J. Northw. Atl. Fish. Sci., Vol. 31: 245–261

Discards from Deep-water Bottom Trawling in the Eastern-Central Mediterranean Sea and Effects of Mesh Size Changes

G. D'Onghia, R. Carlucci, P. Maiorano, and M. Panza
Department of Zoology, University of Bari
Via Orabona, 4 – 70125 Bari, Italy

Abstract

Data on discards were collected during deep-water bottom seasonal trawling surveys targetting red shrimps (*Aristeus antennatus* and *Aristaeomorpha foliacea*) in the Ionian Sea (Eastern-Central Mediterranean). The performance of 3 codends, with stretched mesh sizes of 40, 50 and 60 mm, was tested. A cover with a stretched mesh of 20 mm was employed on each codend.

The discarded catch constituted an important fraction of the total catch (20–50%). This was almost exclusively due to unwanted fish species, while discards of the target species and other commercial species were negligible. Discard rates increased with total catch and depth.

No substantial differences were seen in the overall performance of the codends used. Differences were only detected in the biomass of the escaped fraction of the catch (both marketable and discards) and in the size selectivity. The 40 mm mesh size was not selective in *Aristeus antennatus*. Larger mesh size codend (50 and 60 mm) allowed a higher number of small specimens to escape. The 50% retention sizes increased according to the mesh size in all examined species.

Key words: catch, discards, Mediterrranean Sea, mesh size selectivity

Introduction

According to Alverson *et al*. (1994) the "discarded catch" is the portion of the catch returned to the sea for economic, legal or personal reasons. Generally, the composition of the discarded catch depends on a great number of variables, which include season, gear and fishing method, depth and fishing grounds exploited, duration of the trip and hauls and occurrence of juveniles (Alverson *et al.*, 1994).

Despite the great importance of discarding within the multispecies Mediterranean bottom trawling fisheries, there is only limited information concerning the amount, composition and factors affecting the discards (Stergiou *et al*., 1997 and 1998; Carbonell *et al*., 1998; Moranta *et al*., 2000; Machias *et al*., 2001; Ragonese *et al*., 2001). These studies generally suggest that "discards" from trawl fisheries are generally due to unwanted species (without commercial value), by-catch species (of low commercial value) and undersized specimens of species with higher commercial value.

In the Ionian Sea (Eastern-Central Mediterranean), the deepwater decapod crustacean fishery targets primarily red shrimps *Aristeus antennatus* and *Aristaeomorpha foliacea*. This fishery, along the Calabrian coasts, includes several bycatch species. Some of them, such as *Merluccius merluccius*, *Nephrops norvegicus*, *Parapenaeus longirostris*, *Helicolenus dactylopterus* and *Lophius budegassa*, are valuable species but many others, such as *Phycis blennoides*, *Micromesistius poutassou*, *Lepidorhombus boscii*, *Plesionika martia, Eledone cirrhosa*, are of low commercial value. Many species of no commercial value are often associated with the catch and always discarded (D'Onghia *et al*., 1997; Tursi *et al*., 1998). Although deepwater decapod crustaceans have long been intensively exploited in the Ionian Sea, scientific information on discards determined during fishing is only available in grey literature and the knowledge on the effects of the mesh size changes is very scanty (D'Onghia *et al*., 1998a).

The aim of this paper is to provide information on discards from the deep-water trawling in the Ionian Sea, pointing out the effects of the mesh size changes both on the amount of discards and in terms of 50% retention length for some of the most abundant species in the study area. Full details of the selectivity experiment will be published in a separate paper.

Materials and Methods

Data were collected during 8 seasonal trawl surveys carried out in the Ionian Sea (Fig. 1) from April 1996 to March 1998. A stratified sampling design was adopted in the depth range from 250 to 750 m, where trawl fishing on deepwater red shrimps occurs. 12 hauls of 3-hour duration were carried out from dawn to dusk during each survey, emulating commercial trawling in the area. The locations of the tows were generally the same for each survey.

A commercial 75 tons (GT) motor powered vessel (360 hp), equipped with a nylon otter trawl net, was hired. The performance of 3 codends, with diamond stretched mesh sizes (sMS) of 40, 50 and 60 mm, was tested. A cover with a sMS of 20 mm was employed on each codend. In order to avoid the masking of the codend meshes, the cover net was wider and longer than the test codend, and three arrays of plastic floats were attached to the top to prevent it from collapsing. The 40 mm sMS codend, which is the Italian legal mesh size, was used in all the surveys, while the 60 and 50 mm sMS codends were used in the first and in the last four surveys, respectively. A diagram of the net is shown in Fig. 2. The horizontal and vertical net opening, measured by means of the SCANMAR acoustic system, depended on various factors (depth, warp length, towing speed, etc.) and ranged respectively from 21.5 m to 24 m and from 0.9 m to 1 m (Fiorentini *et al*., 1994). The vessel speed, measured using GPS, was maintained at 2.5–3.0 knots. Basic information on each haul is reported in Table 1.

The "discard rate" (DR) considered as the proportion of the total catch, which is discarded (Alverson *et al*., 1994), was computed for the total catch for each survey and codend. The G-test (Sokal and Rohlf, 1969) was used to evaluate significant changes in the discarded and marketable catch by survey and mesh size. The relationship between discard rate and total catch and between discard rate and depth was determined for the 40 mm sMS codend by means of linear regression.The relationships

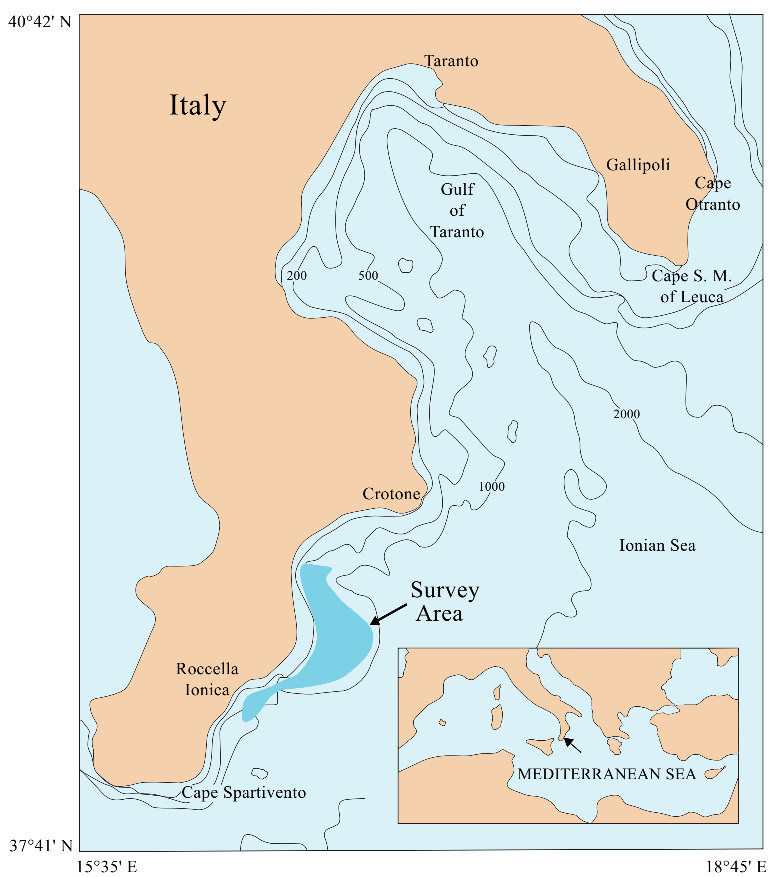

Fig. 1. Map of the Ionian Sea (eastern-central Mediteranean) with indication of the area investigated from April 1996 to March 1998.

