large, horizontal diameter 1.8 times the interorbital width and 57% of preorbital snout length. Spiracle length 54% of orbit diameter, interspace between spiracles 2.2 times the interorbital width. Eight pseudobranchial folds in each spiracle. Pelvic fins large, with deep notch separating both lobes. Anterior lobes

Table I. - *Neoraja iberica* n.sp., morphometrics 40 type specimens: holotype in mm and % TL; mature female, small juvenile female and male paratypes as % TL; all 40 types with min-max-mean values % TL. *[Caractères morphométriques des 40 spécimens-types : en mm et en % LT pour l'holotype, en % LT pour les paratypes femelles adultes, et les femelles et mâles juvéniles ; valeurs minimales et maximales en % LT pour l'ensemble des 40 types.]*

Collection Coll. No.	HT	MB 4869	PT-ZMH 25434	PT-MNCN 259 161	PT-ZMH 25438	min.	max.	mean	Notes as values at times for less than 40 spec.
Sex		mat. male	mat. fem. 316 mm TL	juv. fem. 97 mm TL	juv. male 67 mm TL	18 females and 22 males			
	mm	%	%	%	%				
TL, mm	322.0	100.0	100.0	100.0	100.0	55.0	327.0	229.9	mm
Disc, width	170.0	52.8	54.1	49.5	41.8	25.5	55.0	50.4	-
Disc, length	140.0	43.5	44.0	41.2	43.3	36.4	44.6	42.0	-
Snout length, preorbital	28.8	8.9	10.1	9.3	9.4	7.6	10.8	9.0	-
Snout length, preoral	30.4	9.4	10.8	10.0	11.6	7.9	16.6	10.0	-
Snout length, prenasal	21.5	6.7	7.7	8.2	9.0	4.5	9.0	7.1	-
Orbit, horizontal diameter	16.5	5.1	5.1	5.1	6.3	4.3	6.3	5.1	-
Eyeball, horiz. diameter	13.5	4.2	4.4	-	4.8	3.9	5.1	4.4	37 spec.
Interorbital width	9.2	2.9	3.0	4.4	5.2	2.6	5.2	3.2	-
Spiracle length	9.0	2.8	3.3	2.8	3.0	2.3	3.4	2.9	39 spec.
Interspiracular width	20.5	6.4	6.2	7.4	9.3	5.7	9.3	6.5	-
Orbit + spiracle length	18.3	5.7	5.7	6.5	7.5	5.3	7.5	5.9	-
D1, height	7.3	2.3	2.2	-	1.5	0.8	2.3	1.3	36 spec.
D1, base length	18.8	5.8	6.3	5.2	3.7	3.5	6.4	4.9	39 spec.
D2, height	5.8	1.8	2.1	-	1.2	0.6	2.1	1.3	37 spec.
D2, base length	17.2	5.3	4.8	5.3	3.9	3.4	6.5	5.0	39 spec.
Interdorsal space	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.1	-
C, base length	10.4	3.2	1.8	5.2	2.5	1.3	5.2	2.7	39 spec.
C, height epichordal lobe	1.5	0.5	0.5	-	0.6	0.3	1.2	0.6	36 spec.
C, height hypochordal lobe	0.8	0.2	0.3	-		0.1	0.3	0.2	30 spec.
Tail, postdorsal length	10.4	3.2	1.9	5.2	2.5	1.7	5.2	2.8	39 spec.
Tail, height at V-tips	6.0	1.9	2.2	3.0	2.7	0.5	3.6	2.3	39 spec.
Tail, width at V-tips	10.5	3.3	3.6	3.8	3.3	2.0	4.4	3.4	39 spec.
Tail, height at D1-origin	2.5	0.8	0.9	0.9	1.2	0.7	1.2	0.8	39 spec.
Tail, width at D1-origin	3.4	1.1	1.2	1.2	1.6	0.8	1.6	1.1	39 spec.
Tail, lateral fold length	75.0	23.3	26.7	-		13.8	31.2	23.4	34 spec.
Head length, ventrally	70.3	21.8	22.2	20.6	24.2	8.4	24.2	21.5	39 spec.
Head length, dorsally	50.5	15.7	16.6	16.8	19.0	6.5	19.0	15.8	-
Mouth width	21.9	6.8	6.5	7.0	8.2	6.2	9.3	7.0	-
Internarial width	19.5	6.1	5.9	6.9	6.3	5.4	7.3	6.1	-
Nasal curtain, length	13.5	4.2	4.1	4.0	4.0	3.1	5.5	4.0	37 spec.
Nasal curtain, width each lobe	7.8	2.4	2.2	2.4	3.0	1.8	3.6	2.4	37 spec.
Nasal curtain, space between lobes	10.0	3.1	3.1	3.0	3.1	2.3	3.9	3.2	37 spec.
Gill slit length, 1st	2.7	0.8	1.3	1.5	1.5	0.8	1.6	1.3	39 spec.
Gill slit length, 3rd	3.2	1.0	1.3	1.5	1.9	1.0	1.9	1.3	39 spec.
Gill slit length, 5th	2.5	0.8	1.0	1.3	1.0	0.7	1.3	0.9	38 spec.
Interspace first gill slits	37.4	11.6	12.6	14.4	14.6	10.7	14.6	12.5	-
Interspace fifth gill slits	18.0	5.6	7.4	8.2	9.0	4.1	9.0	6.6	39 spec.
V-length, ant. lobe	39.0	12.1	11.7	10.7	14.3	9.2	14.3	11.1	39 spec.
V-length, post. lobe	60.5	18.8	15.8	11.5	12.5	11.5	18.8	14.7	39 spec.
Clasper, postanus length	67.7	21.0	-	-	6.3	5.7	22.2	12.8	22 spec.
Clasper length	57.3	17.8	-	-	-	2.6	19.7	10.1	21 spec.
Snout tip to mid-anus	119.0	37.0	38.9	36.8	38.1	34.5	40.0	37.6	-
Snout tip to 1st hemal spine	127.0	39.4	41.1	40.0	-	36.9	41.1	39.4	38 spec.
Snout tip to axis max. disc width	84.0	26.1	26.9	24.7	28.4	22.2	28.4	25.3	39 spec.
Mid-anus to D1	153.5	47.7	48.1	50.0	44.0	44.0	51.1	49.1	39 spec.
Mid-anus to D2	171.0	53.1	53.6	55.2	47.8	47.8	56.7	54.0	39 spec.
Mid-anus to tail tip	198.5	61.6	60.3	65.7	61.8	59.6	65.7	61.7	39 spec.

Table II. - *Neoraja iberica* n. sp.: snout angle and meristics of the holotype and 35-37 paratypes as min-max-mean values. *[Angle du museau et caractères méristiques de l'holotype, valeurs minimales, maximales et moyennes pour 35-37 paratypes.]*

	Holotype	min	max	mean	n
Snout angle	122°	119°	145°	132.3°	36
Pseudobranchial folds	8	9	10	9.1	37
Trunk vertebrae Vtr	24	20	27	23.9	37
Predorsal tail vertebrae Vprd	71	67	78	71.5	37
Pectoral radials	64	64	69	65.6	37
Pelvic radials	18	16	20	17.7	35
Upper jaw tooth rows	41	40	52	43.1	37
Lower jaw tooth rows	44	35	48	41.2	35

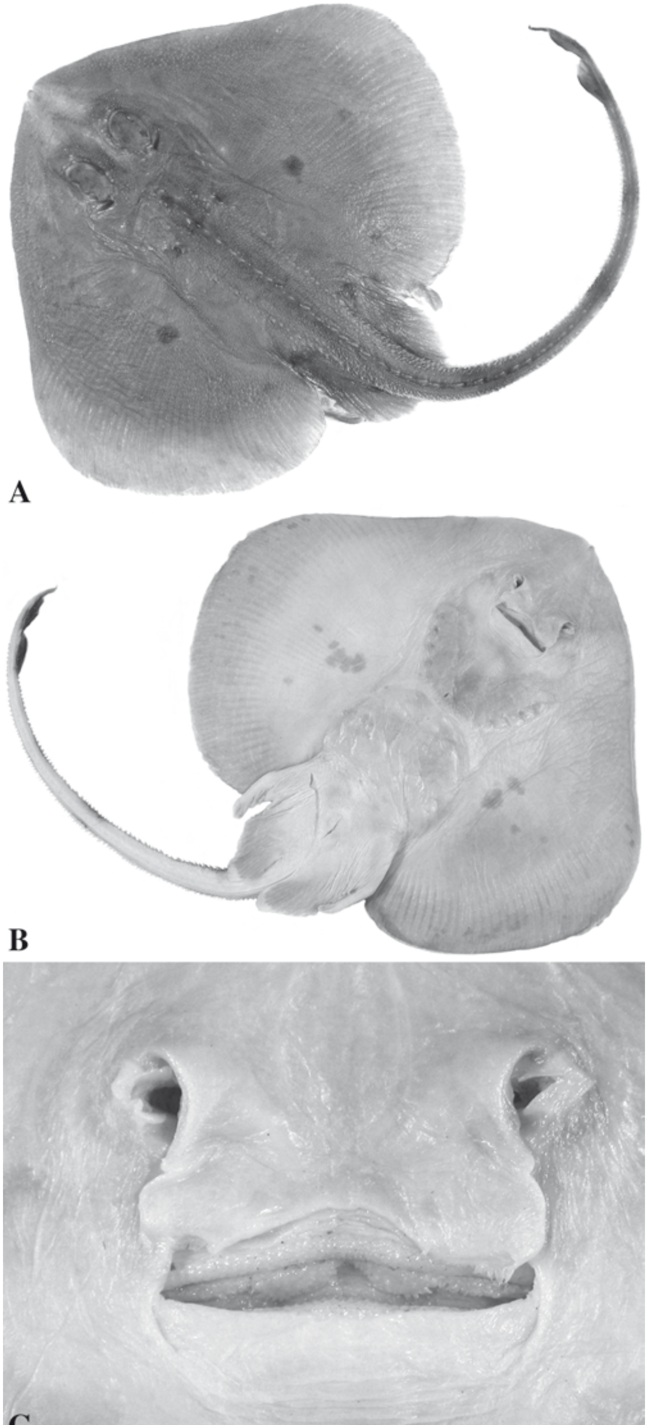

Figure 6. - *Neoraja iberica* n. sp., 316 mm TL mature female paratype, ZMH 25434, in total dorsal (**A**) and ventral (**B**) views, plus enlarged mouth/nasal region (**C**). *[Vue dorsale (**A**), vue ventrale (**B**), et vue détaillée de la région bucco-nasale (**C**).]*

long and broad, distal third narrowing slightly and with bluntly rounded tip. Posterior lobes elongated, with pointed tip, angular outer margin moderately convex over distal two thirds. Anterior lobe 64.5% of length of posterior lobe. Claspers fully developed, evenly elongated, with sharply pointed tip marked off and relatively short terminal region only little widened (Fig. 4B); postanal clasper length 34% of tail length from mid-vent. Tail very long, slender, gradually tapering toward tip, length nearly 62% of the total length; depressed over entire length but less so in posterior third; lateral folds restricted to posterior third of tail and terminating about mid-postdorsal tail length. Dorsal fins low and elongated, 2.6 times (D1) and 3 times (D2) as long as high, D1 slightly larger than D2, their bases connected by transparent membrane above tail surface, D2 and upper C confluent. Both dorsal fins of similar shape, with long, almost straight anterior margin rising at about 45° and continuous with short, rounded upper margin, with maximum height over posterior third of base length, then sloping a little toward pointed apex widely overhanging origin of either D2 or upper caudal, respectively; rear margin strongly inclined forward. Postdorsal tail section long, 60% of D2 base length, with almost equally high upper C fold ¼ of D2 height; lower C fold shorter and only half height of the upper.

Preoral snout length 1.4 times the mouth width, mouth width 31% of ventral head length, and the latter 3.6 times internarial width. Distance between fifth gill slits 48% of distance between first gill slits, and the latter distance 1.9 times the internarial space. Mouth width 1.1 times the distance between nostrils. Anterior nasal flaps not well developed, cone-shaped, with fine fringes along outer edge. Outer margins of nasal curtain strongly undulated, with triangular lobelet at proximal third, nearly square-shaped apices with angular outer corners and transverse, almost straight rear edges set with coarse, mostly bifurcated fringes; isthmus steeply arched (Fig. 4A). Oronasal pits underneath nasal curtain apices absent. Jaws nearly straight, upper jaw distinctly indented medially, with a median lower jaw protrusion accordingly. Jaw teeth in 41 upper and 37 lower rows, in close set parallel series in outer thirds of band but in quincunx arrangement medially. Individual teeth with rhombic crown bearing short, conical cusp on inner corner in median

Table III. - *Neoraja iberica* n. sp.: cranial morphometrics of the holotype (X-ray), two dissected juveniles and three more paratypes (X-rays) as per cent of the nasobasal length. *[Caractères morphométriques du crâne de l'holotype (d'après radiographies), de deux paratypes juvéniles disséqués et de trois autres paratypes (d'après radiographies) en % de la longueur nasobasale.]*

Specimen	Holotype MB 4869	ZMH 25427	ZMH 25428*	ZMH 25431	ZMH 25434	ZMH 25429
	X-ray	Dissected	Dissected	X-ray	X-ray	X-ray
Sex and maturity	Mature male	Immature female	Immature male	Immature female	Mature female	Mature male
TL / DW in mm	322 / 170	230 / 118	252 / 127	191 / 98	316 / 171	318 / 168
Cranium TL (x-ray)	178.7	151.3	ca. 144.0	202.0	182.1	172.3
Nasobasal length	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Max. ethmoidal width	121.7	103.1	98.4	122.7	112.9	120.8
Min. dorsal interorbital width	33.1	30.5	28.0	38.0	30.1	34.6
Min. internasal width	17.1	17.7	16.0	22.7	16.1	17.3
Min. basal plate width	27.0	26.5	24.8	31.3	29.4	28.5
Max. width otic region	73.0	59.3	58.0	70.0	70.6	78.1
Max. width jugular	59.7	58.4	56.0	62.7	60.9	65.4
Rostral shaft length (x-ray)	64.6	51.3	48.0	76.0	71.7	60.8
Rostrum base width	22.1	17.7	17.6	18.7	19.0	21.2
Postnasal length orbit region	30.4	37.2	39.6	30.7	29.0	28.8
Length otic region	30.4	19.5	22.0	29.3	24.4	30.8
Postoccipital length jugal arches	0.0	0.0	0.0	0.0	0.0	0.0
Tip rostrum to tip ant. fontanelle	43.3	24.3	-	55.3	49.5	36.5
Tip rostrum to end ant. fontanelle	91.3	77.9	-	113.3	99.6	84.6
Tip rostrum to tip post. fontanelle	96.2	79.6	-	120.0	106.1	90.0
Tip rostrum to end post. fontanelle	144.1	126.1	-	169.3	154.1	138.5
Tip rostrum to level ant. propterygia	11.4	-	-	6.7	5.7	3.8
Tip rostrum to level max. ethmoidal width	88.2	66.4	-	98.0	93.2	78.8
Tip rostrum to symphysis upper jaw	117.1	91.2	-	133.3	118.3	121.9
Ant. fontanelle length	44.5	40.7	47.2	57.3	50.5	45.8
Ant. fontanelle max. width	20.5	14.6	16.0	22.7	21.9	21.2
Space betw. ant.&post. fontanelles	6.5	8.8	10.8	6.7	7.2	7.7
Post. fontanelle length	49.4	42.5	45.2	52.0	48.7	50.0
Post. fontanelle min. width	1.9	0.4	3.6	4.7	5.0	3.8
Post. font. max. width anteriorly	8.7	4.4	4.8	6.7	7.2	5.8
Post. font. max. width posteriorly	19.0	13.3	12.0	20.0	15.1	15.4
Max. cranial height	-	31.0	28.0	-	-	-
Max. height rostral shaft	-	14.6	14.0	-	-	-
Angle post. edge nasal capsules	79°	80°	80°	70°	71°	75°

rows, with cusp gradually becoming shorter toward mouth corners. Anterior pectoral radials and propterygial elements extended over entire rostral length and almost abutting rostral node at snout tip.

