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Efficacy of a remote control closure of cod-end used in a bottom trawl experience*

FRANCESC SARDÀ, JOAN B. COMPANY and MIGUEL A. ESTÉVEZ

Institut de Ciències del Mar (CMIMA-CSIC), Passeig Marítim de la Barceloneta 37-49, 08003 Barcelona, Spain.
E-mail: siscu@icm.csic.es

SUMMARY: A total of 26 effective trawl hauls using a remotely operated trawl cod-end closure system were carried out to determine whether samples collected in a rear section of the cod-end and in a front section of the cod-end were homogeneous, and can be used as reliable replicates for community sampling and resource assessment. Comparative analyses of these sample hauls and 25 other hauls that did not use the cod-end closure system were also performed. The results indicate certain technical difficulties in the practical operation of the system and that samples were not homogeneous either between the cod-end sections in the same haul or between hauls. The causes of the sample variability in catches from trawl surveys are discussed.

Key words: remote control closure, sampling, bottom trawl, survey, fisheries, fishery technology, Genisea

RESUMEN: EFICIENCIA DE UN SISTEMA DE CONTROL REMOTO PARA CERRADO DEL COPO EN ARTES DE ARRASTRE. – Se han realizado un total de 26 lances con un sistema de control remoto para el cierre del copo en redes de arrastre, con el fin de verificar la utilidad y eficiencia de este sistema para la separación de muestras homogéneas entre las dos partes en que se divide el copo una vez cerrado. También se han llevado a cabo análisis comparativos con otros 25 lances en los cuales no se utilizó dicho sistema. Los resultados indican ciertas dificultades técnicas en el funcionamiento práctico del sistema y que las muestras no fueron homogéneas ni entre lances ni entre las dos partes en que se divide el copo. Se discuten las posibles causas de dicha variabilidad y su implicación en las campañas de evaluación pesquera.

Palabras clave: control remoto de cerrado, muestreo, pesca de arrastre, evaluación, pesquerías, tecnología pesquera.

INTRODUCTION

Bottom trawl surveys are widely used for monitoring demersal stocks when abundance indices are required (Sparre *et al*., 1989; Fiorentini *et al*., 1999). Achieving precise quantification is one of the major problems affecting resource assessment and the different dynamic models employed strive to accomplish this both biologically and statistically (Conquest *et al*., 1996; Pennington and Vølstad, 1991; 1994; Pelletier, 1998). Furthermore, vulnerability of a given species to gear is affected by its behavioural characteristics such as aggregations or vertical distribution patterns (Parrish *et al*., 1964; Svatimskij, 1985; Laevastu and Favorite, 1988).

Technology endeavours to design fishing systems that will allow more exact quantification of catches through precise measurement of the swept area and avoidance of sample contamination by incidental capture of species during shooting and hauling across the water column. Hydroacoustic systems provide information remotely on the horizontal and

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vertical opening of the gear, the distance between the wings and otter doors, towing speed, etc. These recent technological innovations represent significant advances in resolving the former problem. The problem of sample contamination has been solved for fixed mouth systems like those used in plankton tows but for the time being it has not been solved for trawling, and remotely operated closure systems are still in the developmental stage.

Pennec and Woerther (1994) designed a system for dividing the cod-end of trawls into separately closeable sections or compartments with a view to making it possible to establish sample origin at different points in time during tows. Opening or closing the gear during shooting and hauling enables relatively undesirable species to be avoided. One of the goals for developing this remote closing system was to solve the problems posed by the echo-integration of shoals being able to correlate the echograms from the sounders to the species of fish detected. To this end the sounder data is recorded at the same time as trawling in order to identify different species composition along the transects by closing the system at different time lapses. This would permit various tows to be carried out without hauling the net up from the fishing ground, thereby achieving considerable time savings during research, which is useful when large numbers of samples are needed (Pennington and Vølstad, 1991; Folmer and Pennington, 2000). From this starting point, the application of the remote closing system to bottom trawling could be useful for different purposes (replicates, studies on resource patch distribution, avoiding specific biological contamination of samples, etc.). This would be the case, for instance, of trawl surveys using such interpolation methods as kriging when distances between sampling points are short and when we must consider as the sampling point the geographical centre of the tow. A sequence of trawling, hauling, closing the net, shooting at few meters from the bottom, and trawling again would be another application of the system in order to saving time during trawl surveys.

The object of the present study was both to test the technical reliability of the remote control trawl closure system and to ascertain whether catches in the different sections into which the cod-end was divided after closure were similar, in order to determine whether the sub-samples can be regarded as homogeneous replicates. Other aspects linked with sampling and catchability are also discussed jointly with the advantages and disadvantages of applying the closure system to trawl surveys. However, the variability inherent in trawl sampling or catchability due to gear efficiency falls beyond the scope of this paper.