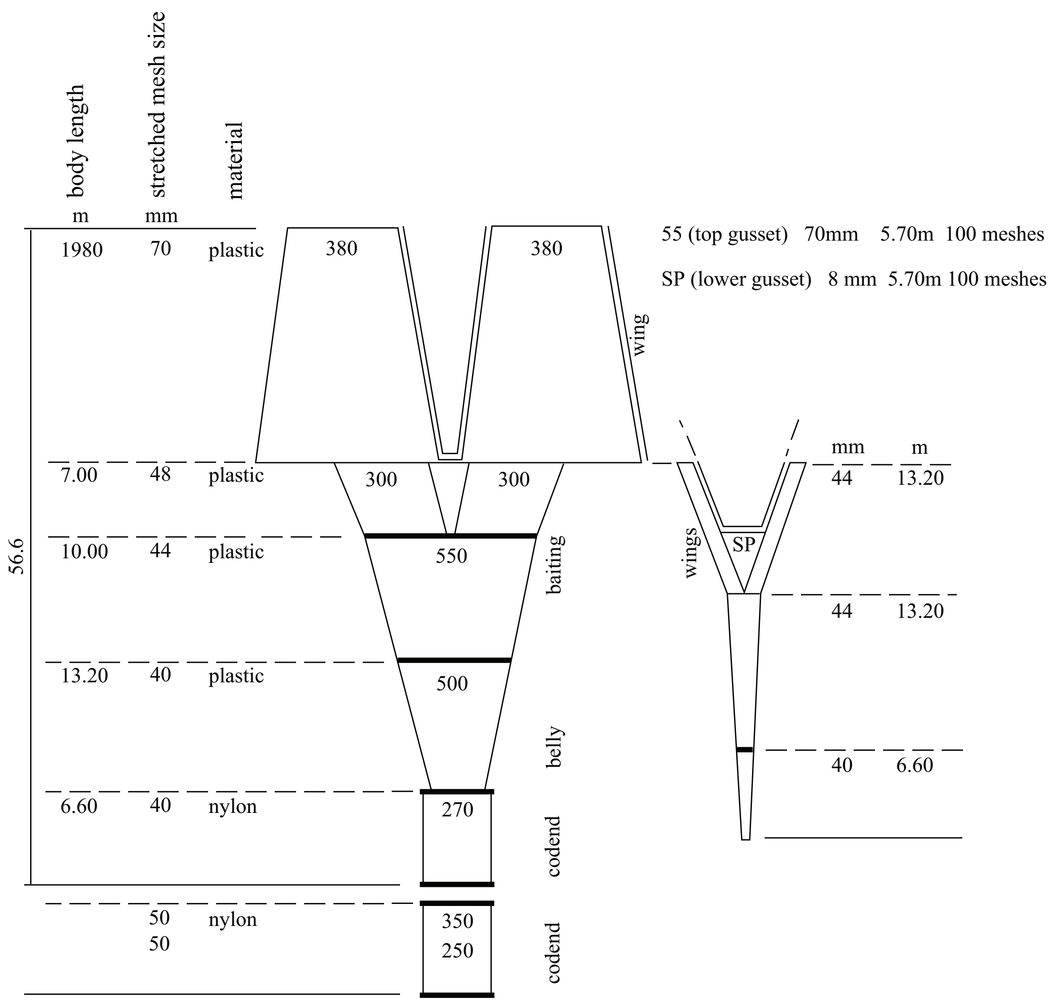

Fig. 2. Diagram of the trawl net used in the Ionian Sea surveys from April 1996 to March 1998.

between total catch, discarded catch, marketable catch that passed into the cover and the mesh size codend were also analysed.

Length-frequency distributions for each codend used were calculated for the following species: a) *Aristeus antennatus* (target commercial species); b) *Helicolenus dactylopterus*, *Phycis blennoides*, *Micromesistius poutassou* (bycatch species); c) *Caelorhynchus caelorhynchus* (unwanted species). According to the covered codend method adopted during each haul (Pope *et al*., 1975), the retention sizes at 50% (L_{50}) were computed for these species using the logistic model as described in Sparre and Venema (1998). The fit of data and the relative significance for each sMS codend was carried out using the maximum likelihood function (Wileman *et al*., 1996).

Results

40 mm mesh size codend

During this study, the average discard rate with 40 mm sMS codend ranged from 0.23 (April 1996) to 0.45 (December 1997) within an average total catch per hour between 11.24 kg/h (July 1996) and 23.32 kg/h (October 1996) (Fig. 3). The highest average DR values were seen during July 1996 and December 1997, however the changes in the rates of the discarded and marketable catch (both target and by-catch species) throughout the 8 surveys were not statistically significant (G-test = 4.36, $p>0.05$).

The relationships between DR and total catch per hour and between DR and depth were both positive (Fig. 4):

TABLE 1. List of the hauls, with indication of the stretched mesh size, date, duration, starting hour, depth, wire length, towing speed, total catch (kg) and total catch per hour (kg/h) carried out in the Ionian Sea from April 1996 to March 1998.