Squamation. - Entire upper disc densely set with fine dermal denticles, except for extreme posterior margins, eyes with fine prickles; denticles coarser, to thornlet size, in malar regions and along sides of trunk. Anterior pelvic lobes smooth, posterior lobes with central patch of fine denticles. Edges of clasper groove over full length densely set with very fine denticles, as well as externally on entire terminal region, and smooth only the proximal half of dorsal clasper stem (Fig. 4B). Dermal denticles sparse directly alongside and between median thorns from nape to 2/3 tail length, but from there rearward more densely set also on back of tail. Laterally along back of tail, a stripe of densely set fine denticles on each side, lower sides of tail densely set with several rows of much larger, hooked thornlets attaining nearly the size of median tail thorns (Figs 4B-C). Both dorsal fins and upper caudal set with fine denticles. Underside of disc and pelvic fins smooth; outer and inner edges and part of terminal surface of claspers set with fine denticles; underside of tail smooth along broad midline, only extreme tail edges with narrow stripe of fine, erect denticles which embedded below dorsal-caudal fin section.

Dorsal thorns appear in various stages of development, shape and size in all areas of their location. The initial ones are evenly cone-shaped, ribbed and on a circular basal plate, with the tip erect and placed centrally; later added or replaced thorns have oval basal plate with low base and long, rearward curving long and pointed tip overhanging rear base; the latter type of thorns also appearing in early development

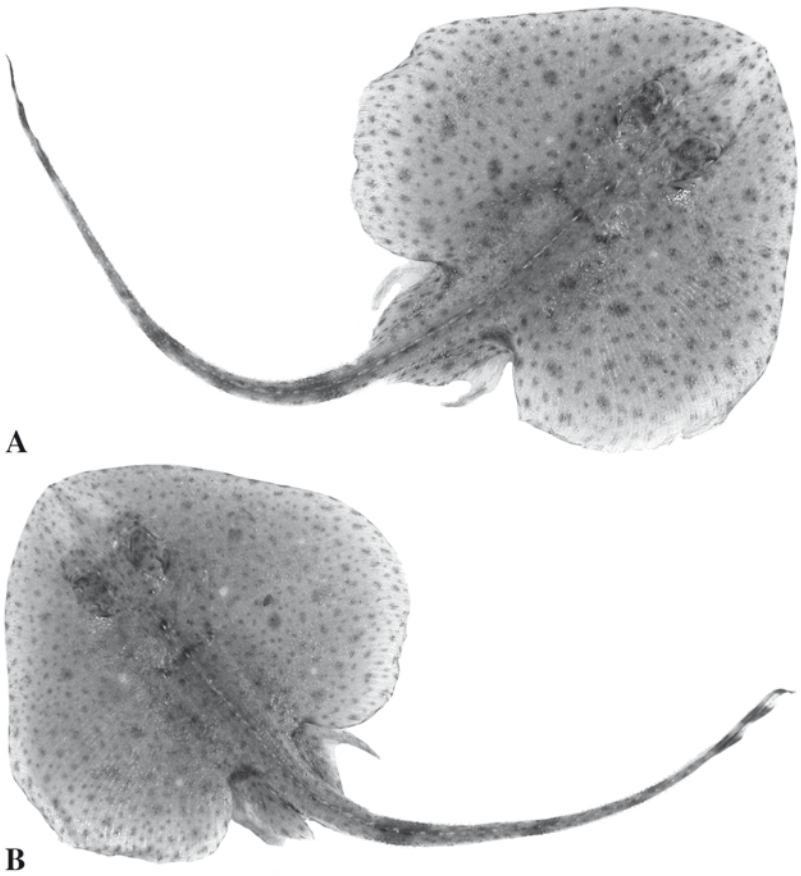

Figure 7. - *Neoraja iberica* n. sp., 129 mm juv. female (MB 4873b) (**A**) and 143 mm TL juv. male (ZMH 25432) (**B**) paratypes showing distinct juvenile dorsal colour pattern. *[Coloration dorsale des paratypes, femelle juvénile de 129 mm LT (**A**) et mâle juvénile de 143 mm LT (**B**).]*

stages, i.e. being whitish, with the low base not yet formed and the long pointed tip being still soft and often embedded under the integument. All three kinds of thorns do appear at orbits, on nape and midline of trunk and tail irregularly mixed resulting in mainly midline thorns set at irregular interspaces. Patch of 7/5 preorbital and 3/2 postorbital thorns on left/right side, respectively, separated by a gap supraorbitally. Pair of small, conical interspiracular thorns at level of occipital joint, only slightly larger than surrounding erect dermal denticles with rearward curving tip. Five median nuchal thorns in a regular line, one in suprascapular position and 1/2 on left/right shoulder (Fig. 3A). Regular mid-row of 12 thorns along back of trunk between shoulder girdle and level of pectoral axils, but these thorns of differing sizes and set at varying interspaces; this median row of thorns continued onto tail with approximately 50 more thorns of different size and shape to near D1, but this row becoming very irregular in posterior half of tail with regard to much smaller size of and much wider spaces between thorns, so that median thorns appear to rather disappear in posterior half of tail length (Fig. 4C). Alar thorns of the permanently erect, hooked, nonerectile type, which form a rather narrow and short stripe inward on left and right wing tip of 2/10 and 2/9 longitudinal/ transverse thorn rows, respectively (Fig. 3B).

Coloration (after preservation in formalin and storage in ethanol) (Figs 2A, 2B). - Upper side medium greyish-brown, slightly darker along midline of body and on tail. Rostral triangle

Specimen	ZMH 25427		ZMH 25428	
Sex and maturity	Immature female		Immature male	
TL / DW in mm	230 / 118		252 / 127	
	left	right	left	right
Max. length	**100.0**	**100.0**	**100.0**	**100.0**
Max. height	86.9	79.6	79.8	80.7
Height at rear corner	61.7	63.9	56.1	57.0
Pre-mesocondyle-length	42.1	43.5	52.6	49.1
Post-mesocondyle-length	49.5	50.9	44.7	48.2
Anterior fenestra height	26.2	25.0	28.1	26.3
Anterior fenestra length	15.0	16.7	7.0	11.4
Postdorsal fenestra height	9.3	10.2	19.3	17.5
Postdorsal fenestra length	13.1	18.5	26.3	22.8
Postventral fenestra height	14.0	15.7	14.9	14.9
Postventral fenestra length	15.0	17.6	27.2	24.6
Total number of postdorsal fenestrae	1	1	1	1
Total number of postventral fenestrae	1	1	1	1

Table IV. - *Neoraja iberica* n. sp.: scapulocoracoid morphometrics as per cent of maximum length of left and right dissected elements of two immature paratypes. *[Caractères morphométriques des scapulocoracoïdes en % de la longueur maximale, mesurés sur les éléments gauches et droits disséqués de deux paratypes immatures.]*

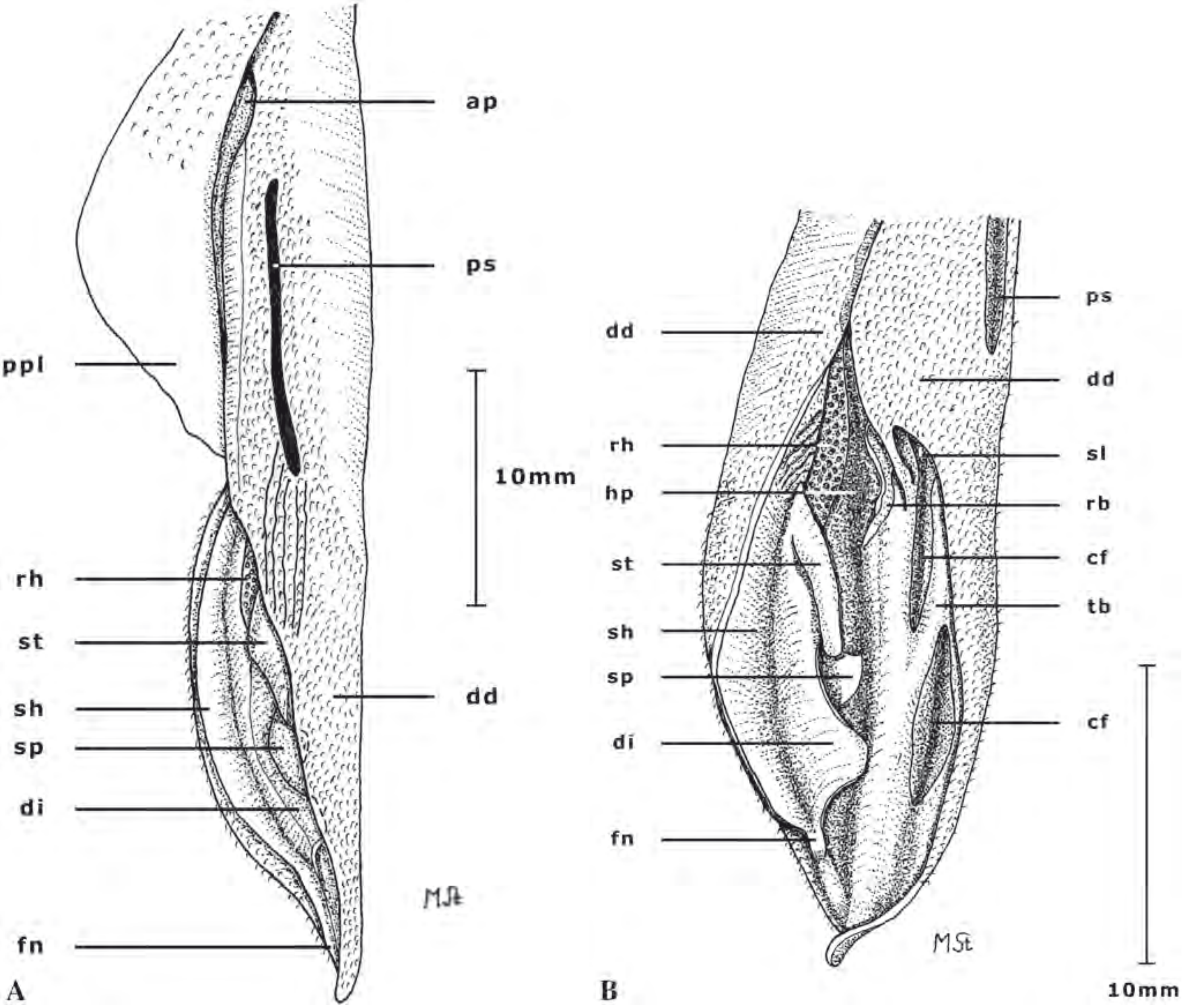

Figure 8. - *Neoraja iberica* n. sp., 318 mm TL mature male paratype ZMH 25429, dorsal view of left clasper showing extension of pseudosiphon and coverage with dermal denticles (**A**), and opened left glans clasper (**B**). Abbreviations as in Fig. 5, and ap = apopyle, ppl = posterior pelvic lobe. *[Vue dorsale du ptérygopode gauche montrant l'extension du pseudosiphon et les denticules cutanés (**A**), et l'extrémité (glans) ouverte du ptérygopode gauche (**B**). Abréviations : voir figure 5, et : ap = apopyle, ppl = lobe pelvien postérieur.]*

semitransparent pale whitish, with rostrum marked off brown. Eyes dusky bluish, broad margins of outer corners and posterior disc semitransparent lighter. Two pairs of circular dark brown spots with pale outer ring on inner pectorals, anterior pair smaller and level with anterior nape, posterior pair larger and level with anterior trunk. Anterior pelvic lobes as disc, with outer margin white only in basal half, whereas inner margin totally edged white; posterior lobes as disc, with white blotch at axils between tail and claspers and narrow pale outer edge. Dorsal side of claspers greyish-brown somewhat darker than disc, except for proximal inner half being paler brown, and also outer edge of the ventral lobe dark brown along clasper groove and its broader terminal region. About seven indistinct dark cross-bars along tail length, with last three through D1, D2 and C respectively, marking the three fins dusky. Lateral tail folds nearly transparent, only at dorsal and caudal fins partly dark. Underside milky-white, with short projection at snout tip brown, broad pale greyish margin to outer corners and posterior pectorals, speckled with pale brown spots, as well as outer margin posterior pelvic lobes. Cloud of largely merged pale brown spots on each pectoral centre. Claspers white, with some brown encroaching from dorsal side at terminal outer margin. Underside of tail only in posterior half irregularly coloured with few pale brown spots at edges, and extreme tail tip dusky. Mouth cavity white.

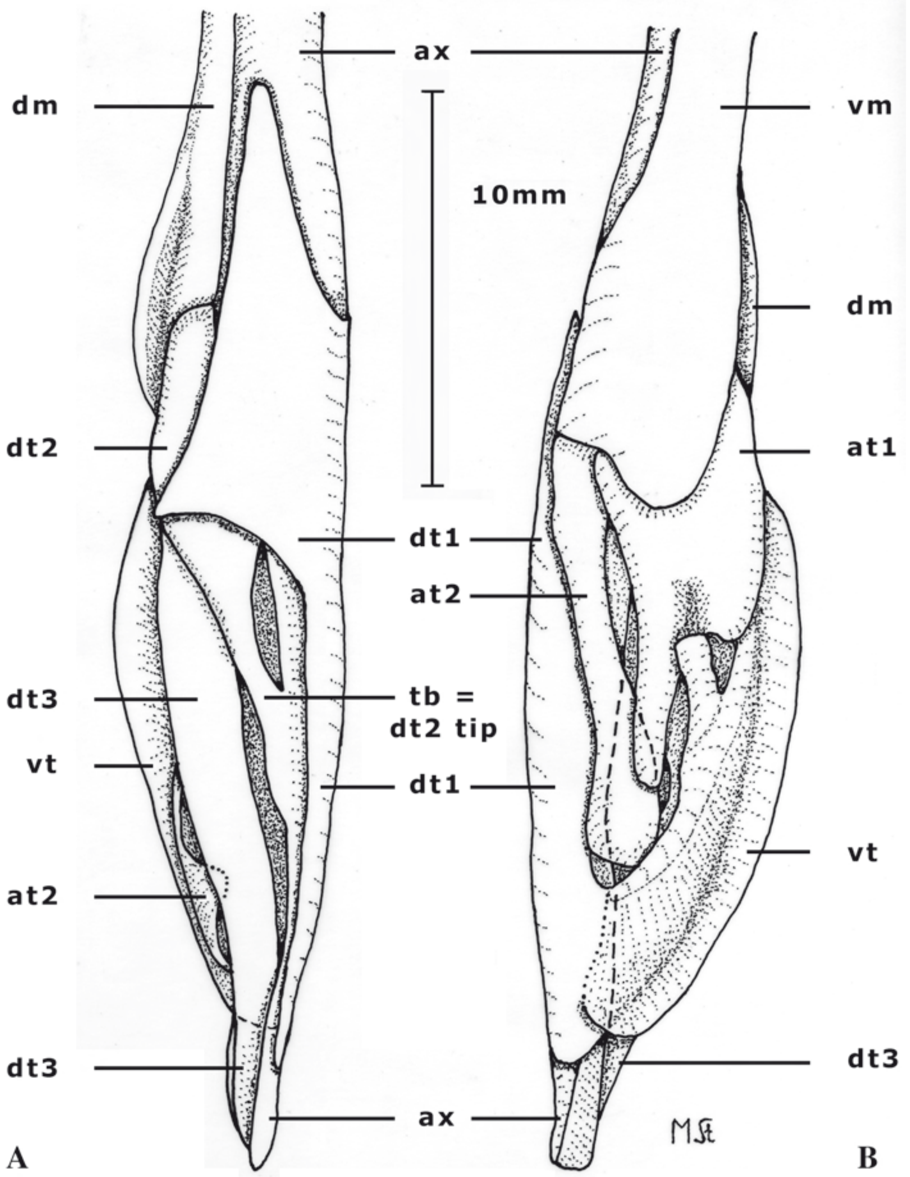

Figure 9. - *Neoraja iberica* n. sp., 318 mm TL mature male paratype ZMH 25429, left clasper skeleton in dorsal (**A**) and ventral (**B**) views. Abbreviations for cartilages: at1-at2 = accessory terminals 1 and 2, ax = axial, dm = dorsal marginal, dt1-dt2-dt3 = dorsal terminals 1, 2, 3 resp., tb = terminal bridge, vm = ventral marginal, vt = ventral terminal. *[Vues dorsale (**A**) et ventrale (**B**) du squelette du ptérygopode de gauche. Abréviations pour les cartilages : at1-at2 = accessory terminals 1 and 2, ax = axial, dm = dorsal marginal, dt1-dt2-dt3 = dorsal terminals 1, 2, 3 resp., tb = terminal bridge, vm = ventral marginal, vt = ventral terminal.]*