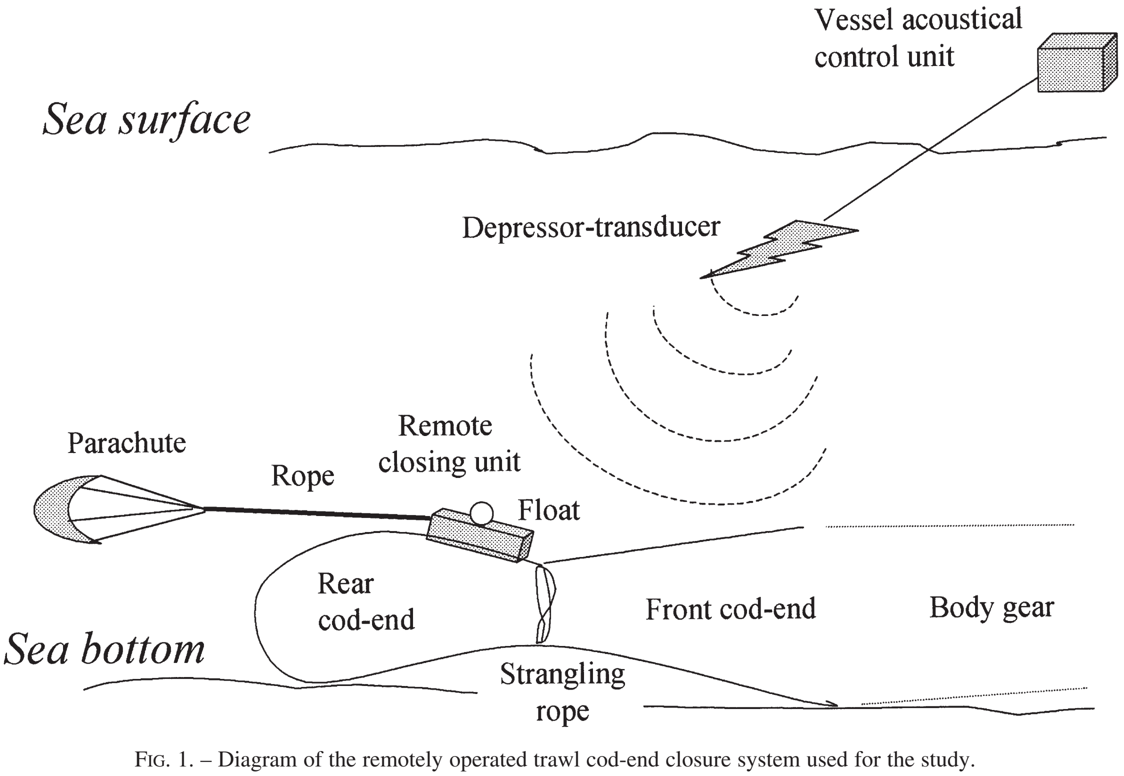

FIG. 1. – Diagram of the remotely operated trawl cod-end closure system used for the study.

MATERIALS AND METHODS

The remotely controlled trawl cod-end closure system

The Genisea Society manufactured in 1996 the remotely controlled trawl cod-end closure system (Fig. 1) used in this study. There are three components. The first is a remotely operated trawl cod-end closure unit. Driven by an acoustic signal sent from the vessel by a transducer, the unit releases a spring that frees a parachute attached at the end of a rope. Water drag on the parachute draws out the rope, tightening a noose around the cod-end at the position where the system has been deployed, thus strangling the net at that point. Depending on the number of units employed, the cod-end may be closed off into various independent sections to select sampling water volumes or depth intervals along the trawl trajectory. The second is a transducer attached to a depressor-*wing* placed about 20 m below the water surface. This transducer emits the acoustic signal towards the trawl closure unit, which when activated draws the cod-end closed. The third is an acoustic remote control unit on board supplied with electrical power from the vessel. It sends the signal to the transducer and is equipped with different channels for each of the optional trawl closure units.

The gear

The trawl used in this experience is the common commercial trawl net used in the region (Catalan coast), with a headrope of 25 m and a total length of 27 m (see Sardà *et al.*, 1998 for further details). The trawl net was operated with a pair of flat, rectangular, iron otter boards measuring 1.20 x 2 m and weighing 400 kg with bridles of 75 m. Scanmar remote control measures give a mean of 13.5 m of horizontal opening and 1.9 m of vertical opening. The cod-end used was of 40 mm stretch mesh with a lifter inside of 12 mm.