Stretched mesh size (mm)	Survey	Haul	Date	Duration (minutes)	Starting hour	Depth (m)	Wire length (m)	Towing speed	Total catch kg	Total catch per hour (kg/h)
40	I	1	4/16/1996	165	06.15	324	1050	2.5	57.88	21.05
40	I	2	4/16/1996	180	09.50	478	1500	2.5	59.92	19.98
40	I	3	4/16/1996	180	13.35	399	1300	2.5	63.05	21.02
40	I	4	4/17/1996	180	06.05	579	1650	2.5	26.19	8.73
40	I	5	4/17/1996	180	09.55	530	1550	2.5	26.63	8.88
40	I	6	4/17/1996	140	13.50	643	1800	2.5	19.67	8.44
40	II	1	7/21/1996	180	06.50	312	1050	2.6	11.17	3.72
40	II	2	7/21/1996	180	10.30	405	1350	2.4	35.7	11.9
40	II	3	7/21/1996	180	15.00	509	1600	2.4	19.41	6.47
40	II	4	7/22/1996	180	05.10	461	1500	2.4	42.33	14.11
40	II	5	7/22/1996	180	09.25	581	1700	2.4	46.56	15.52
40	II	6	7/22/1996	175	13.10	676	1800	2.4	45.86	15.73
40	III	1	10/23/1996	190	06.35	321	1100	2.5	82.9	26.18
40	III	2	10/23/1996	160	10.30	380	1250	2.5	88.79	33.29
40	III	3	10/23/1996	190	14.00	470	1500	2.6	61.91	19.56
40	III	4	10/24/1996	165	08.20	520	1550	2.5	65.66	23.88
40	III	5	10/24/1996	172	12.15	660	1800	2.5	93.55	32.64
40	III	6	10/24/1996	140	16.10	601	1700	2.5	10.17	4.36
40	IV	1	2/15/1997	180	06.50	303	1050	2.6	65.42	21.81
40	IV	2	2/15/1997	190	10.35	387	1300	2.3	51.64	16.31
40	IV	3	2/15/1997	180	14.35	462	1450	2.5	24.76	8.26
40	IV	4	2/26/1997	185	06.15	662	1800	2.6	76.36	24.76
40	IV	5	2/26/1997	175	10.25	606	1700	2.5	52.77	18.1
40	IV	6	2/26/1997	180	14.25	545	1650	2.5	22.28	7.42
40	V	1	5/2/1997	180	06.05	326	1050	2.6	46.53	15.51
40	V	2	5/2/1997	180	09.45	379	1250	2.5	34.77	11.59
40	V	3	5/2/1997	190	13.30	445	1450	2.6	26.35	8.33
40	V	4	5/3/1997	180	06.15	658	1750	2.6	69.83	23.28
40	V	5	5/3/1997	175	10.10	577	1700	2.6	12.22	4.19
40	V	6	5/3/1997	175	14.00	509	1600	2.5	17.9	6.13
40	VI	1	7/23/1997	180	06.05	320	1050	2.5	71.84	23.95
40	VI	2	7/23/1997	175	09.50	388	1250	2.6	16.81	5.76
40	VI	3	7/23/1997	195	13.45	454	1500	2.5	23.92	7.36
40	VI	4	7/24/1997	160	08.00	676	1800	2.5	125.66	47.13
40	VI	5	7/24/1997	175	12.00	606	1700	2.6	38.18	13.09
40	VI	6	7/24/1997	165	16.05	540	1600	2.5	19.4	7.05
40	VII	1	12/10/1997	180	06.25	673	1800	2.3	54.85	18.29
40	VII	2	12/10/1997	180	10.30	590	1700	2.7	16.77	5.59
	VII	3	12/10/1997	125	14.15	515	1600	2.7	19.02	9.13

TABLE 1. (Continued). List of the hauls, with indication of the stretched mesh size, date, duration, starting hour, depth, wire length, towing speed, total catch (kg) and total catch per hour (kg/h) carried out in the Ionian Sea from April 1996 to March 1998.

Stretched mesh size (mm)	Survey	Haul	Date	Duration (minutes)	Starting hour	Depth (m)	Wire length (m)	Towing speed	Total catch kg	Total catch per hour (kg/h)
40	VII	10	12/13/1997	150	06.25	462	1450	2.7	14.52	5.8
40	VII	11	12/13/1997	165	09.45	352	1250	2.5	22.28	8.1
40	VII	12	12/13/1997	148	13.15	243	850	2.8	74.37	30.15
40	VIII	1	3/4/1998	180	06.45	673	1850	2.5	65.13	21.71
40	VIII	2	3/4/1998	180	11.00	589	1700	2.5	46.78	15.6
40	VIII	3	3/4/1998	180	15.00	519	1600	2.5	44.72	14.9
40	VIII	10	3/7/1998	180	05.45	379	1250	2.5	16.69	5.56
40	VIII	11	3/7/1998	165	09.25	461	1500	2.5	26.49	9.63
40	VIII	12	3/7/1998	160	13.00	306	1050	2.5	28.66	10.75
50	V	7	5/4/1997	185	06.05	660	1750	2.6	50.43	16.35
50	V	8	5/4/1997	174	10.20	511	1650	2.5	18.49	6.38
50	V	9	5/4/1997	180	15.40	568	1750	2.5	15.24	5.08
50	V	10	5/5/1997	170	05.45	315	1050	2.6	68.1	24.03
50	V	11	5/5/1997	170	09.20	384	1300	2.5	21.3	7.53
50	V	12	5/5/1997	165	13.00	452	1450	2.5	28.49	10.36
50	VI	7	7/25/1997	170	05.40	305	1050	2.6	50.85	17.95
50	VI	8	7/25/1997	170	09.20	360	1250	2.5	22.77	8.04
50	VI	9	7/25/1997	175	13.05	465	1400	2.5	15.45	5.29
50	VI	10	7/27/1997	180	06.00	666	1800	2.5	44.77	14.92
50	VI	11	7/27/1997	140	10.10	602	1700	2.6	13.92	5.97
50	VI	12	7/27/1997	120	14.10	512	1550	2.7	22.92	11.47
50	VII	4	12/11/1997	180	06.30	659	1800	2.7	27.5	9.16
50	VII	5	12/11/1997	180	10.30	590	1700	2.7	17.75	5.91
50	VII	6	12/11/1997	160	14.20	519	1600	2.7	23.02	8.63
50	VII	7	12/12/1997	145	08.25	474	1450	2.7	31.54	13.05
50	VII	8	12/12/1997	175	11.35	387	1350	2.7	24.39	8.36
50	VII	9	12/12/1997	135	15.15	304	1000	2.8	29.15	12.95
50	VIII	4	3/5/1998	180	06.00	672	1850	2.5	56.09	18.7
50	VIII	5	3/5/1998	180	10.00	582	1700	2.5	70.04	23.34
50	VIII	6	3/5/1998	180	14.00	507	1600	2.5	21.76	7.25
50	VIII	7	3/6/1998	170	06.05	474	1500	2.5	16.06	5.67
50	VIII	8	3/6/1998	180	10.00	369	1300	2.5	9.59	3.2
50	VIII	9	3/6/1998	175	13.50	314	1100	2.5	40.31	13.83
60	I	7	4/18/1996	180	06.10	399	1300	2.5	17.09	5.7
60	I	8	4/18/1996	165	10.05	486	1450	2.5	33.31	12.12
60	I	9	4/18/1996	175	13.50	313	1050	2.5	26.54	9.09
60	I	10	4/19/1996	180	05.45	589	1700	2.6	17.23	5.74
60	I	11	4/19/1996	170	09.40	528	1600	2.6	31.98	11.29
60	I	12	4/19/1996	150	13.25	670	1850	2.6	28.89	11.55
60	II	7	7/23/1996	185	06.00	313	1050	2.4	20.49	6.65

TABLE 1. (Continued). List of the hauls, with indication of the stretched mesh size, date, duration, starting hour, depth, wire length, towing speed, total catch (kg) and total catch per hour (kg/h) carried out in the Ionian Sea from April 1996 to March 1998.