Clasper components (Fig. 5). - Clasper with very elongated but narrow and shallow pseudosiphon (ps) along entire stem section of outer dorsal lobes from about level of apopyle to begin of terminal region (Fig. 5), but ps formed entirely by dorsal dilatator muscle without direct relation to and not formed by the dorsal terminal 1 cartilage of the clasper skeleton. Inner dorsal lobe with deep longitudinal proximal and shallower distal cleft (cf), separated diagonally by terminal bridge (tb). Proximally, integumental slit (sl) spans between axial and dt1-cartilages over and across upper end of the proximal cleft. A new component ’ribbon’ (rb) is defined here: integumental ribbon-like fold located very proximally along midline of glans clasper, originating at base of inner dorsal lobe about level with slit (sl), running diagonally across axial into clasper groove and terminating level with about half length of proximal cleft. Predominant component on inner ventral lobe is the elongated trough-like shield (sh) over nearly entire length of terminal region, with a cutting outer edge of free cartilage and an inward curving dike (di) as a plate-like extension at inner distal end, whereas distal extension as funnel (fn) is poorly developed. Along the proximal inner wall of ventral lobe and to proximal end of shield stretches the rhipidion (rh), an integumental fold with porous outer surface. From underneath proximal end of shield extends diagonally inward a short, finger-like sentinel (st) to half length of terminal region, and originating underneath shield and tip of sentinel curves up a spoon-shaped spike (sp) transversally into the opened glans. Only four among eight mature males showed distally on axial cartilage the rather rudimentary integumental component ’flag’

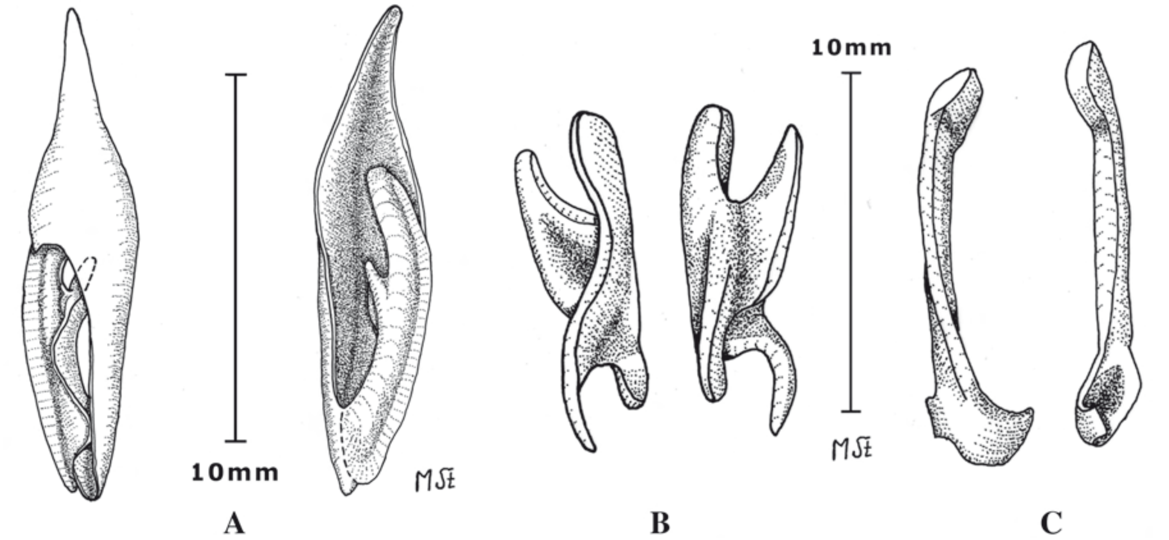

Figure 10. - *Neoraja iberica* n. sp., 318 mm TL mature male paratype ZMH 25429, individual cartilages of left clasper in dorsal and ventral views (left and right, resp.): distally fused dorsal terminal 1 and ventral terminal cartilages (**A**), accessory terminal 1 (**B**) and at2 (**C**) cartilages. *[Cartilages du ptérygopode gauche en vues dorsale et ventrale (à gauche et à droite respectivement) : cartilages dorsal terminal 1 et ventral terminal fusionnés à leur extrémité (**A**), accessory terminal 1 (**B**) et at2 (**C**).]*

Table V. - *Neoraja iberica* n. sp.; pelvis morphometrics of the holotype (X-ray), a juvenile paratype couple (dissected and X-rays) and three more paratypes (X-rays), and relation max. width shoulder girdle / pelvis. (*: From level of max. width / from level of ant. contour. **: From level of max. width). *[Caractères morphométriques de la ceinture pelvienne de l'holotype (d'après radiographies), d'un couple de paratypes juvéniles (disséqués et radiographiés) et de trois autres paratypes (d'après radiographies), et relation entre les largeurs maximales des ceintures pectorale et pelvienne (* : Du niveau de la largeur maximale / depuis le niveau du contour antérieur. ** : Depuis le niveau de la largeur maximale).]*

Specimen	ZMH 25427		ZMH 25428		MB 4869 holotype	ZMH 25431	ZMH 25434	ZMH 25429
Sex and maturity	Immature female		Immature male		mature male	imm. female	mature female	mature male
TL / DW in mm	230 / 118		252 / 127		322 / 170	191 / 98	316 / 171	318 / 168
	Dissected	X-ray	Dissected	X-ray	X-ray	X-ray	X-ray	X-ray
Pelvis max. width	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Median transverse thickness	13.8	13.9	13.6	11.4	10.6	11.8	13.1	13.4
Prepelvic processes length *	25.6 /9.2	19.8/8.9	tips broken	19.1/5.0	18.4/5.7	14.1/2.9	15.6/4.7	17.0/7.6
Iliac processes length**	19.0	18.3	23.3	15.0	10.6	5.9	15.6	14.5
Depth posterior arc	13.8	14.4	13.1	15.9	13.1	8.8	11.3	17.0
Number iliac foramina	2		2		2	2	2	2
Shoulder girdle max. width, mm		26.0		26.5	29.7	22.0	41.5	31.0
Pelvis max. width, mm	19.5	20.2	20.6	22.0	28.2	17.0	32.0	27.6
Relation shoulder girdle / pelvis max. width		**1.3**		**1.2**	**1.1**	**1.3**	**1.3**	**1.1**

(MNCN 259.163, MNHN 2007-0017, ZMH 25437, MNHN 2007-0017) not present in glans clasper of holotype and a paratype illustrated here.

Internal meristics. - Vtr: 24, Vprd: 71, P radials: 64/64, V radials: 19/19 (Tab. II).

Skeletal anatomy. - Proportional measurements of skeletal elements given in tables III-V.

Clasper (Figs 8-10). - Both marginal cartilages do not possess any extended distal process. The large dt1 with pointed proximal process, and with long distal extension curving around the axial to the ventral side, where firmly fused with the distal tip of the large vt cartilage; plate-like elongated dt2 and dt3 cartilages connect distal end of dorsal marginal with tip of axial cartilage, with the distal part of dt2 forming terminal bridge by connecting to the axial at half length of terminal region; ventrally, the elongate ventral terminal forms the outer edge, and it is linked with its medial process with the medio-distal notch of the U-shaped at1, which itself is attached with its proximal notch around the outer 2/3 of the ventral marginal; at the inner end of the vm attaches the elongated, club-shaped aT2. Figure 10 provides enlarged the isolated relevant cartilages, namely the distally fused dt1 and vt, with the latter's outer lamella forming externally the component shield, and with the inward curv-

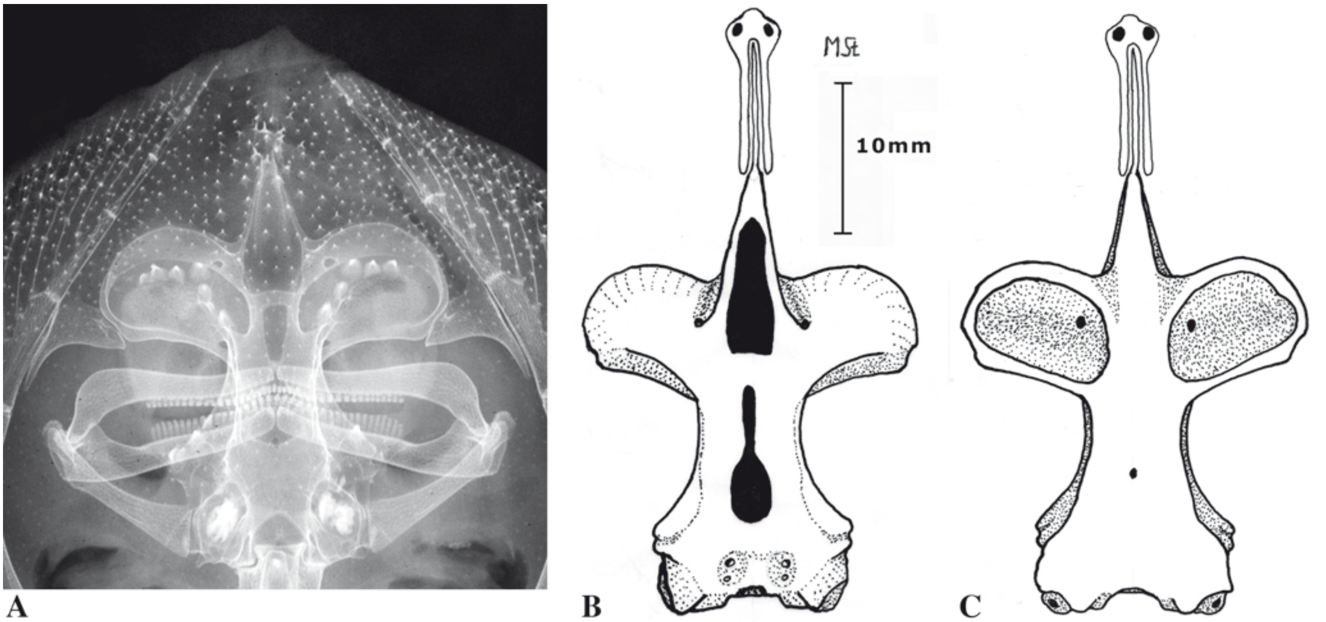

Figure 11. - *Neoraja iberica* n. sp., X-ray of cranium of 322 mm TL mature male holotype (MB 4869) (**A**) and dissected cranium of 230 mm TL juv. female paratype (ZMH 25427) in dorsal (**B**) and ventral (**C**) views. *[Radiographie du crâne de l'holotype, mâle adulte (**A**) et crâne disséqué du paratype, femelle juvénile, en vues dorsale (**B**) et ventrale (**C**).]*

ing process near distal end the component dike, whereas an extension as funnel at distal end is rudimentary; further forms the U-shaped at1 with its distal process external component sentinel, and the club-shaped at2 is the external component spike with its spoon-shaped curved distal end.

Cranium of holotype from X-ray (Fig. 11A; Tab. III). - Rostral base forms moderately broad triangle, base width 18.1% of maximum cranial width; rostral cartilage tapers abruptly at about 2/3 of length to thread-like, non-calcified rostral filament extending to near rostral node. Anterior cranial fontanelle forms elongated narrow triangle with rounded anterior and straight transverse posterior margins; its length 36.6%, its maximum width 16.9% of cranial width. Posterior cranial fontanelle long and club-shaped, with the posterior part being much wider; its length 1.1 times that of anterior fontanelle and 40.6% of cranial width. Fontanelles separated by solid, broad cartilaginous bridge. Nasal capsules very large, with bulging anterior, straight to weakly concave posterior margins and marked preorbital processes; capsules slightly angled forward at 79° to longitudinal axis of cranium. Nasobasal fenestrae absent. Orbital region long, strongly constricted as evenly deep arc; minimum interorbital width dorsally 27.2% of maximum cranial width. Minimum width of basal plate and internasal space 22.2% and 14.1% of cranial width, resp. Otic region relatively long and wide, postorbital processes well marked and separated by notch from smaller pterotic processes. Jugal arches small and delicate, not exceeding contours of occiput. Rostral node thin and plate-like, with two large perforations, and long, thin appendices not fused with rostral shaft; length of appendices about 43% of rostral length.