The sampling

The experiment was carried out on board the R/V *García del Cid* (38 m in length, 1200 HP). In all, 26 hauls were performed using the remotely operated trawl closure system, 16 during the “Nerit I” survey (September 1999) and the remaining 10 during the “Nerit II” survey (June 2000). During “Nerit II”, 25 other hauls were carried out without the trawl closure system at the same depths and in the technical conditions. In order to avoid depth variability in the samples, a specific station around 107 m depth (106 minimum and 108 m maximum) in a single flat fishing ground off the coast of Catalonia was chosen (40º47’N, 1º12’E; western Mediterranean off the delta Ebro river). The same gear was used during the complete progress of the experiment. Tow duration was 90 min, with closure of the cod-end after 45 min. The remote closure system was placed on the middle of the cod-end (2.5 m from the end of the cod-end). In this way the closure system was perfectly able to strangle the net. During the “Nerit I” cruise, the system was used after the standard instructions provided by Genisea (1996). However, due to its bad functioning (see Table 1 for details), it was necessary to discard these hauls for further data analyses. Only one remotely operated trawl closure unit was used during both surveys, in such a way that the cod-end was only closed off into two sections: a rear section and a front section. The number of individuals per species in each cod-end section was counted. In order to compare the effect of the remote closure system in the trawl, the other 25 hauls without a closing system were used in the data processing. All experiments were performed continuously during four 24 h cycles.

It was assumed that species contamination during shooting or hauling of the net was negligible. There were several factors that corroborated this assumption: 1) null presence of epipelagic species in the samples; 2) the mouth spread of the net during shooting is around 7 m because the trawling speed in this moment is low (measured with Scanmar system it represents 50% of the optimum spread during hauling); 3) the trawl sampling was conducted at 107±1 m; at this depth the gear delayed less than 10 minutes to reach the bottom, a very short time period in comparison with the 45 minutes of effective tow duration over the bottom; and 4) during hauling, the gear ascends in vertical position and the vessel is stopped, which means that the fishery capability is negligible.

Data analysis

The catches were standardised as number of individuals per square mile, calculated on the basis of the swept area estimated from the data recorded by a Scanmar remote sensing system deployed in the mouth of the trawl gear (horizontal spread between wings) and the distance covered by the haul (starting and ending geographical GPS positions). With these data, a matrix by species, haul, and cod-end section was constructed. All the species were considered, except those for which no more than a single individual was recorded per haul or species that exhibit many zeros because to yield high variability (Pelletier, 1998). In order to analyse sampling efficiency, individual species were graphically represented in percentages. If the closing system is efficient, the proportion would have been expected to approach 50% between species from front and rear cod-end sections. In order to test differences of all species from 50% individually, a *G-test* with William's correction was performed (Sokal and Rohlf, 1981).

To compare hauls carried out with and without the trawl closure system, the complete matrix of catches was employed for processing the seven hauls performed with the closure system and the 25 hauls performed without the closure system on the same cruise under the same working conditions ("Nerit II"). To determine the importance of variability between all these catches due to the behaviour of the species, a hierarchical cluster analysis was performed using the linear correlation index and the UPGMA aggregation algorithm after *ln (n+1)* data transformation (Lleonart and Roel, 1984; Pennington, 1996).

RESULTS

Technical aspects

The operation of the remote trawl closure system encountered certain practical difficulties during the "Nerit I" survey, and the system worked correctly in just one haul. Table 1 gives the details for all hauls and indicates the incidences of closure system operations. The main problem was the failure of the remote trawl closure unit to work properly, for a variety of reasons: a) the trawl closure unit exhibited a tendency to rotate getting clogged by mud due to its re-placement under the net; consequently, it failed to receive the closing signal; b) the system worked but failed to close with sufficient strength to strangle the cod-end, and hence the species frequently passed through the strangled knot and appeared mixed together on the rear section of the cod-end, without any separation between the two sections of the cod-end; and c) the system worked properly, but the rope or the parachute fastener ring broke. As a consequence of these operational difficulties, the "Nerit I" hauls were disregarded for further analysis.

During the "Nerit II" survey, a twin system to the previous one was used. Thus, the following modifications were made: a small float was placed in the trawl closure unit to improve buoyancy (Fig. 1) and prevent blockage by mud; the rope was shortened and the parachute fastener rings were strengthened and attached by a swivel; the original parachute was replaced by a stronger one, and a piece of cork was attached to the cover of the housing of the unit to enhance detachment and buoyancy upon release. With these modifications, the effectiveness of the system operation improved markedly and worked well in 70% (7 of 10) of the experimental trawls. Therefore, only the data collected on the "Nerit II" survey, after these technical improvements had been made, were used in the data analysis.

TABLE 1. – Technical success of experimental hauls employing the remotely operated trawl cod-end closure system from Genisea during the cruises "Nerit I" (with standard closure system) and "Nerit II" (with modified closure system). Explanation of the outcomes in Material and Methods.