Stretched mesh size (mm)	Survey	Haul	Date	Duration (minutes)	Starting hour	Depth (m)	Wire length (m)	Towing speed	Total catch kg	Total catch per hour (kg/h)
60	II	8	7/23/1996	185	10.35	478	1500	2.4	11.68	3.79
60	II	9	7/23/1996	170	14.40	400	1350	2.4	18.96	6.69
60	II	10	7/24/1996	175	05.50	511	1600	2.4	15.06	5.16
60	II	11	7/24/1996	180	09.40	573	1700	2.4	36.7	12.23
60	II	12	7/24/1996	180	13.40	655	1850	2.4	34.42	11.47
60	III	7	10/25/1996	180	06.45	664	1800	2.5	86.59	28.86
60	III	8	10/25/1996	180	11.00	586	1650	2.3	6.22	2.07
60	III	9	10/25/1996	180	15.00	515	1600	2.3	38.81	12.94
60	III	10	10/26/1996	175	06.35	452	1450	2.5	74.53	25.55
60	III	12	10/26/1996	175	14.05	326	1050	2.6	48.91	16.77
60	IV	7	2/27/1997	180	06.40	274	1050	2.6	21.81	7.27
60	IV	8	3/4/1997	180	06.35	669	1800	2.6	86.61	28.87
60	IV	9	3/4/1997	180	10.35	611	1700	2.5	35.96	11.98
60	IV	10	3/4/1997	180	14.25	532	1650	2.5	19.2	6.4
60	IV	11	3/5/1997	180	06.05	470	1450	2.6	23.62	7.88
60	IV	12	3/5/1997	150	12.15	397	1250	2.5	28.9	11.56

$DR = 0.1856 + 0.0093$ Total catch per hour; $r = 0.35$; $n = 48$; $p<0.01$

$DR = -0.3142 + 0.0013$ Depth $r = 0.67$; $n = 48$; $p<0.01$

Concerning the catch composition, 162 species were collected. Two of them (*Aristeus antennatus* and *Aristaeomorpha foliacea*) were target species, 34 were by-catch with variable commercial value and 126 were unwanted species. Discarded catch was mostly due to unwanted species (99.25% on average), mainly represented by *C. caelorhynchus, H. italicus*, *N. sclerorhynchus, H. mediterraneus, C. agassizi* and *G. melastomus*. The contribution of bycatch species (both with high and low commercial value) to the discards was very low (0.75% on average) (Fig. 5). This latter contribution was mainly represented by small specimens of *H. dactylopterus, P. blennoides* and *M. poutassou*. The differences between these two discard fractions (unwanted and by-catch species) within the whole discarded catch between the surveys were not statistically significant (G-test = 0.46, $p>0.05$).

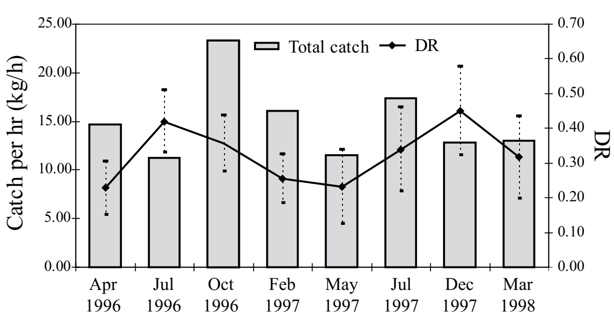

Fig. 3. Average total catch per hour (kg/h) and average discard rate (DR), with relative standard error, computed by survey for 40 mm mesh size codend.

Fish, crustaceans and cephalopods represented 90.8%, 6.4% and 2.8% of the discarded catch, respectively. In the marketable catch, the highest fraction on average comprised crustaceans (66.9%), followed by fish (24.2%) and cephalopods (8.9%).

Mesh size codend comparison

The average DR for the 50 mm sMS codend ranged from 0.18 (July 1997) to 0.37 (December 1997) as part of an average total catch per hour between 10.61 kg/h and 9.68 kg/h, respectively. The 60 mm

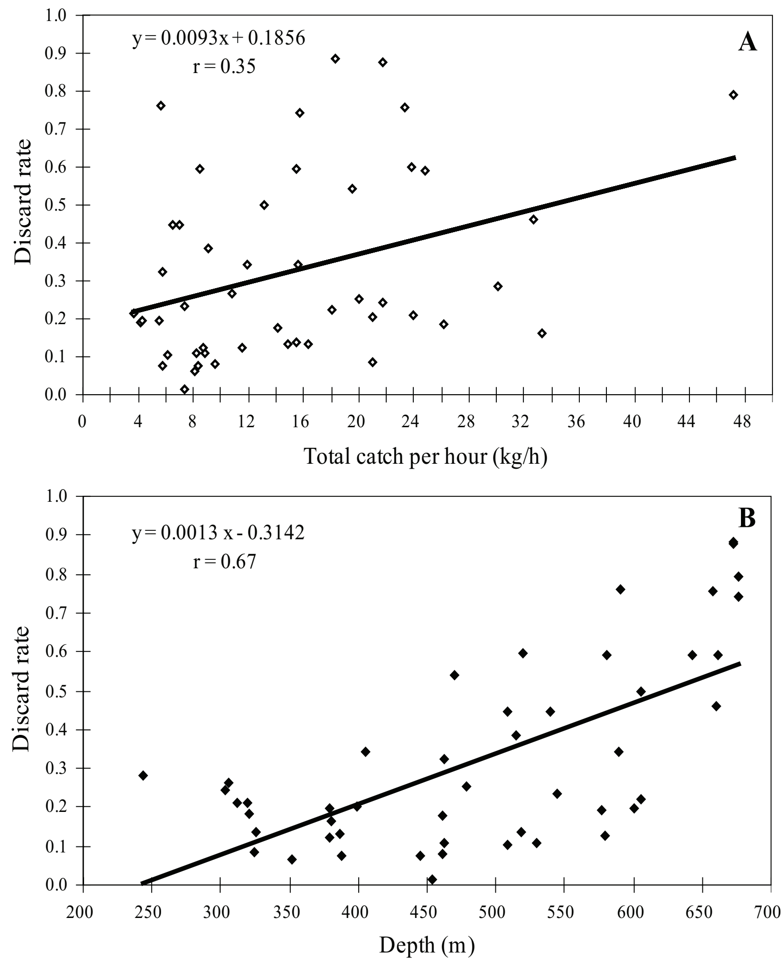

Fig. 4. Relationship between discard rate and total catch per hour (**A**) and discard rate and depth (**B**) computed for the hauls carried out with the 40 mm mesh size codend.