Scapulocoracoid (Fig. 12; Tab. IV). - One large, vertically to somewhat diagonally oval anterior fenestra is situated nearly completely in the dorsal part of the element above a horizontal line through all three condyles. Post-mesocondyle length of the element is only a bit larger than pre-mesocondyle length, except for the left element of the immature male (ZMH 25428) with a little longer pre-msc-section. A moderately large to very large, more or less horizontally oval postdorsal and postventral fenestra close to horizontal midline, resp. In the female (Fig. 12A), the scapulocoracoid shows a rectangular, rather low overall shape with angular contours, with maximum length being 1.6 times the height at rear corner; the dorsal margin is horizontally concave, with very well marked angular rear corner, the postdorsal margin slopes steeply to metacondyle, as well as the postventral margin from this condyle; ventral margin horizontally nearly straight. In its left element both, postdorsal and postventral fenestrae are equally rather small and of the same size, their length is 87.5 and 100.0%, resp., of that of the anterior fenestra; in its right element, however, pdf and pvf are almost twice as large as in the left element and their length is 111.0 and 105.6% of the af, resp. In the male (Fig. 12B), the element rather displays a more compact, relatively higher and ovoid overall shape with rounded contours, with maximum length being 1.8 times the height at rear corner; dorsal margin is more or less horizontally straight to weakly concave, the rear corner widely angled to rounded but not sharply angular, and postdorsal margin slopes at about 45° angle diagonally to metacondyle, as also does the postventral mar-

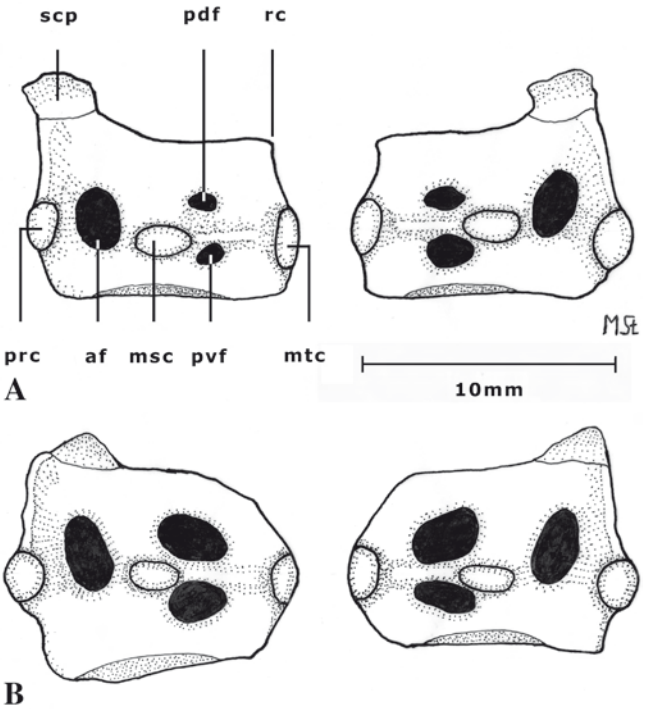

Figure 12. - *Neoraja iberica* n. sp., left and right scapulocoracoids of 230 mm juv. female (ZMH 25427) (**A**) and 252 mm TL juv. male (ZMH 25428) (**B**) paratypes in lateral views. Abbreviations: af = anterior fenestra, msc = mesocondyle, mtc = metacondyle, pdf = postdorsal fenestra, prc = procondyle, pvf = postventral fenestra, rc = rear corner, scp = scapular process. *[Scapulocoracoïdes gauches et droits des paratypes, femelle juvénile (**A**) et mâle juvénile (**B**), en vue latérale. Abréviations : af = fenestra antérieure, msc = mésocondyle, mtc = métacondyle, pdf = fenestra postdorsale, prc = procondyle, pvf = fenestra postventrale, rc = angle postérieur, scp = processus scapulaire.]*

gin from mtc, so that the rear contour appears triangular or trapezoid, rather than rectangular as in the female. The large, oval anterior fenestra is equal in size and shape in left and right element, and corresponds well with the af of the female. However both, postdorsal and postventral fenestrae are about twice as large in the male than in the female, and further are both fenestrae different in size and shape in left and right element of the male.

Pelvic girdle of holotype from X-ray (Fig. 13; Tab. V). - Prepelvic processes are very short, solid conical and outward inclined; two obturatorial foramina in each iliac region; pelvic bar weakly angled only, more so in the female (Fig. 13 B); posterior contour an evenly rounded deep arc in the male, with transition to iliac regions as well marked angles, whereas in the female the rounded arc is much shallower, with transition to iliac regions hardly marked. Iliac processes massive and longer in the male than in the female. Proportionally, the female pelvis is apparently wider than that of the male, whose iliac regions also are more massive, as is shown as well by the relation of maximum width of shoulder girdle to that of the pelvis, resp. (Tab. V).

Variation in paratypes

Proportional morphometrics are given in table I as range and mean.

Like in most rajid species, the shape of disc differs in young and females from that of mature males, in that the latter have a strongly undulated anterior disc margin, whereas in young of both sexes and also larger females it is at most weakly undulated to evenly convex. As a rule the bases of dorsal fins are confluent in this species, but exceptionally do specimens show a more or less distinct interspace separating both dorsals. Only four immature males (ZMH 25428, MNHN 2007-0014, MB 4873c, ZMH 25433) among the Portuguese samples and only one male (MNCN 259.159) among the new Spanish samples had dorsal fins separated. As is demonstrated by the values in table I, there is no obvious sexual dimorphism in proportional morphometrics, and values present in general only a moderate range.

There is little variation in shape and density of dermal denticles on dorsal surface of disc, posterior pelvic lobes, on eyes, tail and on dorsal and upper caudal fins. All specimens are smooth ventrally, except for prickles along the extreme outer edges of the tail. Sides of tail in small juveniles possess only one to two irregular rows of enlarged thornlets. In all specimens, the median row of thorns begins directly posterior to shoulder girdle, or at most on anterior trunk, and appears more regular in young in shape of and distance between thorns. However, from smallest specimens onward, median thorns become rapidly much smaller from about half tail length to D1, to become very insignificant, irregularly spaced and seemingly disappearing with growth. The drastic reduction of median thorns in posterior half to one third of tail is a natural condition and does neither display a late development of thorns in this section with growth, nor a reduction or absorption of existing normal thorns as specimens grow. Thus there is some variation in number of median thorns in small and large specimens. Likewise is some variation displayed in number of orbital, nuchal and scapular thorns, as these appear to be replaced rather often and so vary in number and shape. Also scars are present where thorns have been lost, and have been counted especially in the median row series.

Preorbital thorns of different developmental stages were found in a patch of 2-8, mostly 4-6, on each side. Supraorbitally usually no thorns but a gap separating pre- and postorbital thorns, only very exceptionally may a small supraorbital thorn appear. Postorbital thorns, again differing in development, were found in the range of 2-5, mostly 2-4, each side. Only in about 50% of the specimens was a small supraspiracular thorn present on each side, but regularly was found a pair of small, conical interspiracular thorns with a very few exceptions. Thorns along midline of nape are mostly large and appear in the range of 2-7, mostly 4, with the maximum numbers resulting from few cases with paired thorns anteriorly,

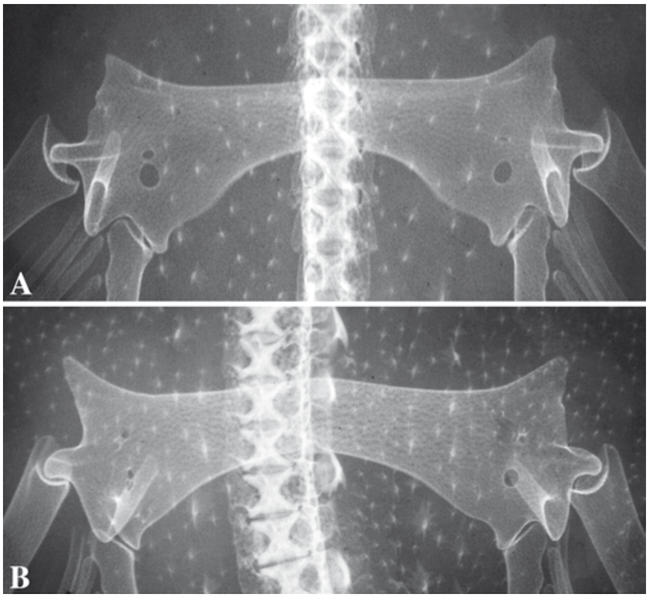

Figure 13. - *Neoraja iberica* n. sp., X-rays of pelvic girdles in dorsal views of 322 mm TL mature male holotype (MB 4869) (**A**) and juv. female of 262 mm TL (TCWC 13204.01) paratype (**B**). [*Radiographies en vue dorsale des ceintures pelviennes de l'holotype mâle adulte (**A**) et du paratype femelle juvénile (**B**).]*

and in one specimen was also a pair of smaller lateral nuchal thorns present. On mid-shoulder mostly a single thorn, but in one third of specimens a second one located usually over rear edge of shoulder girdle. Thorns on shoulders vary from 0-4 on each side, often differing on both sides in number and also in arrangement, i.e. side by side, or in triangular position, but mostly were only one or two thorns found on each shoulder. Median thorns from anterior trunk to level of pectoral axils, mostly in rather regular line and at equally short interspaces, numbered 7-17, mainly in the range of 10-15. Much greater range is shown in number of median tail thorns for reasons mentioned above, with extremes from 25 to about 60, if obvious scars and very tiny thorns in posterior half of tail to D1 are included; about 35-40 is the most frequent count, which however all rather relative due to the uncertainty with counting the tiny median thorns along posterior half of tail. Apparent large thorns from posterior to shoulder girdle to about midlength of tail are in the range of 28-51.

Most obvious is in this species the change in dorsal ground colour from ochre-brown in young to rather medium greyish-brown in larger specimens, along with lively colour pattern in young fading toward mature stages. Figures 2A and 6A show the regular appearance in adult males and females, i.e. of the lively ornamentation of juveniles and half-grown ones remain one or a few pairs of the larger dark spots and eventually one or two pairs of the pale or whitish dots, or specimens may even appear nearly plain brownish. Figure 7 shows the dorsal appearance of small juvenile specimens MB 4873b and ZMH 25432, namely the disc, incl. rostral area and eyeballs, and posterior pelvic lobes are scattered to the extreme outer edges with dark brown oval to circular dots and spots, and of the latter several symmetrical pairs on inner parts of both pectorals are larger and pale edged; mostly two pairs of circular whitish spots are found on inner pectorals level with posterior nape (the larger) and level with posterior trunk (the smaller), and although fading with growth these do often also remain in larger specimens. Occasionally are nuchal and scapular thorns pigmented dark, and few specimens showed a dark transverse bar over shoulder girdle, including the darkly pigmented thorns, and others display dark edging at pectoral axils and/or a dark blotch on pelvic origin. Further are the usually eight blackish-brown cross-bars or somewhat asymmetrically paired saddle blotches along tail more apparent in small specimens. The white underside of disc displays seemingly in smaller specimens with very thin disc margins dark spots and dots, which however are translucent from the dorsal pattern. The intensity of the broad greyish margin to outer disc corners and posterior margins, as well as that to posterior pelvic lobes, varies but becomes indistinct rather in larger specimens. Further variation is shown by the appearance in several specimens (e.g., in the holotype and paratype female ZMH 25434, see Figs 2B, 6B) of variously large clouds on inner ventral pectorals of more or less distinct medium brown spots merging to various degrees.

Internal meristics. - Vtr: 21-26, Vprd: 67-74, P-radials: 60-69, V-radials: 15-20 (Tab. II).

Size

Min.-max. sizes of the material are 55 (neonate)-327 mm TL, with 327 mm for the largest male and 316 mm TL for the largest female; largest adolescent male was 278 mm, smallest mature male was 295 mm TL. Males appear to mature between about 280-290 mm TL.

Distribution (Fig. 1)

Upper slope of southern Iberian Peninsula within Bay of Cadiz at 270-670 m depth. One oblique haul from 172-414 m (ZMH 25427) presumably took the specimen at the deeper part of the haul. Bottom temperature and salinity, if taken, at capture stations were approximately between 12.76 and 13.95°C and 36.18 and 37.20 psu, resp., according to data obtained by J. Baro. Regarding bottom substrate, which was not specifically registered during trawl operations, J. Baro's colleague V. Diaz del Rio provided the following summary for the general condition: "Sediments become progressively finer-grained with increasing depth of water and distance from the sea shore. On the upper slope, there is a strong dominance of contourite deposits composed of fine and very fine, occasionally muddy, sands created by the contour-flowing of the strong outflow current of Mediterranean water through the Strait of Gibraltar".

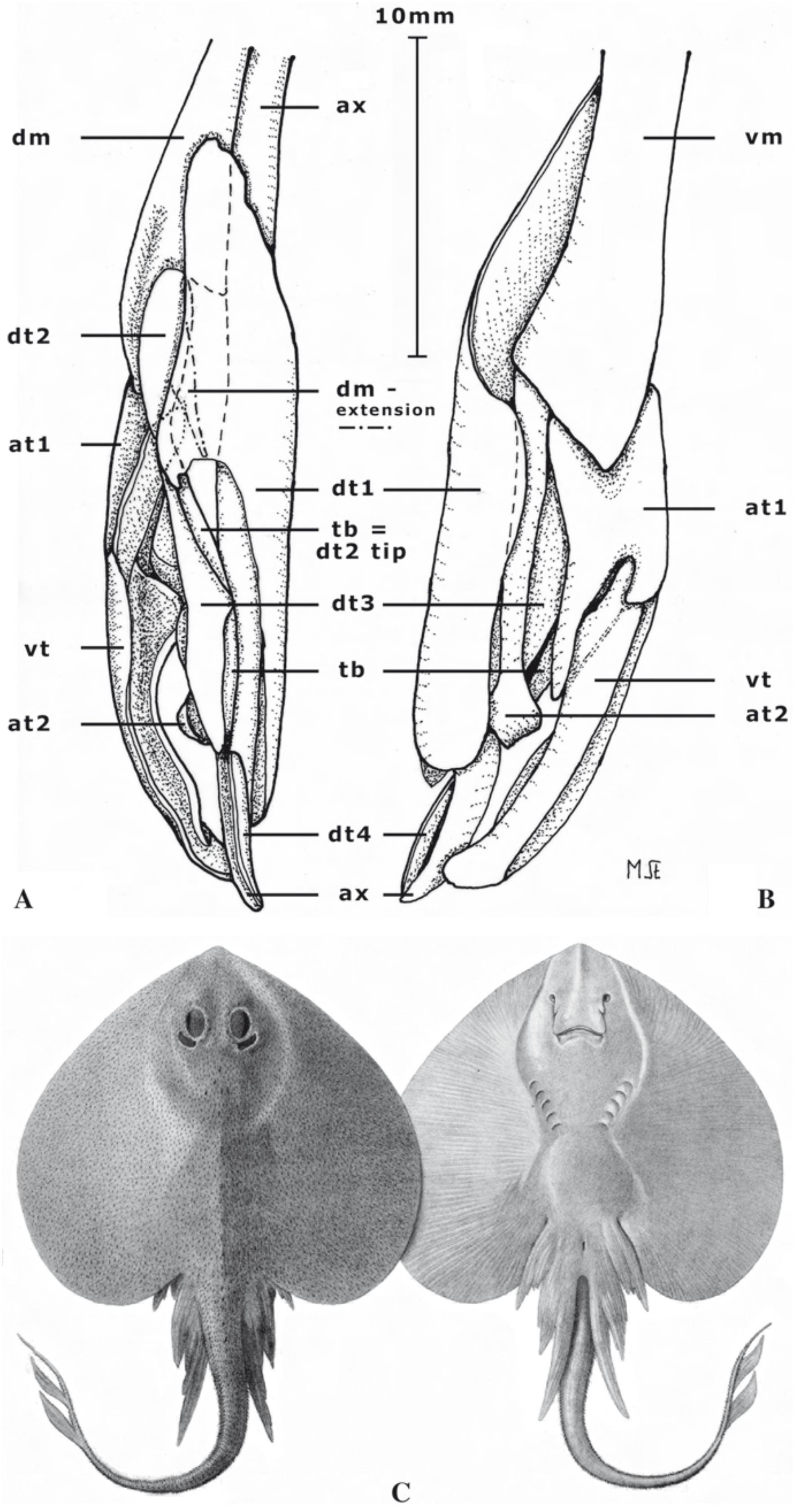

Figure 14. - *Raja fullonica* of Vaillant (1888) (non Linnaeus); mature male about 260 mm TL (MNHN 83-149) = *Neoraja* sp.; skeletonised left clasper in dorsal (**A**) and ventral (**B**) views. Abbreviations as in figure 9; plus dt4 = dorsal terminal 4. Vaillant's original plate 4 illustrations (**C**) of this specimen. *[Mâle adulte d'environ 260 mm LT =* Neoraja *sp. ; vues dorsale (**A**) et ventrale (**B**) du ptérygopode gauche décharné avec son squelette apparent. Abréviations : voir la figure 9 ; plus : dt4 = dorsal terminal 4. Planche 4 originale de Vaillant illustrant ce spécimen (**C**).]*

Etymology

Named for the type localities which are a very restricted area of the eastern North Atlantic along south-western slope of the Iberian Peninsula, in both the Portuguese and Spanish sectors.