	NERIT I cruise			NERIT II cruise	
Ident. code	Technical success	Outcome	Ident. code	Technical success	Outcome
P37	NO	Signal not received	P39	YES	Catch not separated
P38	NO	Worked but failed to close	P40	YES	
P39	NO	Worked but failed to close	P41	YES	
P40	YES	Catch not separated	P42	YES	
P41	NO	Parachute not released	P48	YES	Catch not separated
P42	NO	Parachute failed to open	P49	YES	
P43	NO	Signal not received	P50	YES	
P44	NO	Parachute lost	P51	YES	Catch not separated
P45	NO	Signal not received	P56	YES	
P46	NO	Clogged with mud	P57	YES	
P52	NO	Signal not received			
P56	YES				
P58	NO	Signal not received			
P59	NO	Clogged with mud			
P61	NO	Worked but failed to close			
P62	NO	Signal not received			

TABLE 2. – Species abundance matrix by haul ("Nerit II"). The number of the cod-end section is given in brackets. (1), rear section and (2), front section. In bold, species not significantly different from the expected proportion 1:1.

Species	Code	Hauls with remote closing system													
		40(1)	40(2)	41(1)	41(2)	42(1)	42(2)	49(1)	49(2)	50(1)	50(2)	56(1)	56(2)	57(1)	57(2)
Antonogadus megalokynodon	1	302	0	332	49	52	106	78	245	0	115	277	327	594	138
Arnoglossus laterna	2	754	208	190	837	1042	1481	117	408	386	2299	830	1527	1782	554
Boops boops	3	0	104	284	49	0	212	233	163	541	230	**969**	**982**	858	554
Callionymus maculatus	4	804	156	332	443	260	847	1167	2286	386	1034	830	655	6733	2076
Capros aper	5	**151**	**156**	47	197	104	106	78	327	116	2184	138	982	660	277
Cepola rubescens	6	1256	156	1706	1527	156	317	117	82	77	805	1661	1091	726	208
Citharus linguatula	7	704	156	1422	887	2396	3492	1518	408	232	4023	1661	436	726	830
Eutrigla gurnardus	8	1307	677	**900**	**887**	1198	2434	2335	571	463	2759	692	1418	990	277
Gobius niger	9	50	104	142	99	**104**	**106**	233	82	39	115	69	327	**66**	**69**
Helicolenus dactylopterus	10	0	0	190	0	0	212	0	0	0	460	554	218	264	69
Lesueurigobius friesii	11	4322	729	4645	1478	1198	1799	78	816	232	1954	5121	2400	6205	484
Lophius spp.	12	251	208	332	197	365	529	1051	204	77	575	415	218	198	277
Macroramphosus scolopax	13	251	52	95	49	**104**	**106**	117	41	0	0	**138**	**109**	330	69
Merluccius merluccius	14	4070	781	4787	2709	2344	7831	3463	0	270	5402	19931	10182	3498	2180
Mullus barbatus	15	352	469	521	296	208	529	584	245	39	575	554	545	594	484
Ophidion barbatum	16	0	0	0	0	1198	4868	0	0	386	2529	0	0	0	0
Phycis blennoides	17	50	0	95	0	**52**	**53**	117	41	77	115	**138**	**109**	132	35
Serranus hepatus	18	1307	365	1564	1084	**573**	**529**	584	735	386	2759	1522	1200	2376	969
Symphurus nigrescens	19	452	0	711	542	417	1587	350	735	193	1034	554	1200	**2640**	**2768**
Trachurus spp.	20	151	208	995	296	0	0	233	1551	734	651	0	0	**2244**	**2215**
Trisopterus minutus	21	7789	4219	4929	8670	1823	8889	3619	2531	1351	13333	10934	8291	8911	2145
Chlorotocus crassicornis	22	151	0	47	0	1406	3280	117	41	116	38	0	109	0	0
Liocarcinus depurator	23	1156	521	1659	1281	5938	2751	4786	1878	347	3793	**1384**	**1418**	4290	3322
Macropodia longipes	24	503	0	427	197	469	106	39	82	193	38	692	109	0	0
Nephrops norvegicus	25	553	0	1848	296	1042	423	2101	327	1544	38	**35**	**36**	99	208
Parapenaeus longirostris	26	302	104	427	246	156	423	233	82	39	575	277	327	132	0
Pontocaris lacazei	27	0	0	95	0	208	423	117	82	0	460	138	218	264	69
Solenocera membranacea	28	50	0	190	0	0	12169	0	0	579	0	0	0	0	138
Eledone cirrhosa	29	503	104	1232	690	0	106	233	41	**39**	**38**	692	982	198	69
Illex coindetii	30	201	0	190	99	0	1270	39	82	734	575	35	109	594	0
Sepiolidae	31	151	104	1801	640	0	635	117	327	347	1149	692	109	528	138
Sepia elegans	32	151	104	0	99	0	106	117	82	77	690	277	109	0	0