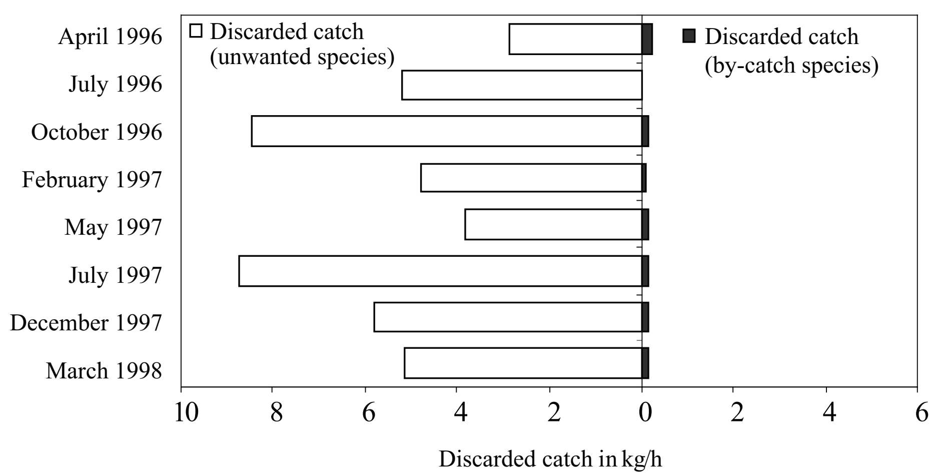

Fig. 5. Average discarded catch per hour, due to unwanted and by-catch species, computed for each survey carried out in the Ionian Sea with the 40 mm mesh size codend.

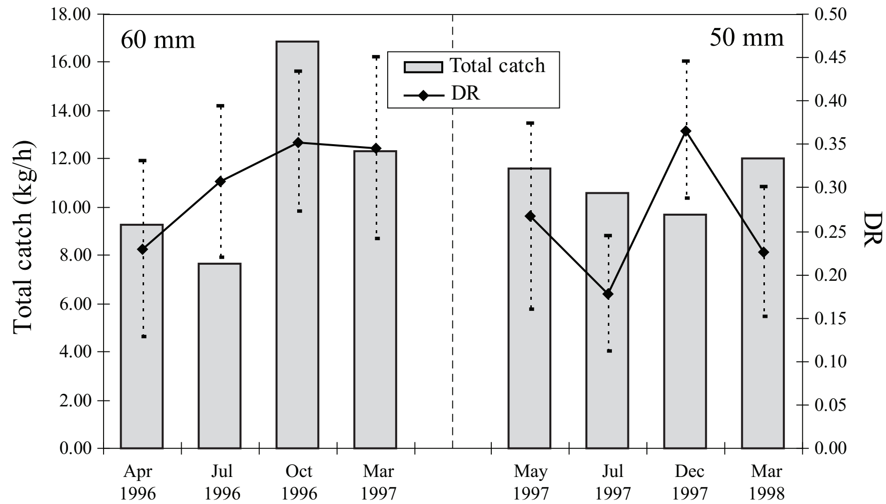

Fig. 6. Average total catch per hour (kg/h) and average discard rate (DR), with relative standard error, computed by survey for 60 and 50 mm mesh size codend.

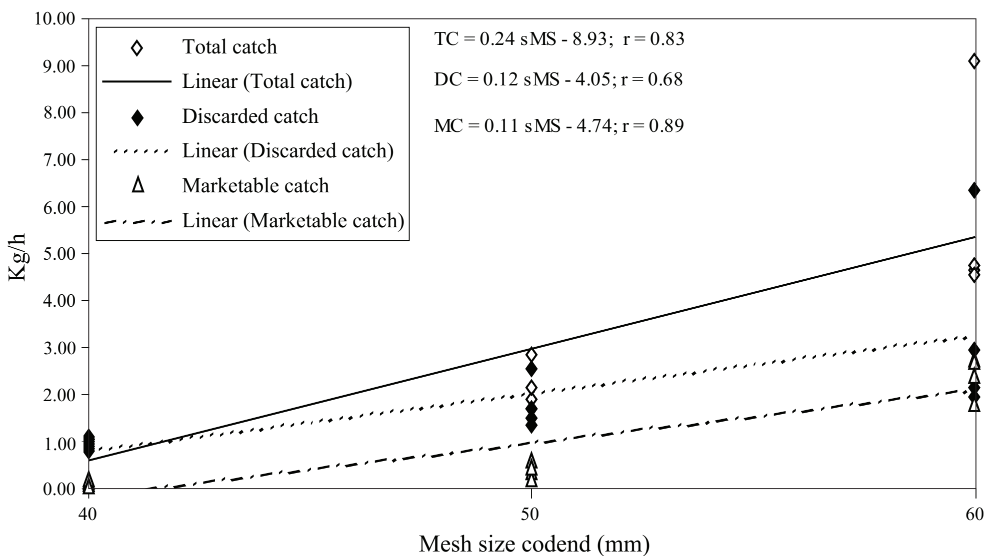

Fig. 7. Different relationships computed for total catch (TC), discarded catch (DC) and marketable catch (MC), in kg per hour retained in the cover in relation to stretched mesh size of codend.

sMS codend showed mean DR values between 0.23 (April 1996) and 0.35 (October 1996) within an average total catch per hour of 9.25 kg/h and 16.87 kg/h, respectively (Fig. 6).

The changes in discarded and marketable catch (both target and by-catch species) with the three codends, considered for the pooled data were not statistically significant (G-test = 0.45, p>0.05). The relationship between the catch passing into the cover (total, marketable and discards) and the mesh size of the codend was positive (Fig. 7). Moreover, the changes of the discard fraction relative to the total catch in the cover with the different sMS codends were not significant (G-test = 0.12, p>0.05). In other words, the proportion between marketable and discards in the cover did not change with increasing mesh size in the codend.

No substantial differences were found between the three codends with regard to the qualitative composition of discards and marketable components of the catch.

Size distribution and selectivity parameters

Concerning *Aristeus antennatus*, the individuals caught with the 40 mm sMS codend were almost fully retained. The fraction escaping into the cover increased according to the mesh size (Fig. 8). The retention sizes at 50% computed for the 50 and 60 mm sMS codends were 19.0±0.2 and 25.4±0.2 mm carapace lengths respectively (Fig. 9). Only specimens crushed during hauling and sorting operations were discarded with all three codends.

Specimens of *Helicolenus dactylopterus* smaller than 100 mm total length (TL) were always discarded. Their number retained in the codend decreased markedly with mesh size, thus reducing the discarded fraction (Fig. 10). The best fit of data in the selectivity curves was shown for the 40 and 50 mm mesh sizes, which provided comparable selectivity parameters (SR, SF) and L_{50} values of 55.2±0.5 mm TL and 74.6±1,1 mm TL, respectively (Fig. 11).

Individuals of *Phycis blennoides* smaller than 160 mm TL were always rejected. Larger specimens up to 240 mm TL specimens were retained or discarded according to their state of preservation. The discarded fraction in the codend decreased according to the mesh size while the percentage fraction of the specimens escaping into the cover increased (Fig. 12). The 50 % retention sizes were 90.9±0.8 mm TL for the 40 mm sMS, 112.4±2.4 mm TL for 50 mm and 173.9±3.3 mm TL for 60 mm (Fig. 13).