Interspecific comparison

N. iberica is already clearly distinguished from its four congeners by its relatively light ochre to medium greyish-brown dorsal ground colour (*vs* plain dark ground colour, or bluish in *N. caerulea*) and by its pattern of largely symmetrically arranged dark brown dots and spots plus a few pairs of small whitish spots on pectorals and posterior pelvic lobes (*vs* no dorsal colour pattern at all). *N. iberica* has an almost totally white underside with at most faint greyish broad margins to outer corners and posterior pectoral margins, as well as to posterior pelvic lobes, and as a rule is its underside of tail plain white. The four congeners, in contrast, show distinctly dark to even blackish broad margins ventrally at least at outer corners and along posterior pectorals, as well as to posterior pelvic margins, and hardly ever a plain white underside of tail. Head and the centre of disc ventrally are usually plain white in *N. iberica*, with at most a cloudy blotch of pale brown, partly merging spots on inner pectoral centres in few specimens. In contrast, as a rule congeners display more or less large dark areas also on underside of head, interbranchially, along line of gills slits, on belly and inner pectorals to at times almost totally dark discs, as well as their underside of tail is always marbled light and dark, largely blotched dark, or even totally dark in anterior half or two thirds of length.

The four congeners resemble each other and *N. iberica* in further external aspects like: general shape, squamation and even morphometric proportions, tooth row counts and internal meristics (Vtr, Vprd, P and V radials), as well as their scapulocoracoids and pelvic girdles are very similar, as largely demonstrated by McEachran and Compagno (1982). Even claspers, except for *N. carolinensis* with no mature males yet known, show externally and in their skeleton a very similar aspect, in that outer surfaces display a rather intensive coverage of fine dermal denticles, and the ‘pseudosiphon’ groove on outer dorsal lobe is either lacking (*N. stehmanni*, *N. caerulea*), or present but formed as a longitudinal, very proximally located groove largely (*N. africana*) or totally (*N. iberica*) within the dorsal dilatator muscle. All congeners with mature males known show externally and in their clasper skeleton the component ‘terminal bridge’ separating two distinct ‘clefts’ on inner dorsal lobe (not labelled by Hulley, 1972, Fig. 4, as neither external components ‘dike’ and ‘funnel’, but likely present according to skeleton Fig. 5), and the lateral ‘dike’ and distal ‘funnel’ extensions of ventral terminal cartilage in its distal third. The large clasper cartilages dorsal terminal 1 and ventral terminal – each of characteristic shape, and dt1 curving around axial distally – are firmly fused with their distal tips on inner ventral side, with (*N. stehmanni*, *N. africana*, *N. iberica* but rudimentary in the latter) or without (*N. caerulea*) distal extension of vt forming external component ‘funnel’, depending on whether the dt1 or the vt is the longer element at distal fusion, and if the vt shows a more or less distinct distal extension. Further differences are due to presence (*N. stehmanni*, *N. africana*) or absence (*N. caerulea*, *N. iberica*) of a distal extension of the dorsal marginal cartilage and so a more or less distinct external component ‘pseudorhipidion’. The accessory terminal 1 and 2 cartilages are in all species, with mature males known, of genus-typical U-shape, with Z-shaped distal lateral extension, or straight club-shaped with spatulate, curved tip, respectively. The number of dorsal terminal cartilages, other than dt1, may vary from mostly three (*N. stehmanni*, *caerulea*, *iberica*) to four (*N. africana*) as a sequence connecting as dorsal lobe support the distal end of dorsal marginal with the terminal bridge to the axial and the very tip of the axial cartilage. To a degree, presence or absence, or distinctiveness of external components supported by cartilages, as well as clasper cartilages themselves may depend on age of a mature male specimen, in that continued growth of cartilage extensions and the increasing degree of skeletal calcification may make up some of the interspecific differences. This may also hold true for integumental components in the glans, as was found in *N. iberica*. Of eight mature males, only three (MNCN 259.163, MNHN 2007-0017, ZMH 25437) showed a rudimentary component flag (fg) in both claspers as a low integumental flap on distal end of the axial cartilage, but a flag showed only in the right glans clasper of MNHN 2007-0017. Such natural variation demonstrates the apparent gradual development of the flag, if it shows at all?, as mature males grow larger and become older.

Based on the revision by McEachran and Compagno (1982) and availability of better species specific information, a final conclusion can now be drawn regarding the generic identity of the *Breviraja* sp. (*Raja fullonica* of Vaillant, 1888, non Linnaeus; Fig. 14C) as mentioned and commented on in CLOFNAM (Stehmann, 1973 and 1979 [Suppl.]) and in FNAM (Stehmann and Bürkel, 1984), which appears to have been taken at 614 m depth on the continental slope off northern Spain, i.e. in the southern Bay of Biscay. This single, badly disintegrated, partly skeletonised mature male of approximately 260 mm TL (MNHN 83-149) has been re-investigated to the still possible details by the senior author, incl. radiographs. It can be assigned now to the genus *Neoraja*, based on mainly the following features: cranium without nasobasal fenestrae and with obviously broad basal rostral triangle narrowing abruptly to a delicate rostral shaft being disintegrated like rostral node and its appendices, but with anterior propterygia and pectoral radials apparently extending forward to nearly snout tip. Totally skeletonised claspers, no more providing any indication of integumental components in the terminal region, do however show all *Neoraja*-typical features of the terminal skeleton (Figs 14A, 14B): large dt1 with proximal extension and distally curving around axial onto ventral surface; elongated vt with anterior notch and medial extension linking with ventral surface of at1 but distally (? no more due to disintegration) not fused to and longer than dt1, further with distal, inner dorsal plate-like, upward curving extension (dike); dt2 to dt4 sequence of dorsal terminal cartilages linking distal end of dm, which has an outer distal extension (pseudorhipidion), with tip of axial, and dt2 with its distal end fused with axial (terminal bridge) and head of dt3; at1 and at2 typically of U-shape with Z-shaped lateral extension and club-shape with spatulate tip, respectively. Internal meristics fall well into the range for congeners: Vtr 25, Vprd 73, P radials approximately 65, and tooth rows approximately 40 in each jaw. Further external characters also fit well the generic diagnosis: individual thorns but no thorn triangle on nape/shoulder region (2 median nuchal, none suprascapular, probably one on each shoulder) and about six small orbital thorns each side; from directly posterior to shoulder girdle one median row of about 50 thorns to D1 (10 on trunk, about 39 on tail) but almost disappearing after two thirds of tail length a fair distance in front of D1. Upper side totally spinulose. Lateral tail folds only in posterior third of tail length.

However, several distinct features distinguish this *Neoraja* sp. from its five congeners: disc of this mature male very evenly inverse heart-shaped, without obvious undulation of anterior margins as is typical in mature males (correctness of pl. 4 in Vaillant, 1888, assumed); colour (in present bad condition and preserved) dorsally and ventrally sort of plain medium brown, without any indication or remains of dorsal colour pattern; dorsal fins widely separated by space of about two times D1 base length, both very short-based and fan-shaped much higher than long, with probably interdorsal thorns between both; this mature male shows a strikingly long postdorsal tail section, which is about twice as long as the distance from D1 origin to D2 base end, bearing a long, low epichordal C lobe terminating a bit anterior to tip of tail.

If the locality in the southern Bay of Biscay at a depth of 614 m has been interpreted correctly, it is surprising that no additional specimens have been discovered. Hence doubts remain concerning the locality of the specimen. The poor condition of the specimen also recommends to not yet formally name this species

DISCUSSION

One may wonder, why *N. iberica* has been only recently discovered, although European slope waters are among the best investigated for a long time, and this moderately rare species lives at upper to middle slope depths having been commercially fished on the bottom for fish and crustaceans again for a long time by local fishermen. The very small size of this pygmy skate species may mainly be responsible, that is has been overlooked probably and/or been discarded at sea or mistaken on a first glance for juveniles of not marketable size of one of the well know, larger growing skate species landed regularly for human consumption. Its very small size eventually also prevented its being caught by trawls, or made it easier for specimens to escape from a trawl. Such circumstances may also have delayed the discovery of *N. caerulea* within the Rockall Trough to the west of Scotland and Ireland until the 1970s, despite its exceptional blue dorsal colour making it indeed obvious in any catch, in particular because commercial deep water fishing there has been carried out by large factory stern trawlers using trawls with large mesh size – unlike the small local fishing boats along the Iberian Peninsula south coast.

Species of the genus *Neoraja* show at least in the Eastern Atlantic mostly an unusually localized, very limited distribution not only compared with other offshore deep water but likewise shelf species of skates. However, their small size is an apparent reason for them being unable to migrate over long distance, and they may have occupied particular ecological niches within their restricted habitat areas, where they have been found living sympatrically with larger species of other deep water skates. Knowledge of their biology is still too limited for confirming the latter assumption. According to Compagno *et al.* (1991) is *N. stehmanni* an endemic off the west coast of South Africa from mainly about Saldanha Bay to south of Agulhas Bank, with so far only one more northern record south west of Orange River mouth at 292-1025 m depth. It is said (*loc. cit.*) to have been caught in considerable numbers of mostly adults off Cape Town and Saldanha Bay in limited areas below 600 m depth. *N. caerulea* has only been found at about 600-1260 m depth within the Rockall Trough to the west of Scotland and Ireland on the continental slope and slopes of surrounding submarine banks, with occasional records also on the outer slopes of the latter banks delimiting the Trough to the north and west. Bottom water temperatures at capture localities were between 6.41° and 9.102°C, mostly between 6.4° and 6.9°C, and salinities between 35.171 psu and 35.326 psu. The species thus appears to live within the NE Atlantic water mass characterised by temperatures higher than 6°C and salinity of more than 35 psu. If this holds true, the depth range of *N. caerulea* will be limited to a maximum of about 1300 m (Stehmann, 1976; Stehmann and Bürkel, 1984). *N. africana* was so far found with three type specimens on the Central West African continental slope off Gabon at 900-1030 m and 4.35° to 4.66°C (Stehmann and Séret, 1983) and with one postembryonic female off Mauritania/Rio de Oro at 1490-1640 m depth (Stehmann, 1995). With these two widely separated localities and apparently greater depth range, *N. africana* shows a wider geographical distribution within the Eastern Atlantic than its congeners. *N. iberica* with its very limited distribution, eventually sharply restricted by the outflow of high salinity Mediterranean water through the Strait of Gibraltar, is geographically intermediate between *N. africana* and *N. caerulea*, and the *Neoraja* sp. of Vaillant (1888) from off the north coast of Spain – correctness of its locality given – is intermediate between *N. iberica* and *N. caerulea*. The only NW Atlantic congener, *N. carolinensis*, was found with all but one of six type specimens off North Carolina at 695-1010 m, 4.18-4.56°C and 34.929-34.958 psu, only one paratype off Florida at 1000-1008 m, 6.09°C and 35.035 psu (McEachran and Stehmann, 1984).

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Appendix by the authors

added to PDF of CYBIUM 32(1): 51–71, 2008

by

Matthias F.W. Stehmann, Bernard Séret, Esmeralda M. Costa & Jorge Baro

Dear colleagues and reprint exchange partners, May 2008

We would like to add below to the publication PDF, containing black & white photographic illustrations of type specimens, in favour of all readers and users and particularly for better field identification of the newly described species:

a) Resumo in Portuguese and Resumen in Spanish,
b) photographic illustrations of figures 2–4 and 6–7 in colour.

The layout of this appendix was prepared by Joachim Stehmann.

Resumo – *Neoraja iberica* n. sp., uma nova espécie de raia pigméia Europeia (Elasmobranchii, Rajidae) proveniente do declive superior da Península Ibérica (Atlântico Nordeste).

A descrição da *Neoraja iberica* n. sp., é baseada em séries de 50 espécimes–tipos representando todos os tamanhos de ambos os sexos provenientes do declive da costa sul da Península Ibérica, abrangendo os sectores português e espanhol. Esta espécie de raia pigméia foi encontrada com comprimentos totais máximos de 316 mm e 327 mm para as fêmeas e os machos, respectivamente sendo os espécimes mais pequenos uma fêmea com 55 mm TL e um macho com 67 mm TL. A distribuição geográfica no declive continental superior é muito limitada tal como as outras três congéneres do Atlântico oriental. Apesar das características internas específicas do crânio, do escapulacoracóide e do esqueleto do pterigopódio, esta nova espécie é facilmente distinguida externamente das suas quatro congéneres denominadas *N. stehmanni, N. caerulea, N. africana* e *N. carolinensis* por possuir: face dorsal com côr de base ocre a mais ou menos castanho–acinzentado e cinzento escuro, com uma ornamentação viva nos espécimes pequenos com pontos e manchas castanhas escuras em toda a superfície do disco e nos lobos pélvicos posteriores até à extremidade das margens; acrescido frequentemente de poucos pares de pontos e manchas esbranquiçadas na face interna das barbatanas peitorais; 7–8 barras transversais escuras ou assimetricamente carregado de pares de manchas ao longo da cauda, cujo padrão se desvanece com o crescimento, reduzindo-se nos adultos a poucos pares de manchas, maiores e desvanecidas nas suas orlas, e acrescidas, sobretudo, de 1–2 pares de pontos esbranquiçados, e com barras transversais ou carregadas de manchas ao longo da barbatana caudal que se vão tornando menos nítidas; faces ventrais do disco, barbatanas pélvicas e cauda de côr branca, quando muito com uma margem acinzentada esbatida até ao disco posterior e lobos pélvicos, podendo ocasionalmente aparecer no centro de cada barbatana peitoral uma `nuvem´ de manchas castanhas fundidas.

Um espécime macho maturo com cerca de 260 mm TL, proveniente da parte sul da Baía da Biscaia e em mau estado de conservação, originalmente identificado por Vaillant (1888) como *Raja fullonica* L, 1758, é actualmente atribuído ao género *Neoraja*, baseado principalmente nas características dos seus pterigopódios quase reduzidos a esqueletos.

Discute-se sumariamente, para cada espécie, a natureza ocasional da informação disponível e a sua gama de distribuição muito limitada ao longo do Atlântico Oriental, desde a África do Sul até à Escócia, ocorrendo quatro dessas espécies a oriente e uma única espécie a noroeste do Atlântico.

Resumen – *Neoraja iberica* n. sp., una nueva especie Europea de raya pigmea (Elasmobranchii, Rajidae) del talud superior de la región Sur Atlántica de la Península Ibérica (Atlántico Nororiental).

Se describe *Neoraja iberica* n. sp. a partir de una serie constituida por 50 especimenes tipo que cubren todo el rango de tallas de ambos sexos provenientes del talud sur atlántico de las costas portuguesa y española de la Península Ibérica. La longitud máxima total encontrada para esta especie de raya pigmea ha sido de 316 mm para las hembras y de 327 mm para los machos. Los individuos más pequeños fueron una hembra neonata de 55 mm LT y un macho de 67 mm LT. Como ocurre con sus tres congéneres del Atlántico Oriental su distribución geográfica sobre el talud superior es muy restringida. Además de características internas específicas de la anatomía del cráneo, de la cintura torácica y del pterigópodo, externamente esta nueva especie es fácilmente distinguible de sus cuatro congéneres *N. stehmanni, N. caerulea, N. africana* and *N. carolinensis* por su patrón de coloración dorsal, que va desde el ocre al gris oscuro pasando por un marrón grisáceo intermedio sobre el que se dispone, en los ejemplares de menor talla, una vívida ornamentación de puntos y motas de color marrón oscuro por todo el disco y los lóbulos posteriores de las aletas pélvicas hasta sus márgenes externos; además aparecen frecuentemente unos pocos pares de motas y puntos blanquecinos en la zona interna de las aletas pectorales y 7-8 bandas negruzcas transversales o bien manchas pareadas oscuras y alargadas dispuestas asimétricamente en la cola. Este patrón se desvanece con el crecimiento y llega a reducirse en los adultos a tan sólo unos pocos pares de manchas más grandes y oscuras, motas con bordes difusos y, en la mayoría, 1-2 pares de los puntos blanquecinos, además las bandas transversales o manchas alargadas a lo largo de la cola son menos patentes. El lado inferior del disco, de las aletas pélvicas y de la cola son blancos, con presencia en la mayoría de un débil borde grisáceo en la parte posterior del disco y los lóbulos de las aletas pélvicas, aunque ocasionalmente aparece un sombreado formado por motas entremezcladas de color pardo en el centro de cada pectoral.