Catch analysis

Tables 2 and 3 show the species density on hauls with and without remote closure system. The comparison between species in the hauls using remote closure system revealed clear differences between the two cod-end sections (*G- test,* $p<0.05$), and very few species occurred in the same proportion between the rear and front cod-end sections (Table 2; indicated in bold). The line separating the species caught in the front and rear sections of the cod-end can be observed to vary from 50% in a completely irregular manner (Fig. 2). Percentage shares by species were also observed to vary from haul to haul, for example, for species nos. 3 (*Boops boops*), 10 (*Helicolenus dactylopterus*), 27 (*Pontocaris lacazei*) and *28 (Solenocera membranacea*), revealing erratic patterns for species occurrence in the front and rear sections of the cod-end, not only in the same haul but also among the different hauls. That is, both inter and intra-haul variability exists. Even the hauls conducted at the same hour from correlative days had significantly different results between species of the haul pairs: 40-49; 40-57, 49-57 and 41-50 (*G-test*; $p < 0.05$). In some cases certain species were observed to occur only in the front or the rear cod-end compartment. This was true for several benthopelagic species, such as *Boops boops* and *Trachurus* spp., but it was also an unexpected finding for such typically benthic species (Table 2) as *Nephrops norvegicus* (trawl P40), *Symphurus nigrescens* (P40), *Pontocaris lacazei* (P41), and *Eledone cirrhosa* (P42). Some species tended to show great variability, which could be indicative of non-homogeneous spatial distributions of the individuals of these species. *Helicolenus dactylopterus*, *Ophidion barbatum*, and *Solenocera membranacea* are three examples of this latter case.

The cluster analysis (Fig. 3) showed an initial segregation into two major groupings, i.e., day-time and night-time hauls, with different similarity values. Within these groupings, the hauls carried out using the remotely operated closure system were clustered separately from the other hauls. In the day-time group, hauls P40, P49, P41 and P57, formed a sub-group separated from the other day catches. In the night-time group, hauls P42 and P50 also

Table 3.- Species abundance matrix by haul (“Nerit II”).

		Hauls without remote closing system																							
Species	Code	P32	P33	P34	P35	P36	P37	P38	P39	P43	P44	P45	P46	P47	P48	P51	P52	P53	P54	P55	P58	P59	P60	P61	P62	P63
Antonogadus megalokynodon	1	52	0	395	398	0	535	69	164	0	396	0	69	0	426	287	215	0	335	0	59	458	288	154	66	173
Arnoglossus laterna	2	0	2264	3947	1029	2127	2407	1714	1480	2962	1978	2224	2193	868	3153	2867	1649	1335	1897	1837	386	2291	1550	1460	1642	1270
Boops boops	3	3197	0	0	531	10499	2474	1920	493	0	1319	3411	1234	601	682	430	143	593	2120	1837	0	0	144	922	1773	1039
Callionymus maculatus	4	516	1578	6315	963	618	2139	617	0	409	1451	3855	548	534	10823	860	1434	1038	558	1072	684	3665	2307	3151	1510	5656
Capros aper	5	774	617	658	365	412	1137	1920	329	306	725	1409	2125	935	341	1147	502	371	670	230	178	229	108	384	394	231
Cepola rubescens	6	774	755	395	365	686	3477	343	164	204	363	222	240	1035	1023	287	1649	1001	1172	880	238	458	541	769	0	2193