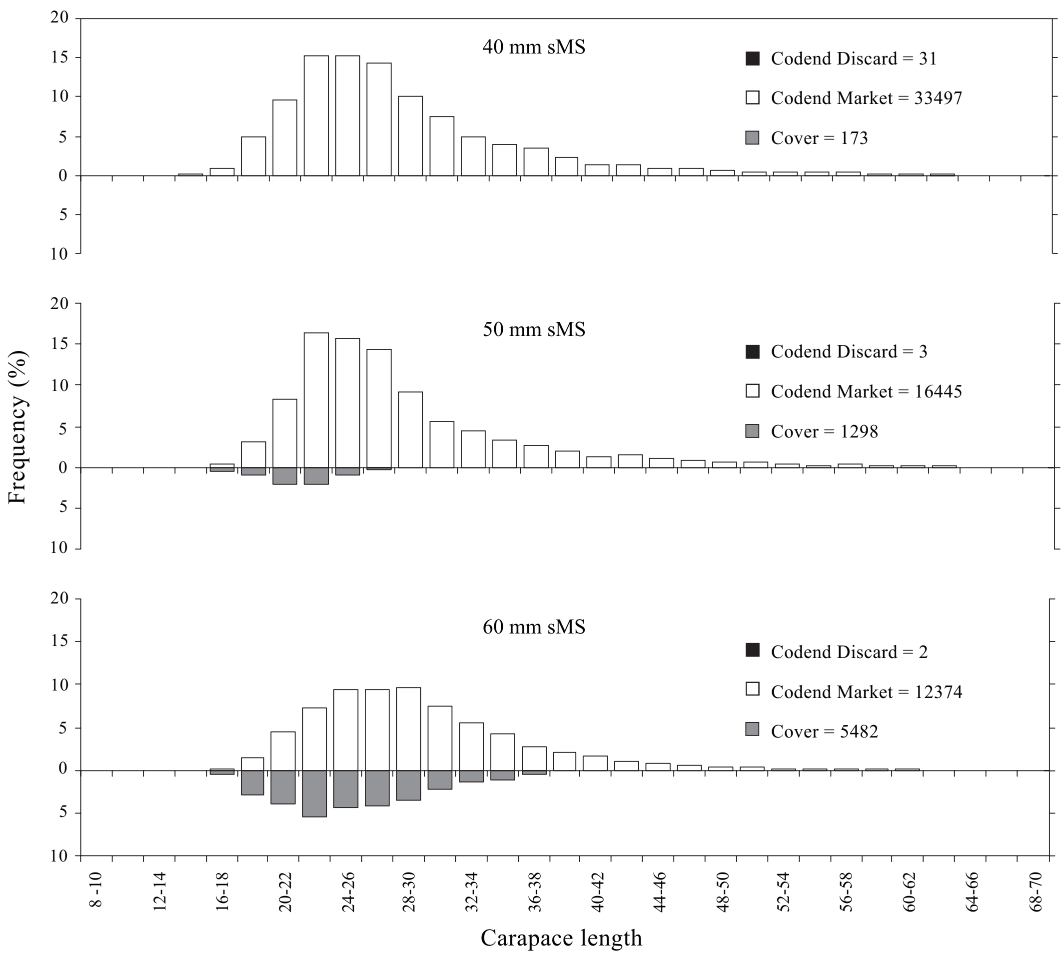

Fig. 8. Length frequency distribution of *Aristeus antennatus* collected in the codend (40, 50 and 60 mm stretched mesh size, sMS) and in the cover with indication of discarded and marketable fraction.

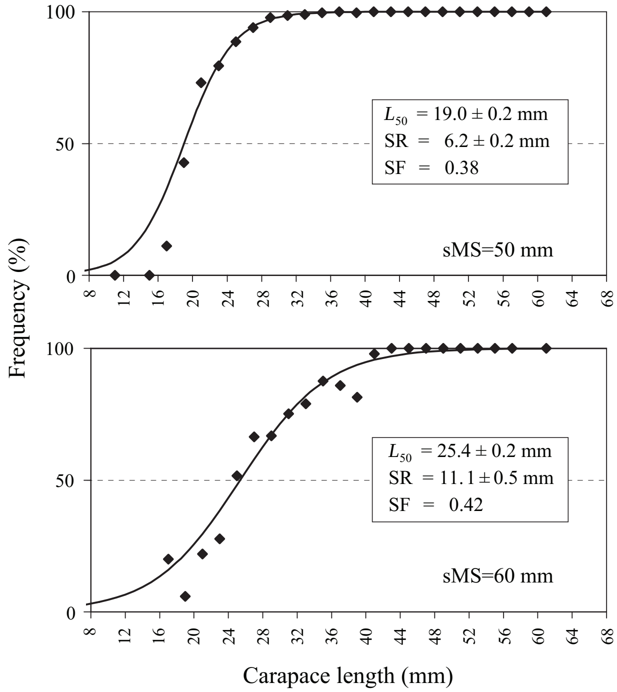

Fig. 9. Estimated selectivity curves for *Aristeus antennatus* by stretched mesh sizes (sMS) showing the retention size at 50% (L_{50}), selection range (SR) and selection factor (SF).

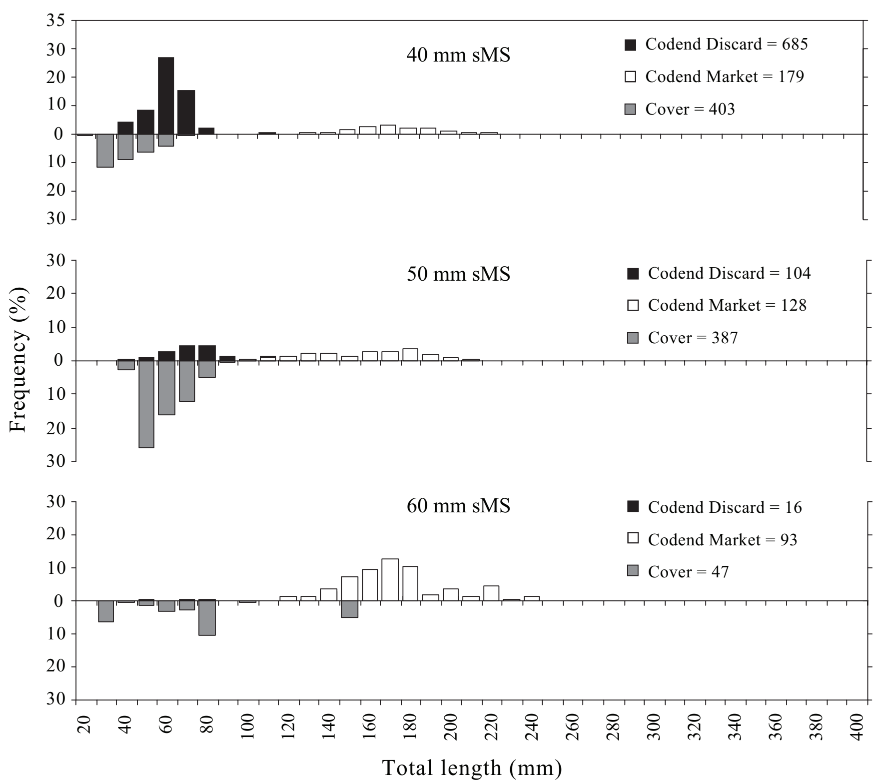

Fig. 10. Length frequency distribution of *Helicolenus dactylopterus* collected in the codend (40, 50 and 60 mm sMS) and cover with indication of discarded and marketable fraction.