Un macho maduro conservado en mal estado de aproximadamente 260 mm de LT procedente del Golfo de Vizcaya, originalmente identificado por Vaillant (1888) como *Raja fullonica* L, 1758, se incluye ahora en el género *Neoraja* principalmente en base las características anatómicas de sus pterigópodos casi totalmente reducidos a esqueleto.

Se discute brevemente la fragmentada y muy limitada distribución de cada especie a lo largo de todo el Atlántico Oriental, desde Sudáfrica hasta Escocia, con la presencia de cuatro o cinco especies en el Atlántico Oriental y tan sólo una en el Noroccidental.

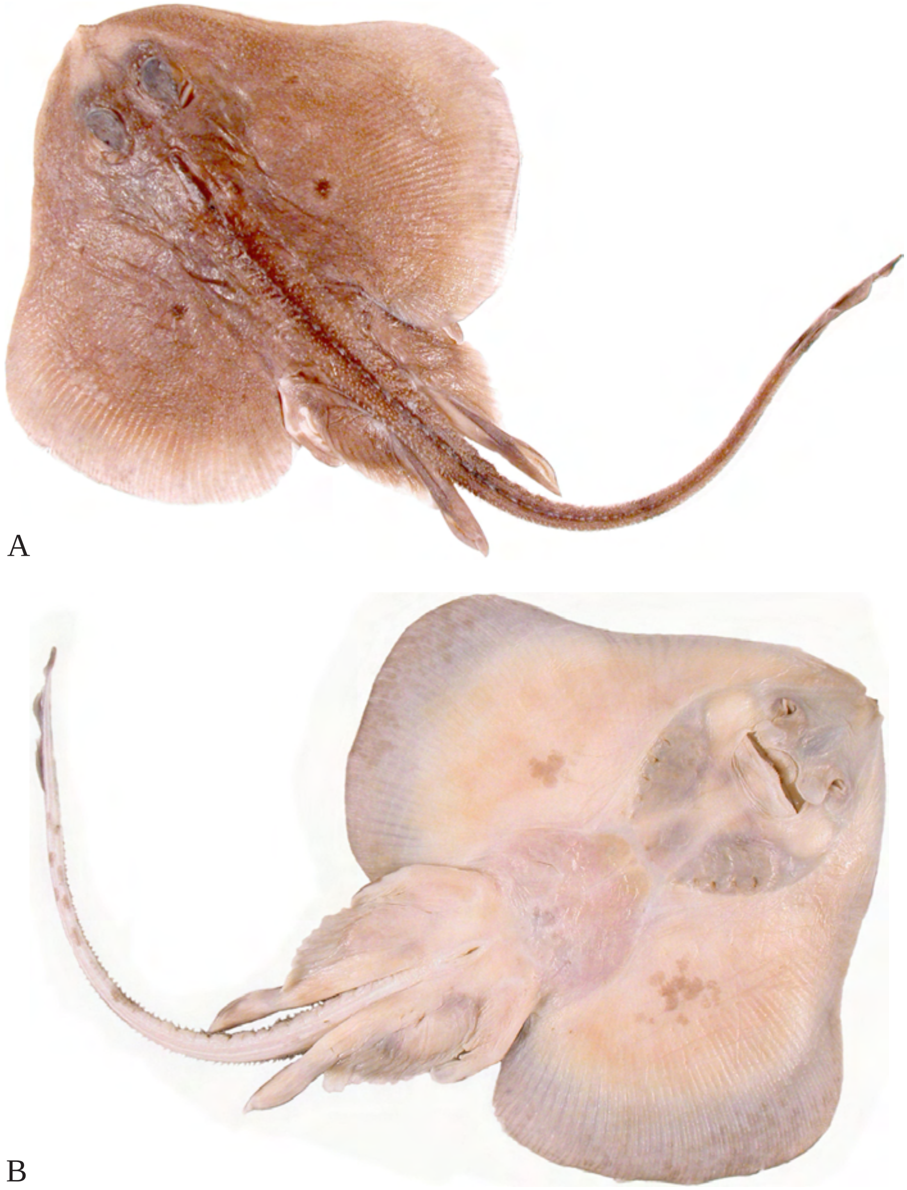

Figure 2. – *Neoraja iberica* n. sp., 322 mm TL mature male holotype, MB 4869, in total dorsal (A) and ventral (B) views.

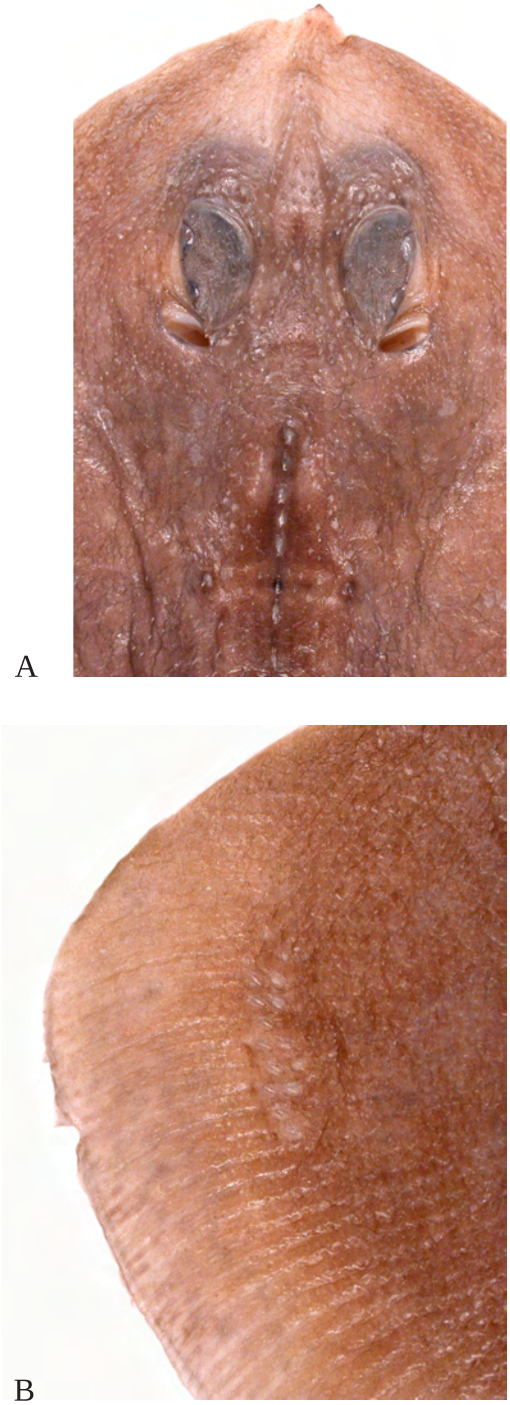

Figure 3. - Neoraja iberica n. sp., 322 mm TL mature male holotype, MB 4869, close ups of head dorsally (A) and of left wing tip with alar thorn field (B).

Figure 4. – *Neoraja iberica* n. sp., 322 mm TL mature male holotype, MB 4869, close ups of mouth/nasal region (A), pelvic fins and claspers dorsally (B) and enlarged tail section dorsally (C) showing transition from regular median thorn row to its becoming irregular and almost disappearing in posterior half of tail.

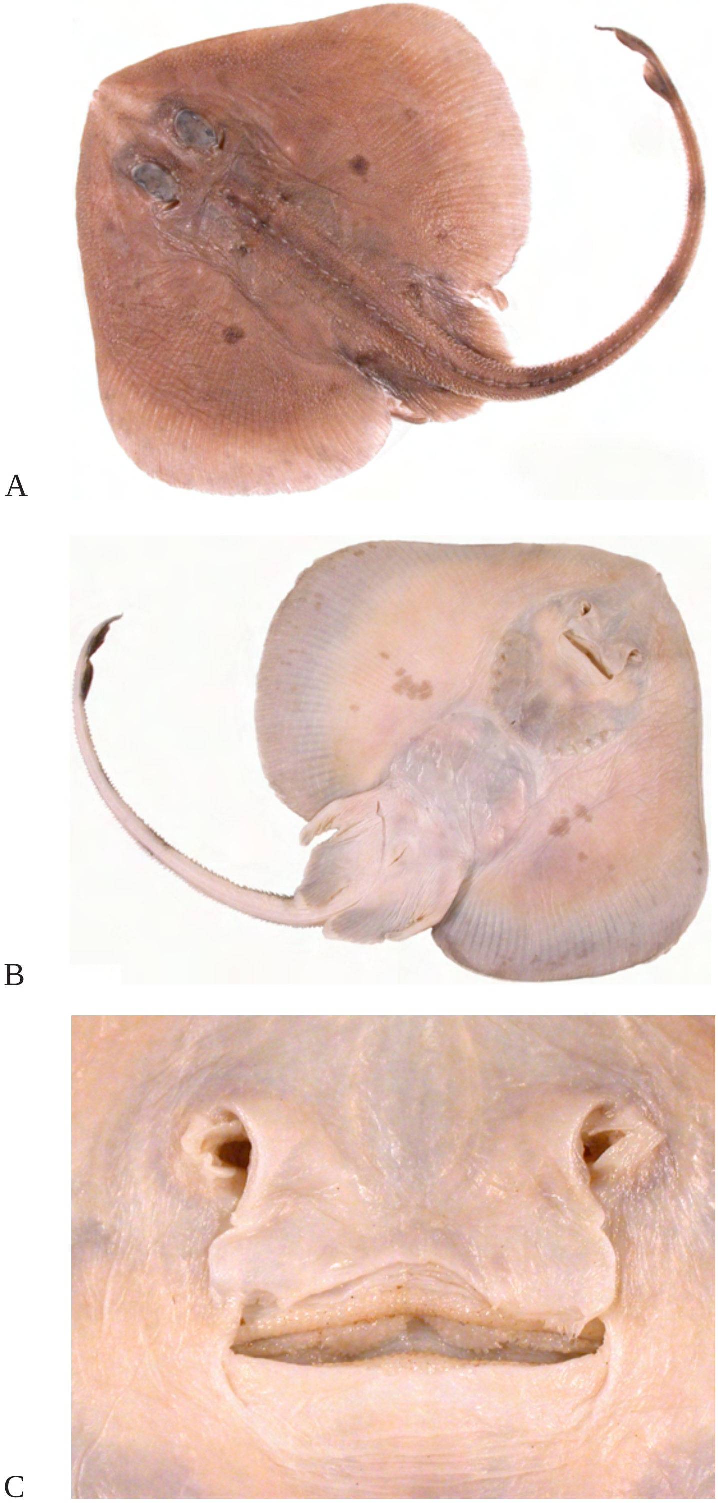

Figure 6. – *Neoraja iberica* n. sp., 316 mm TL mature female paratype, ZMH 25434, in total dorsal (A) and ventral (B) views, plus enlarged mouth/nasal region (C).

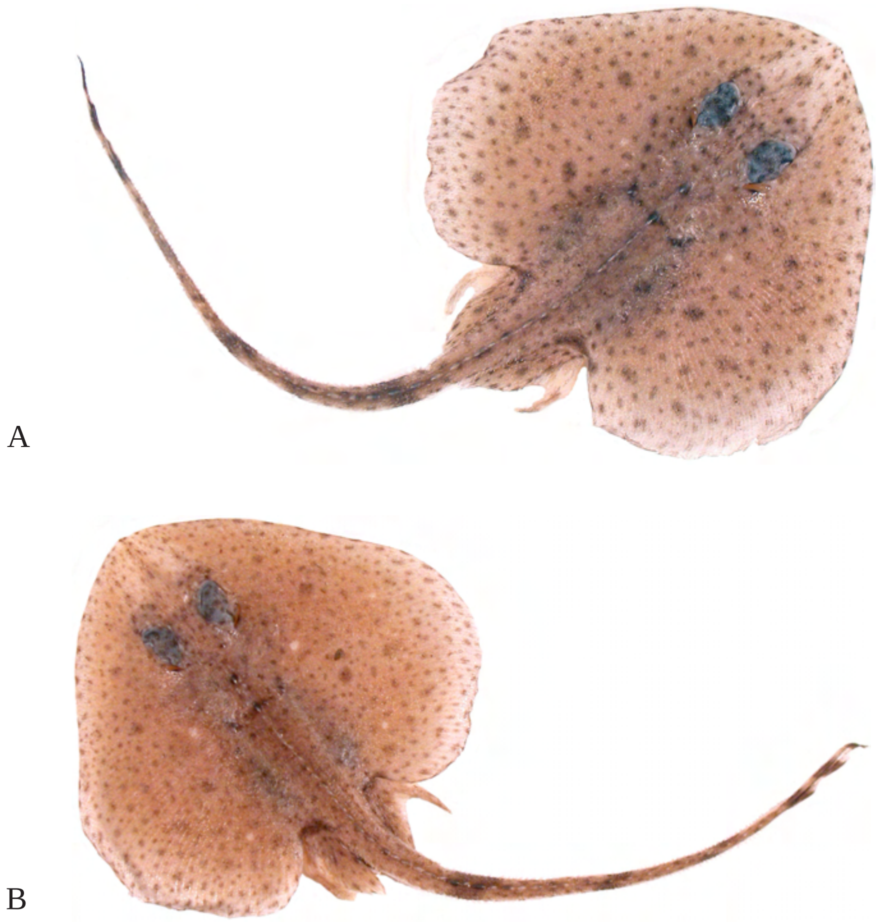

Figure 7. – *Neoraja iberica* n. sp., 129 mm juv. female (MB 4873b) (A) and 143 mm TL juv. male (ZMH 25432) (B) paratypes showing distinct juvenile dorsal colour pattern.

ERRATA slip by the authors, June 2008

Neoraja iberica n.sp. Stehmann, Séret, Costa & Baro, 2008 - Cybium 32(1):51-71

Even proofreading by eight eyes cannot exclude errors 100% - to our regret! Please note the following corrections concerning meristics of the holotype and paratypes:

Table II on page 58, column 1 for the holotype:

Pectoral radials, instead of 64, should read **65**
Pelvic radials, instead of 18, should read **19**
Lower jaw tooth rows, instead of 44, should read **37**.

Accordingly, on page 63 for the holotype's '*Internal meristics*':

P radials, instead of 64/64, should read **65/65**

The tooth row counts for the holotype on page 58, left column below, are correct with 41 upper and 37 lower jaw.

Ranges and values in Table II for the paratypes are correct but not in accordance with text on page 66, right column:

Accordingly, on page 66 for '*Internal meristics*' of the paratypes:

Vtr, instead of 21-26, should read **20-27**
Vprd, instead of 67-74, should read **67-78**
P-radials, instead of 60-69, should read **64-69**
V-radials, instead of 15-20, should read **16-20**

We apologise for these errors having slipped through, but better discovered by ourselves than by the readers of our contribution. Thank you all for your kind understanding that 'nothing is perfect'!