Citharus linguatula	7	1856	3773	8289	4117	480	1137	549	822	4085	2506	1335	754	200	3750	5878	2652	1335	1451	2220	267	8361	2884	2306	591	2482
Eutrigla gurnardus	8	52	0	0	0	0	167	274	1151	3677	198	148	69	0	2642	3298	72	148	112	77	297	3092	0	0	0	115
Gobius niger	9	155	206	0	398	0	334	69	164	0	0	74	0	67	256	0	287	148	223	536	0	229	288	307	197	231
Helicolenus dactylopterus	10	2836	1784	0	266	412	3009	274	0	102	330	0	343	0	256	430	72	74	223	230	178	687	469	154	131	0
Lesueurigobius friesii	11	258	3156	0	3220	755	3677	69	987	0	3231	890	548	1135	5539	3154	3513	2076	670	2144	654	8933	2667	1998	1839	1674
Lophius spp.	12	258	0	395	797	309	568	137	0	2196	890	519	308	367	298	1434	538	741	502	536	178	802	721	922	328	462
Macroramphosus scolopax	13	413	206	132	166	274	334	549	0	102	198	371	343	334	85	143	358	222	335	77	30	229	72	154	263	115
Merluccius merluccius	14	4848	8232	2730	3918	5215	5583	4800	1919	1889	3198	3188	1851	14788	8692	3011	13872	9528	11606	8345	921	3970	7209	19983	9982	16678
Mullus barbatus	15	928	1029	0	432	1167	1371	1303	822	204	659	667	925	367	426	1147	358	408	1116	498	89	458	649	1076	460	519
Ophidion barbatum	16	52	5213	6841	3884	69	0	0	164	5004	4023	0	0	0	0	5161	2294	297	0	0	238	6986	541	154	0	0
Phycis blennoides	17	103	0	33	299	69	267	137	164	204	66	371	0	67	85	430	143	148	223	230	30	344	144	154	0	115
Serranus hepatus	18	0	1372	2237	1129	2265	0	2674	2467	1328	1121	3411	754	2070	1875	1577	1434	1557	2009	1684	89	1374	721	3228	2430	1270
Symphurus nigrescens	19	1960	0	5657	2025	1510	2006	1509	0	0	2308	3336	1371	0	0	0	3226	1928	558	2144	565	3321	2091	3074	1116	1674
Trachurus spp.	20	1496	69	0	797	12558	3844	1783	2961	102	791	4745	4798	11416	6221	0	3011	12827	14842	26489	594	0	2163	7840	14382	0
Trisopterus minutus	21	14697	9672	11709	12383	13381	19121	67611	6086	7762	11013	20538	17957	16423	10652	11470	9893	15645	14730	7809	2794	7101	4470	6302	7093	7445
Chlorotocus crassicornis	22	0	1715	3947	1029	69	267	0	0	4392	1583	148	0	0	85	6165	1075	148	0	0	535	3894	937	77	66	115
Liocarcinus depurator	23	774	8849	9210	9229	1578	3610	1097	3289	9805	4023	4819	960	1869	4261	8172	5878	6673	1786	5359	713	17867	28873	4688	2036	2251
Macropodia longipes	24	722	274	263	398	892	602	0	0	0	594	519	822	668	85	573	932	667	893	536	149	458	144	154	525	404
Nephrops norvegicus	25	0	3670	724	1560	103	134	0	164	306	1781	0	69	167	85	287	2509	519	0	38	802	458	2235	346	0	115
Parapenaeus longirostris	26	0	480	691	1162	412	435	171	658	1123	1451	519	308	134	511	1004	932	630	223	498	59	1489	397	307	427	231
Pontocaris lacazei	27	52	0	658	166	0	0	69	0	0	198	148	0	0	341	573	72	222	0	230	30	687	288	77	131	173
Solenocera membranacea	28	0	4665	24734	8466	0	134	0	0	0	8705	297	0	0	85	14911	9463	964	0	77	1516	29206	10057	77	131	115
Eledone cirrhosa	29	619	412	395	564	206	602	446	164	204	165	408	206	567	682	287	645	890	446	1225	149	687	541	845	952	1731
Illex coindetii	30	464	720	132	365	789	201	137	164	0	758	408	377	467	383	3011	394	779	670	153	238	0	108	922	197	1154
Sepiolidae	31	258	2950	1710	1295	412	0	411	164	919	2242	667	274	935	426	717	2079	2373	502	727	149	344	1009	1153	460	808
Sepia elegans	32	0	137	132	266	412	201	69	0	0	264	222	206	0	170	143	574	445	223	77	0	0	72	384	164	289