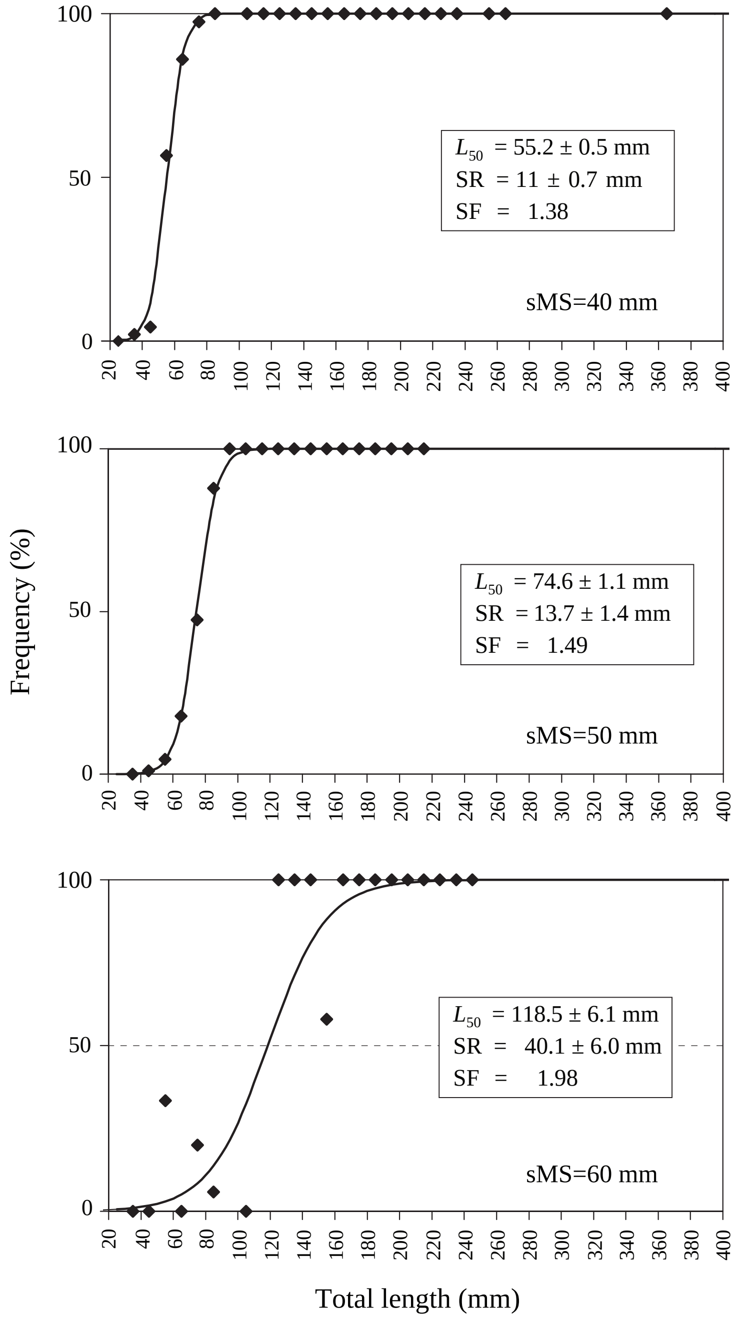

Fig. 11. Estimated selectivity curves for *Helicolenus dactylopterus* by stretched mesh sizes (sMS).

Micromesistius poutassou is a demersal species whose recruitment occurs on the continental shelf, so that only larger specimens are captured on the slope (Tursi *et al*., 1993) Fish smaller than 190 mm TL were always discarded. Only with the 60 mm sMS codend did a noticeable proportion of individuals escape into the cover (Fig. 14). However, the available data did not fit any reliable selection curve.

For *Caelorhinchus caelorhinchus* the fraction of specimens escaping into the cover also increased with mesh size in the codend (Fig. 15). The retention sizes