Cah. Biol. Mar. (2013) 54 : 309-317

Cases of abnormal hermaphroditism in velvet belly *Etmopterus spinax* (Chondrichthyes: Etmopteridae) from the southern coast of Portugal

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Abstract: The authors described in this note three hermaphroditic specimens of the Velvet belly *Etmopterus spinax* (Linnaeus, 1758) captured off the southern coast of Portugal (Algarve), during commercial trawl fisheries. The concomitant presence of a pair of claspers and a normal and complete female reproductive system allowed considering these specimens as hermaphrodites. These three specimens are the first cases of hermaphroditism recorded in *E. spinax* to date and the second reported case of hermaphroditism in chondrichthyan species in Portuguese waters. The authors summarized and comment the different records of hermaphroditism known to date in sharks, pointing out that such a phenomenon is extremely rare within this group.

Résumé : *Cas d'hermaphrodisme anormal chez le sagre noir* Etmopterus spinax *(Chondrichthyes: Etmopteridae) de la côte méridionale du Portugal*. Les auteurs décrivent dans la présente note trois spécimens hermaphrodites de sagre noir *Etmopterus spinax* (Linnaeus, 1758), capturés devant la côte méridionale du Portugal (Algarve), lors de chalutages commerciaux. La présence d'une paire de ptérygopodes et d'un appareil reproducteur femelle complet et normal permet de considérer ces spécimens comme hermaphrodites. En outre, ces trois spécimens sont les premiers cas d'hermaphrodisme signalés chez *E. spinax* et le second d'hermaphrodisme rapporté chez les chondrichthyens dans les eaux portugaises. Les auteurs résument et commentent les différents signalements d'hermaphrodisme connus à ce jour chez les requins, mettant en évidence qu'un tel phénomène est extrêmement rare dans ce groupe.

Keywords: Abnormal hermaphroditism • Chondrichthyes • Etmopteridae • *Etmopterus spinax* • Southern coast of Portugal

Introduction

Velvet belly lantern shark *Etmopterus spinax* (Linnaeus, 1758) is a small to medium-sized common shark, well known in the eastern Atlantic, from Iceland and Norway to Portugal (Quéro et al., 2003). South Strait of Gibraltar, the species is reported off Morocco (Lloris & Rucabado, 1998), Mauritania (Maurin & Bonnet, 1970), Senegal (Capapé et al., 2001a & b), Guinea Bissau (Sanches, 1991), Azores (Sanches, 1986; Santos et al., 1997), Madeira (Sanches, 1986) and the Cape Verde Islands (Menezes et al., 2004), also in southern Africa (Compagno, 1984). *E. spinax* is

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reported in both Mediterranean Basins (Capapé, 1989; Golani, 2005), in waters between 150-200 m to 400 m, and probably more (Quignard & Capapé, 1971), however, it has been recorded down to 2200 m in the Ionian Sea (Sion et al., 2004).

Previous studies on the reproductive biology of *E. spinax* showed that it is a viviparous aplacental species, with a gestation period not exceeding one year. Sexual maturity is reached at similar sizes for specimens from off the British Isles (Hickling, 1963) and those from the Tunisia coast (Capapé et al., 2001b). Additionally, in each area, males matured at a smaller size than females, 350 mm and 380 mm respectively, with 460 mm the maximum size recorded for both sexes. However, Compagno (1984) noted that the maximum size observed was 600 mm. Capapé et al. (2001b) recorded near term embryos, having 126 mm total length and weighing 6.03 g in pregnant females. Lo Bianco (1909), Hickling (1963) and Capapé et al. (2001b) considered that the gestation period did not exceed a year. Food composition and feeding habits of *E. spinax* have been studied from different marine areas of the eastern Atlantic and Mediterranean. Stomach contents were analyzed and showed that the species feeds on crustaceans, teleosts and cephalopods (Relini Orsi & Wurtz, 1977; McPherson, 1980; Capapé et al., 2003).

Off the southern Portuguese coast (Algarve), *E. spinax* is commonly caught as bycatch by bottom trawls, being always discarded at sea since it has no commercial value (Borges et al., 2002). Thus, in order to obtain information on fisheries discards, research was carried out on board commercial bottom trawl fisheries trawlers targeting red shrimp, *Aristeus antennatus* (Risso, 1816), deep-water rose shrimp *Parapenaeus longirostris* (Lucas, 1847) and Norway lobster *Nephrops norvegicus* (Linnaeus, 1758) operating off the southern coast of Portugal (Algarve). Of the 629 specimens of *E. spinax* sampled during the survey, three revealed an abnormal genital apparatus, and constituted new cases of hermaphroditism; the first recorded to date in this species, to the best of our knowledge.

The aims of the paper are to describe each specimen, define the kind of hermaphroditism, normal or abnormal, and comment and discuss hermaphroditism in shark species. Of the three categories of abnormalities reported by Dawson (1964, 1966 & 1971) and Dawson & Heal (1971) in chondrichthyans, hermaphroditism is probably the most interesting due to the fact that it directly concerns reproductive organs and reproduction.

Material and Methods

The whole sample including three abnormal specimens was collected during fishing carried out between February 1999 and September 2000, mostly on muddy and sandy bottoms, using a minimum codend mesh size of 50 mm. Specimens were taken to the laboratory where they were frozen whole for later study and processed after thawing. Identification to species level was confirmed from Compagno (1984) and McEachran & Branstetter (1984).

During the study, all measurements were recorded to the nearest lowest millimeter. Total length was measured in a straight line from the tip of the snout to the posterior tip of the caudal fin, depressed along the anterior-posterior axis of the fish (Compagno, 1984 & 2001). Total body weight, eviscerated weight, the weights of the ovaries and the liver after being excised were recorded to the nearest lower centigram. Lengths of left and right male claspers were recorded, and state of the claspers (flexibility or rigidity) was noted. Inner clasper lengths were measured from the point of insertion at the cloaca to distal tip of clasper and outer clasper lengths were measured from the point of outside insertion in the pelvic fin to tip of clasper (Compagno, 1984 & 2001).

Additionally, maximum oviduct widths, right oviducal gland, length and width, ovaries length, width and weight, oocyte diameters and uteri width were recorded. All measurements of reproductive organs were taken with a digital caliper with 0.01 mm precision and weights with a digital scale to an accuracy of 0.01 g. Sexual maturity was ascertained macroscopically and was determined following the maturity scale proposed by Stehmann (2002) for viviparous chondrichthyan species. Test for significance was performed by chi-square test with $p < 0.05$ following the methodology of Schwartz (1963).

Results

The first specimen was caught in March 1999, at depths ranging from 561 to 650 meters, between 36°46´04´´N-36°53´15´´N and 7°37´55´´W-7°53´08´´W (Fig. 1). It measured 320 mm in total length and weighted 130.71 g. Eviscerated and liver weights were 85.33 and 20.49 g, respectively. Claspers were soft, flexible and longer than extreme tips of posterior pelvic fins lobes, but the left clasper was rather smaller, 3 mm outer length; 19 mm inner length, than the right one, 6 mm outer length; 22 mm inner length. Both left (LO) and right (RO) ovaries were transparent and almost equally of the same length, 46.59 mm in LO and 46.80 mm in RO, and weight, 0.13 g in LO and 0.14 g in RO. The right ovary was slightly wider, 5.58 mm, than the left ovary, 4.78 mm. Some small-sized transparent ovarian eggs (oocytes) in the ovaries were visible, but not macroscopically measurable. Oviducal glands (OG) appeared to be in a developing stage, measuring 12.06 mm in length and 4.58 mm in width (right OG). Oviducts were widened posteriorly forming the

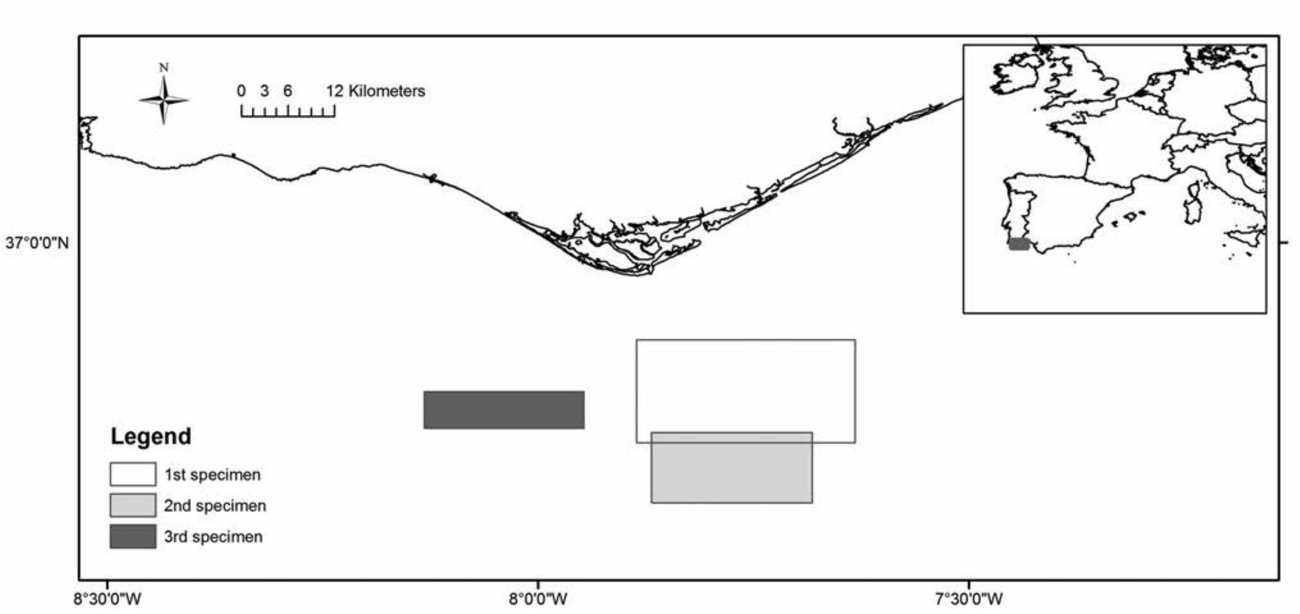

Figure 1. *Etmopterus spinax*. Map of southern Portugal showing the capture areas of the three abnormal hermaphroditic specimens.

uterus, and the widths of right and left sides were 5.36 and 5.53 mm, respectively (Fig. 2). Measurements and weights of the internal female reproductive organs were within the range of values observed in normal maturing females of similar total length, with exception of a wider uterus. The state of these organs allowed us to classify this specimen as a maturing female, according to Stehmann (2002).

The second specimen was caught in September 1999, at depths ranging from 595 to 640 meters, between 36°41´53´´N-36°46´47´´N and 7°40´55´´W-7°52´05´´W (Fig. 1). It had a total length of 319 mm and a total weight of 132.90 g. The eviscerated body weight and liver weight were 84.56 and 25.65 g respectively. Both claspers were soft, flexible and extended beyond the extreme tips of

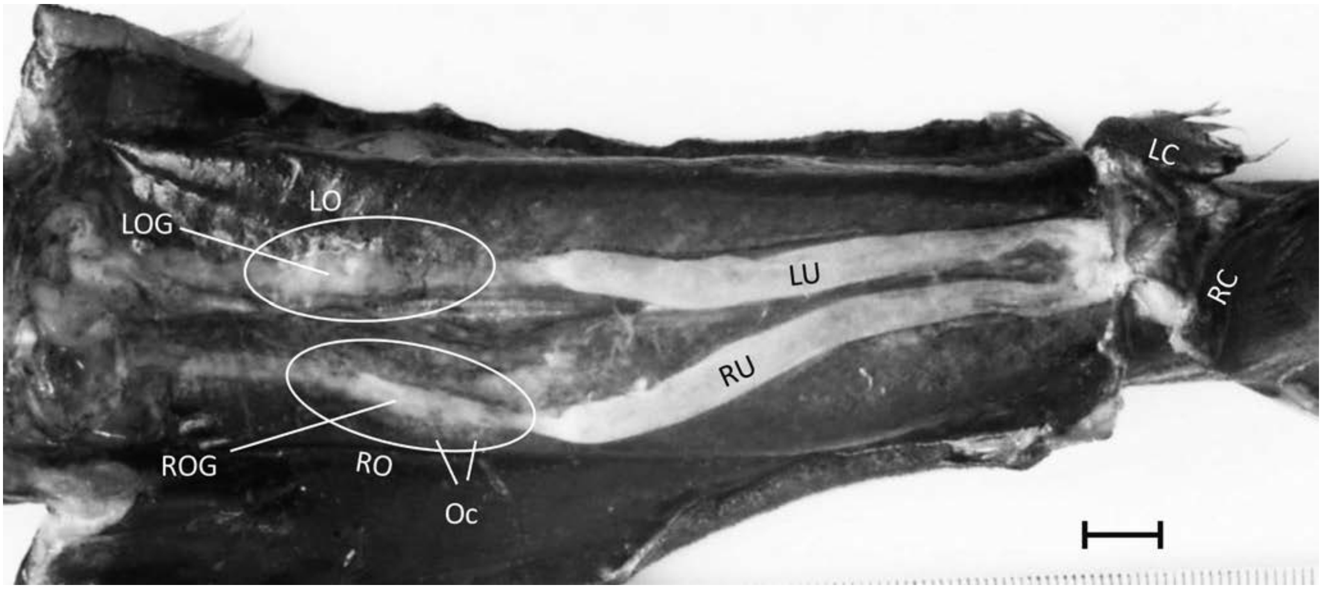

Figure 2. *Etmopterus spinax.* Ventral view of the abdominal cavity of the first abnormal hermaphroditic specimen of *Etmopterus spinax*, showing normal female reproductive organs and claspers. LC, left clasper; RC, right clasper; LOG, left oviducal gland (underneath the ovary); ROG, right oviducal gland (underneath the ovary); LO, left ovary; RO, right ovary; Oc, oocyte; LU, left uterus; RU, right uterus.