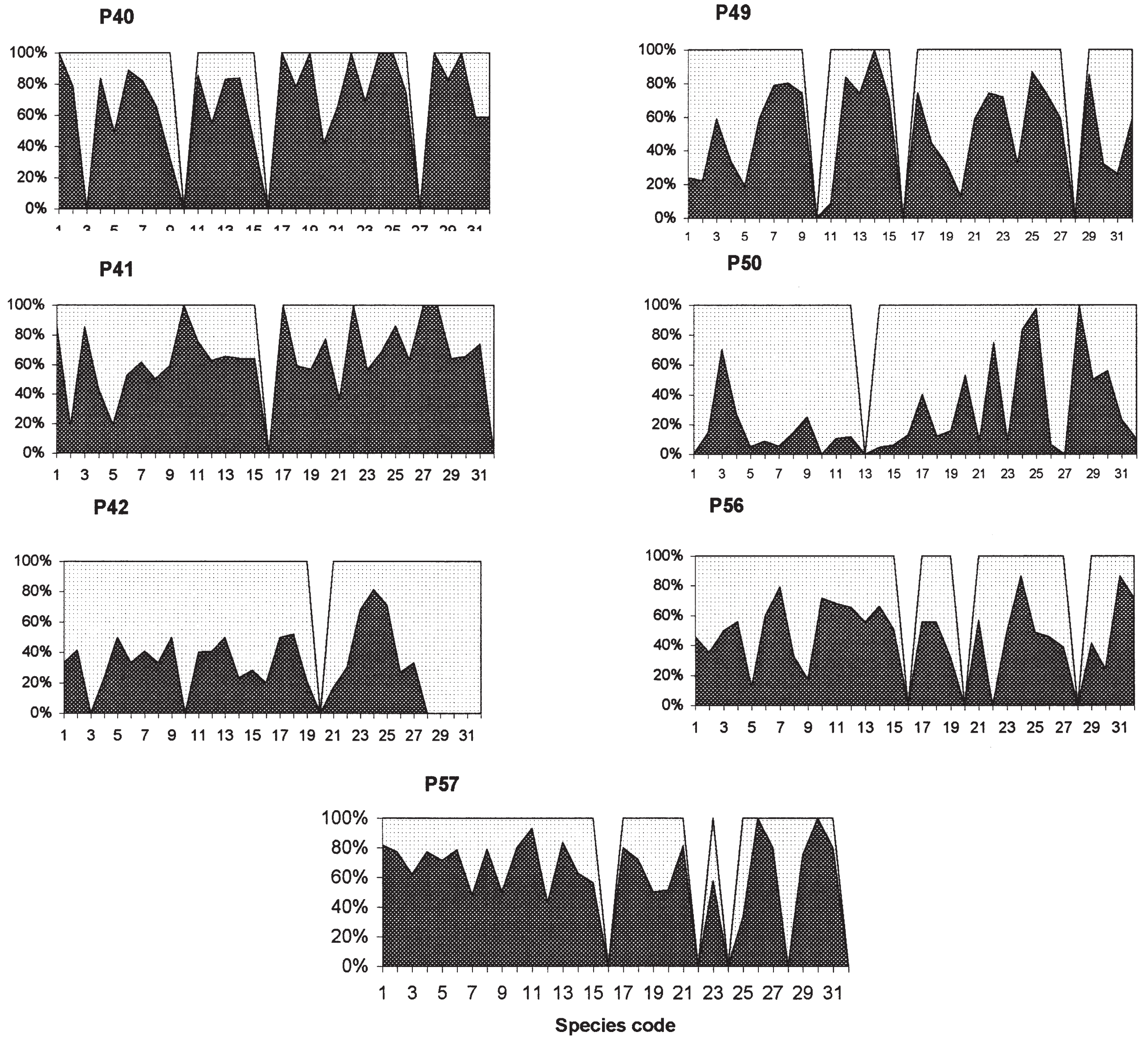

FIG. 2. – Percentage species composition in the front (dark color) and rear (clear color) sections of the cod-end by trawl with remote closing system during cruise "Nerit II" (species codes in Table 2).

appeared in the same group, though with a lower level of similarity. Only haul P56 was in the group with the rest of the hauls. Then, it is demonstrated that day-night variability due to the benthopelagic behaviour of some species influences catches more than general catch variability or the effect that the remote closure system can produce on the working characteristics of the gear during the haul, in the conditions in which the experiment was performed.

DISCUSSION

After suitable modifications to the remotely operated closure unit had been made, the operational success rate was 70%. We expect that, with additional modifications, higher values of technical success can be achieved. However, the system still requires too careful handling bearing in mind that fishing manoeuvres call for systems capable of withstanding the heavy jolts that come with hard, fast-paced work.

Two hauls, P48 and P51, had no catches in the front section of the cod-end. The conclusion drawn from these results is that the system was sometimes not strong enough to fully strangle the net or that the parachute did not open completely and hence failed to prevent displacement of the catch back into the rear of the cod-end. If system operation is still problematic for a small gear like the one used in our

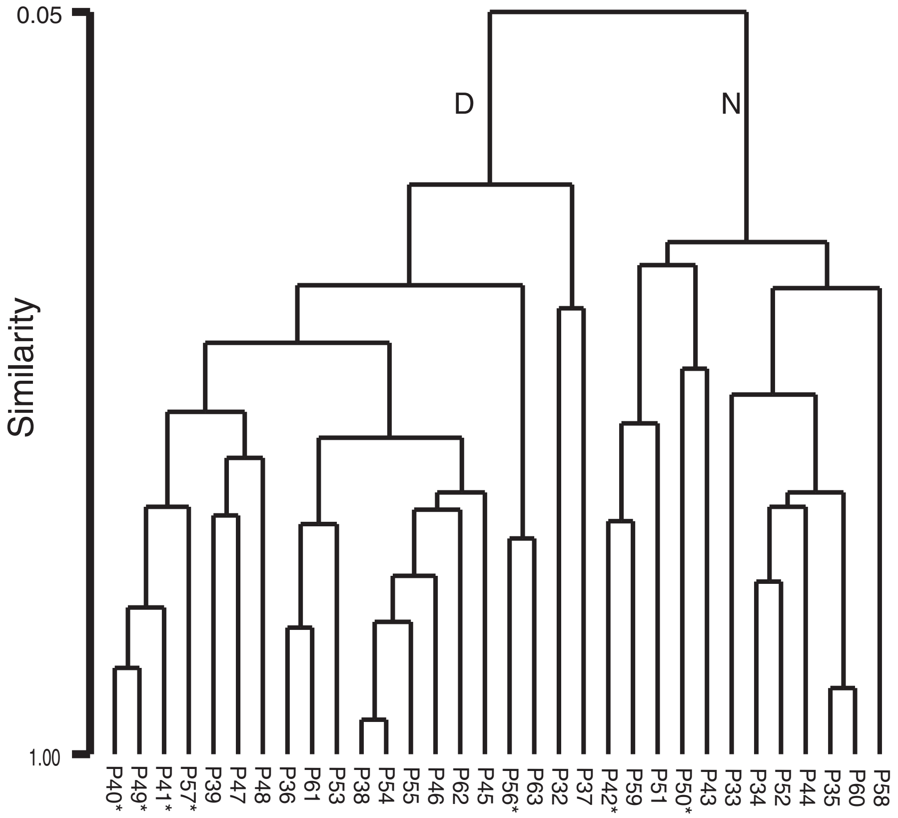

FIG. 3. – Dendrogram analysis showing similarity among hauls carried out with and without the remotely operated trawl cod-end closure system. *, hauls employing the remotely operated trawl cod-end closure system; D, day, N, night.

experimental hauls, effectiveness can perhaps be expected to be even lower in a larger gear with a full cod-end towed at higher speed.

Fishery stock assessment is often based on data of abundance indices found from trawl surveys aimed at specific target species. These indices are taken from different kind of vessels with different fishery capabilities. This made it necessary to conduct studies on trawl and vessels inter-calibrations (Svatimskij, 1985; Gordon and Berstsd, 1992; Sangter and Breen, 1998; Pellitier, 1998; Fiorentini *et al.*, 1999). All these methods are usually based on the assumption that: 1) the target species are present in a great percentage of the hauls; 2) the number of species captured is sufficient to obtain significant and conclusive results; and 3) the species distribution is spatially homogeneous.

Although the study of the general variability in the catches was not a goal of this paper, the results presented here demonstrate that the catch variability was very high. This aspect has been studied widely to estimate densities on trawl surveys (Godø *et al.* 1990; Pennington, 1996; Pennington and Vølstad, 1991, 1994; Folmer and Pennington, 2000). Despite this variability inherent to trawl surveys to assess target species, the cited authors indicate that short hauls are at least as efficient as long ones in catching fish of any size and that the efficiency of trawl surveys can be increased by reducing haul duration and increasing the total number of hauls. On the other hand, two hauls will always be different if the density of a given resource changes with the day-night time. Therefore, Pennington (1996) supported that the spatial distribution of marine organisms is highly patchy. Because of this patchy distribution, data from marine abundance surveys are highly skewed and have a large variance, and the sample mean has a low level of precision even for relatively intense surveys (Pennington and Godø, 1995). Also, Maynou *et al.* (1996, 1998) demonstrated a highly patched distribution for crustaceans in the Mediterranean. In this sea a multiespecific fishery exists (Farrugio *et al.*, 1993), and the differences observed between hauls may be due to the aggregation pattern of the species or to their day-night behaviour along the water column. Svatimskij (1985) found that diurnal migrations of cod resulted in changes in the size and sex composition of catches, and Laevastu and

Favorite (1988) indicate that the catches were also affected by the direction of trawling with respect to the current.

The results also showed that differences between day-time and night-time catches were the major differences observed between hauls at the same depth. Working at different depths would introduce noise masking the experimental results because some species occur at different depths. This finding draws attention to the need to conduct research into day-night variations in resource distribution and assessment. It should also be noted that these results are valid only for the gear and sampling protocols used in the present experiment and that the results could well differ for other trawl gear configurations or sampling strategies covering a broader swept area.

In several hauls carried out using the remotely operated closure system, certain species appeared only in the front or rear section of the cod-end. It can therefore be concluded that the species were not distributed homogeneously in the study area. In other words, certain not very mobile benthic species may be present at high densities in aggregations while other, more highly mobile species are not uniformly represented. These factors are intrinsic to all trawl sampling of marine species. If sample design had taken into account a certain minimum area as being representative of the community and longer tows had been used, the similarity values between the hauls and between the cod-end sections would probably have increased. Conversely, there would be a corresponding loss in the precision of the information on the small and medium-scale spatial-distribution of the resources and on day-time and night-time abundance, two aspects which are of great importance in determining the exact resources locally and making a precise assessment, as pointed out by Pennington and Vøldtad (1991), Pennington (1996) and Folmer and Pennington (2000). Though the variability in trawl surveys is an important matter to discuss, this aspect has never been studied in Mediterranean waters.

In conclusion, the remotely operated trawl cod-end closure system considered here is still not fully reliable technically and thus is still not suitable for regular deployment. Therefore, we believe that in the future, after further technical improvement, the system's quantitative effectiveness in both bottom and pelagic trawls will increase considerably. The remote closing system shows a low level of efficiency in taking homogenous samples from rear and front sections of the cod-end. However, we do not have any evidence that the remote closing system affected the species composition of the catches in any way, so the representativeness of the catch in each section of the cod-end and the high variability observed must be an actual reflection of the species community distribution. From this point of view, our results may suggest that remote closing systems can be useful for replicate samples assuming a high variability of the resource on the western Mediterranean shelf. In a monospecific context the remote closure system would probably increase its efficiency and take more homogeneous samples, but the use of this system in Mediterranean waters is highly doubtful. Further studies aimed at improving design in trawl surveys should be encouraged in the Mediterranean, bearing in mind the high spatial, seasonal and day-night variability of some species.

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