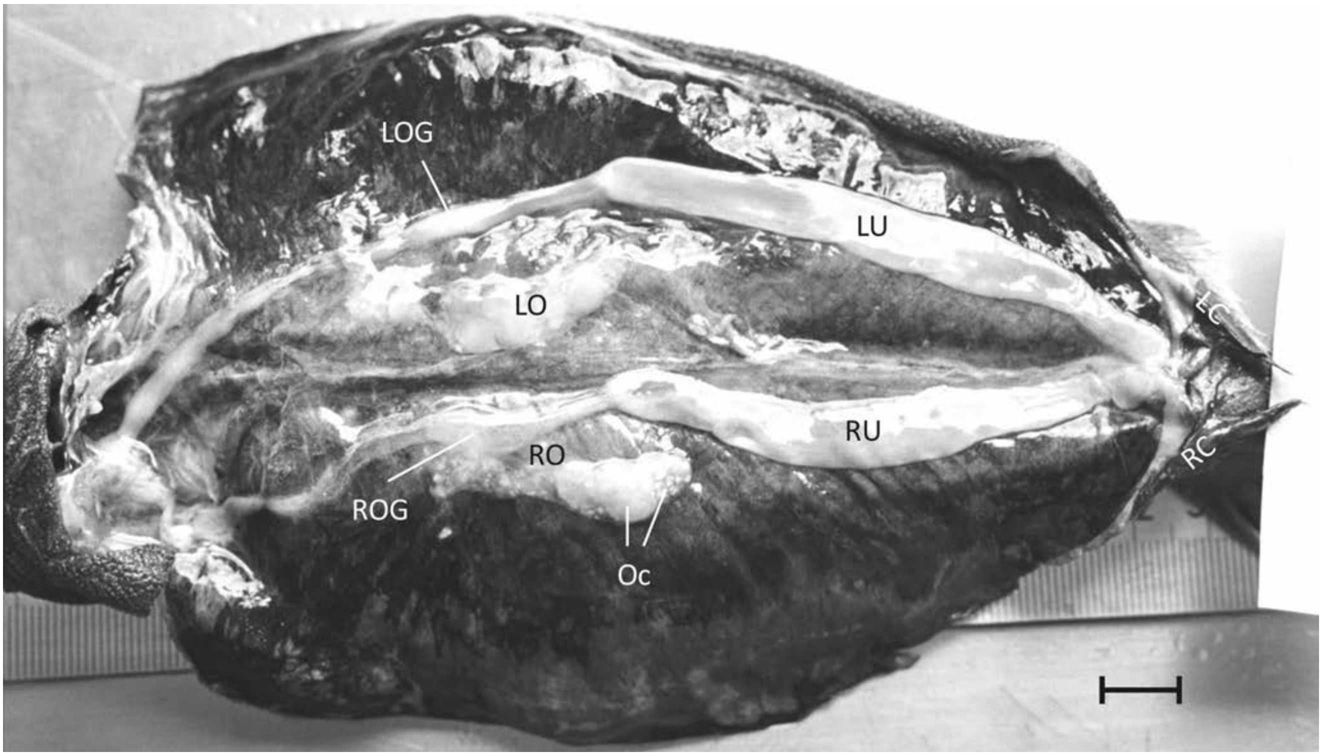

Figure 3. *Etmopterus spinax.* Ventral view of the abdominal cavity of the second abnormal hermaphroditic specimen of *Etmopterus spinax*, showing normal female reproductive organs and claspers. LC, left clasper; RC, right clasper; LOG, left oviducal gland; ROG, right oviducal gland; LO, left ovary; RO, right ovary; Oc, oocyte; LU, left uterus; RU, right uterus.

posterior pelvic fins lobes, being the left clasper quite smaller, 3 mm outer length; 22 mm inner length, than the right clasper, 7 mm outer length; 26 mm inner length. The left ovary was rather smaller, 41.03 mm and wider, 10.60 mm, but also heavier, 0.22 g, than the right ovary, which was 45.16 mm in length, 7.25 mm in width and 0.15 g in weight. Both ovaries exhibited translucent oocytes having different small sizes, 5.15 mm maximum diameter, easily recognizable by naked eye. The right oviducal gland measured 12.81 mm in length and 5.40 mm in width. Oviducts were still narrow, 2.40 mm in left side and 3.38 mm in right side, posteriorly widened forming the uterus, with widths quite similar on both left and right sides, 9.51 and 9.91 mm, respectively (Fig. 3). The description of the internal female reproductive organs fits the criteria of a maturing female defined by Stehmann (2002). Measurements and weights of the internal female reproductive organs were comparable to those of normal maturing females of the same size, and only the inner right clasper length presented a size similar to this of maturing males having the same total length.

The third specimen was caught in September 1999, at depths ranging from 465 to 590 meters, between 36°47′05′′N-36°49′38′′N and 7°56′49′′W-8°07′55′′W (Fig. 1). The total length of this specimen was 376 mm and the total weight was 238.57 g. The eviscerated body and liver weighed 147.04 and 59.78 g, respectively. Both left and right claspers were of the same size, 10 mm outer length; 29 mm inner length, and were rigid and longer than the extreme tips of the posterior pelvic fin lobes. Ovaries were large, well rounded and measured 63.10-74.63 mm in length, 15.71-19.82 mm in width and 2.45-4.23 mm in weight, on the left and right side, respectively. The specimen contained enlarged yolked oocytes, easily counted and measured, and almost all about the same size, with a maximum diameter of 13.48 mm. The right oviducal gland measured 15.28 mm in length and 5.40 mm in width. Oviduct width ranged from 3.28 mm in left side to 5.30 mm in right side. The uterus was rather wider on the right side, 10.01 mm, than on the left side, 9.06 mm (Fig. 4). The condition of both ovaries and uterus allowed us to classify this specimen as a mature female according to Stehmann (2002). The internal female reproductive organs measurements and weights are typical of those found in the same range size of normal mature females, with the exclusion of the uterus (narrower) and the oviducts (wider). As no normal mature male more than 330 mm in total length was sampled, it was not possible to verify if the claspers of this specimen approached the length of normal mature males.

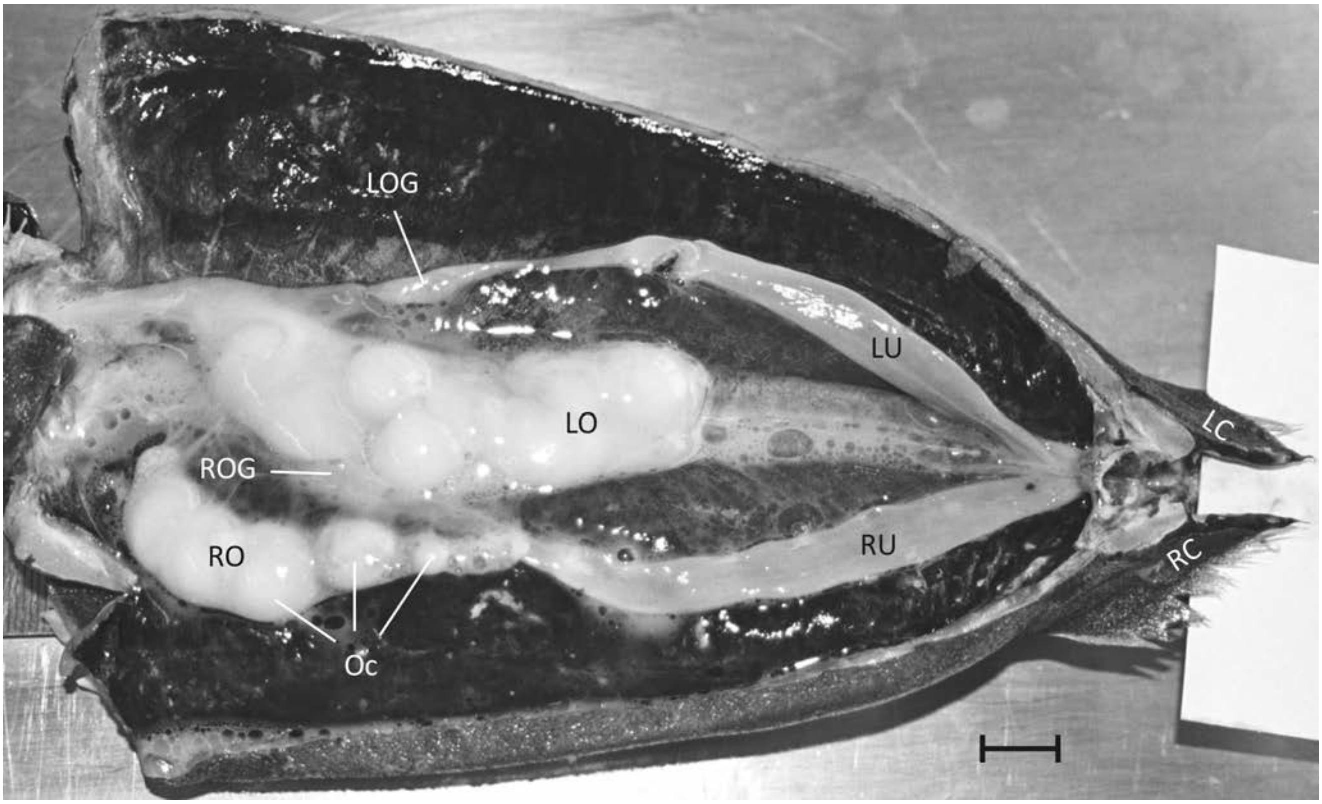

Figure 4. *Etmopterus spinax.* Ventral view of the abdominal cavity of the third abnormal hermaphroditic specimen of *Etmopterus spinax*, showing internal normal female reproductive organs and male claspers. LC, left clasper; RC, right clasper; LOG, left oviducal gland; ROG, right oviducal gland; LO, left ovary; RO, right ovary; Oc, oocyte; LU, left uterus; RU, right uterus.

Discussion

Although *Etmopterus spinax* has been the subject of studies concerning some aspects of its reproductive biology and diet and feeding habits, no case of hermaphroditism has to date been reported for the species. Thus, the three *E. spinax* described in the present paper constitute the first cases of hermaphroditism ever recorded for the species, and the second for chondrichthyans in Portuguese waters; the first one was described in the Portuguese dogfish *Centroscymnus coelolepis* (Bocage & Capello, 1864) by Veríssimo et al. (2003). Consequently, the low occurrence of *E. spinax* hermaphroditic specimens highlights the rarity of such an abnormality, in agreement with Atz (1964), and the reports of Dawson (1964, 1966 & 1971) and Dawson & Heal (1971).

Two types of hermaphroditism are generally reported in chondrichthyans such as 'abnormal hermaphrodite' and 'normal hermaphrodite' following Atz (1964) and Iglesias et al. (2005), and defined also as 'pseudo-hermaphrodite' and 'true hermaphrodite' by Irvine et al. (2002). Normal hermaphrodites or true-hermaphrodites exhibit internally both sexes with claspers and when mature the individual could assume both male and female functions; while all other cases of hermaphroditism would be defined as abnormal or pseudo-hermaphroditism (Irvine et al., 2002; Iglesias et al., 2005). Additionally, Atz (1964) and Bortone & Davis (1994) noted that intersexuality is considered when primary or secondary characters of both sexes are present in a same specimen. The presence of claspers characteristic of males and a normal and complete female reproductive system in the three *Etmopterus spinax* specimens described, allowed us to state that they are abnormal or pseudo-hermaphrodite sharks, following the definitions cited above.

In Table 1, we have summarized reports of the 30 hermaphroditism cases available to date in the literature; it appears that number of normal hermaphrodite cases, 16, did not significantly differ from that of abnormal hermaphrodites, 14, with $\chi^2 = 2.00$, df = 1, p = 0.31. Conversely, of the 14 hermaphroditism cases reported in batoid species by Ribeiro-Prado et al. (2009), only 4 were normal hermaphrodites, the 10 other cases were abnormal hermaphrodites; with this difference being statistically significant ($\chi^2 = 50.00$, df = 1, $p < 0.05$). This phenomenon, especially normal hermaphroditism, seems to be more

Table 1. *Etmopterus spinax*. Normal and abnormal cases of hermaphroditism recorded in shark species from different marine regions including the specimens described in this note.

Family	Species	Hermaphroditism	Reproductive mode	Capture site	Authors
Hexanchidae	*Notorynchus cepedianus*	Normal*	Yolk-sac viviparous	?	Daniel (1928)
Etmopteridae	*Etmopterus baxteri*	Normal	Yolk-sac viviparous	Southern Australia	Irvine (2004, in Jones et al., 2005)
Etmopteridae	*Etmopterus granulosus*	Abnormal	Yolk-sac viviparous	Eastern New Zealand	Wetherbee (1996)
Etmopteridae	*Etmopterus granulosus*	Normal	Yolk-sac viviparous	South-east Tasmania	Irvine et al. (2002)
Etmopteridae	*Etmopterus unicolor*	Abnormal*	Yolk-sac viviparous	Suruga Bay, Japan	Yano & Tanaka (1989)
Etmopteridae	*Centroscyllium fabricii*	Abnormal*	Yolk-sac viviparous	Western Greenland	Yano (1995)
Etmopteridae	*Etmopterus spinax*	Abnormal	Yolk-sac viviparous	Southern Portugal	This study
Somniosidae	*Centroscymnus coelolepis*	Normal	Yolk-sac viviparous	Central Portugal	Veríssimo et al. (2003)
Somniosidae	*Centroscymnus owstonii*	Abnormal	Yolk-sac viviparous	Suruga Bay, Japan	Yano (1985, in Irvine et al., 2002)
Squalidae	Centrophorus lusitanicus	Abnormal	Yolk-sac viviparous	Coast of Senegal	Cadenat (1960)
Squalidae	*Squalus acanthias*	Abnormal	Yolk-sac viviparous	Western Canada	Rowan (1929)
Squalidae	*Squalus acanthias*	Abnormal	Yolk-sac viviparous	?	Gelsleichter et al. (1997, in Irvine et al., 2002)
Squalidae	*Squalus megalops*	Abnormal	Yolk-sac viviparous	South-eastern Australia	Braccini (2009)
Heterodontidae	*Heterodontus portusjacksoni*	Normal	Yolk-sac viviparous	South-western Australia	Jones et al. (2005)
Heterodontidae	*Heterodontus portusjacksoni*	Normal	Oviparous	South-western Australia	Jones & Potter (2009)
Carcharhinidae	*Prionace glauca*	Normal	Placental viviparous	Central Long Island, USA	Pratt (1979)
Scyliorhinidae	*Apristurus longicephalus*	Normal *	Oviparous	New Caledonia	Iglésias et al. (2005)
Scyliorhinidae	*Apristurus longicephalus*	Normal	Oviparous	West Australia	Iglésias et al. (2005)
Scyliorhinidae	*Apristurus longicephalus*	Normal*	Oviparous	South-western Japan	Iglésias et al. (2005)
Scyliorhinidae	*Scyliorhinus canicula*	Abnormal	Oviparous	France	Borcea (1904)
Scyliorhinidae	*Scyliorhinus canicula*	Normal	Oviparous	British waters	Bamber (1917)
Scyliorhinidae	*Scyliorhinus canicula*	Abnormal	Oviparous	British waters	Murray & Baker (1924)
Scyliorhinidae	*Scyliorhinus canicula*	Normal*	Oviparous	British waters	Arthur (1950)
Scyliorhinidae	*Scyliorhinus canicula*	Normal	Oviparous	British waters	Fuller & Zacharov (1960)
Scyliorhinidae	*Scyliorhinus canicula*	Normal	Oviparous	Coast of Tunisia	Capapé & Zahnd (1974)
Scyliorhinidae	*Scyliorhinus canicula*	Abnormal	Oviparous	Bristol Channel, UK	Ellis & Shackley (1997)
Scyliorhinidae	*Scyliorhinus stellaris*	Normal	Oviparous	Southern France	Vayssière & Quintaret (1914)
Scyliorhinidae	*Scyliorhinus stellaris*	Normal	Oviparous	Coast of Tunisia	Capapé et al. (1979)
Triakidae	*Iago omanensis*	Abnormal	Placental viviparous	Northern Arabian Sea	Compagno & Springer (1971)
Triakidae	*Iago omanensis*	Abnormal*	Placental viviparous	Madras coast, India	Devadoss & Batcha (1997)

* Several specimens were observed by authors

characteristic of sharks than batoids. Normal hermaphroditism is evident in both aplacental and viviparous species. Although such abnormality is considered very rare in chondrichthyans (Atz, 1964), a high percentage of normal hermaphrodites were observed in the brown lantern shark *Etmopterus unicolor* (Engelhardt, 1912) by Yano & Tanaka (1989), and the black dogfish *Centroscyllium fabricii* (Reinhardt, 1825) by Yano (1995), while Iglesias et al. (2005) stated that hermaphroditism is the normal condition of reproduction in the longhead catshark *Apristurus longicephalus* Nakaya, 1975.

The causes of hermaphroditism in chondricthyan species still remain difficult to explain (Atz, 1964; Ribeiro-Prado et al., 2009). As in other vertebrates, hermaphroditism may have different origins, probably genetic and/or hormonal. Unfavorable environmental conditions such as radio-activity contamination could play an important role (Yano & Tanaka, 1989; Scenna et al., 2007), and other pollutants may be implicated in the wild (Ribeiro-Prado et al., 2009). The large variations of hermaphroditism cases in different chondrichthyan species reported to date, especially the recent observations of Iglesias et al. (2005), support the need of further and more detailed studies on this subject.

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