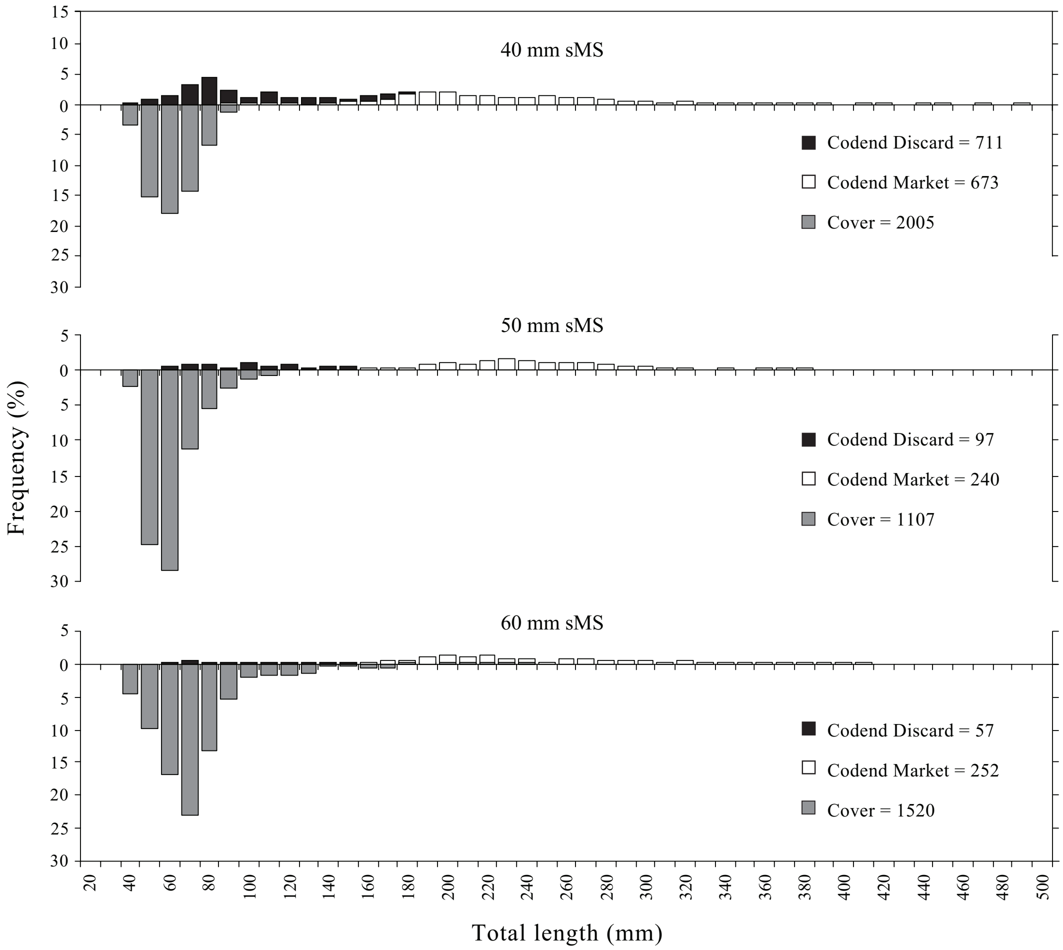

Fig. 12. Length frequency distribution of *Phycis blennoides* collected in the codend (40, 50 and 60 mm sMS) and cover with indication of discarded and marketable fraction.

at 50% for the three sMS codends were 24.9±0.1 mm PAL, 33.9±0.4 mm PAL and 47.4±0.6 mm PAL respectively (Fig. 16). Both the selection range and the selection factor computed for the 60 mm sMS codend were markedly greater than those calculated for 40 and 50 mm.

Discussion

The discarded catch from the deep-water shrimp fishery in the Ionian Sea constitutes an important fraction of the total catch (20–50%), as shown in other Mediterranean areas (Carbonell *et al*., 1998; Moranta *et al*., 2000; Machias *et al*., 2001; Ragonese *et al*., 2001). It is almost exclusively due to unwanted fish species while discards of the target species *A. antennatus* and *A. foliacea* and other commercial species were negligible. Although the discard rate varied monthly, no significant differences were seen between the seasons. In contrast, the discard rate increased with total catch and depth as shown in the northeastern Mediterranen (Machias *et al*., 2001). According to Stergiou *et al*. (1998), the positive increase in discards with total catch could be due to the decreasing selectivity of codends as they fill and meshes become masked. Moreover, a greater fraction of crushed specimens may occur when the codend is full. The positive increase in discards with depth may be attributed to the greater abundance of unwanted species, such as the macrourid fishes, *Hoplostethus mediterraneus* and *Galeus melastomus*, in the study area (Matarrese *et al*., 1996; D'Onghia *et al.*, 1998b).

According to Ragonese *et al*. (2001), no substantial differences were seen in the quantitative and qualitative overall performance of the codends used. Differences were only detected in the biomass of the escaped fraction of the catch (both marketable

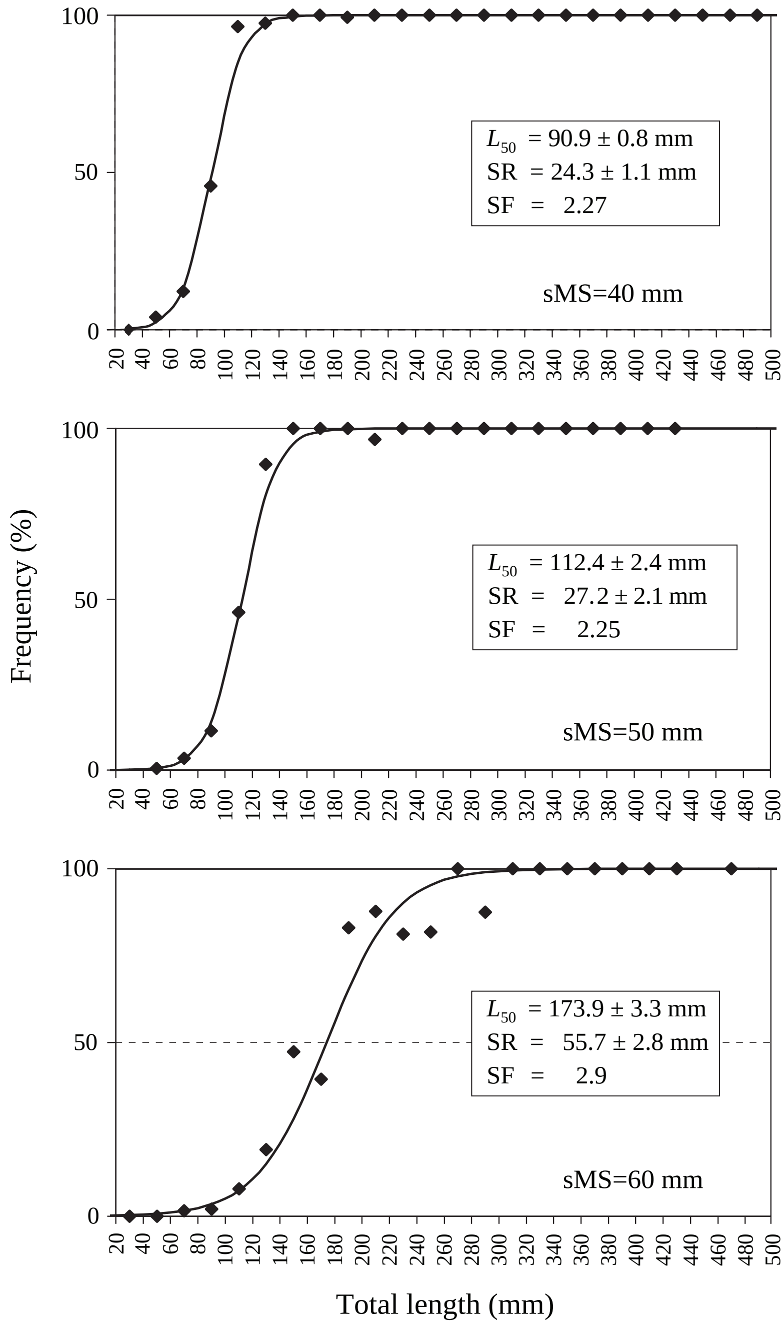

Fig. 13. Estimated selectivity curves for *Phycis blennoides* by stretched mesh sizes (sMS).

and discards) and in the size selectivity. In particular, both the number of small specimens escaping from the meshes and the 50% retention sizes increased with the mesh size in all examined species. The selection range and the selection factor also generally increased with the mesh size indicating a different selection process between the codends. This could be the consequence of the pooling of data in addition to other factors, which could affect the selection curve (Briggs, 1986). However, the 60 mm sMS mostly reduces the capture of *A. antennatus* specimens smaller than 30 mm CL, which have the lowest market value and most of them are generally immature. It avoids almost completely the catch of *H. dactylopterus* and *P. blennoides* juveniles otherwise discarded using the presently used codend (40 mm sMS) and allows a large

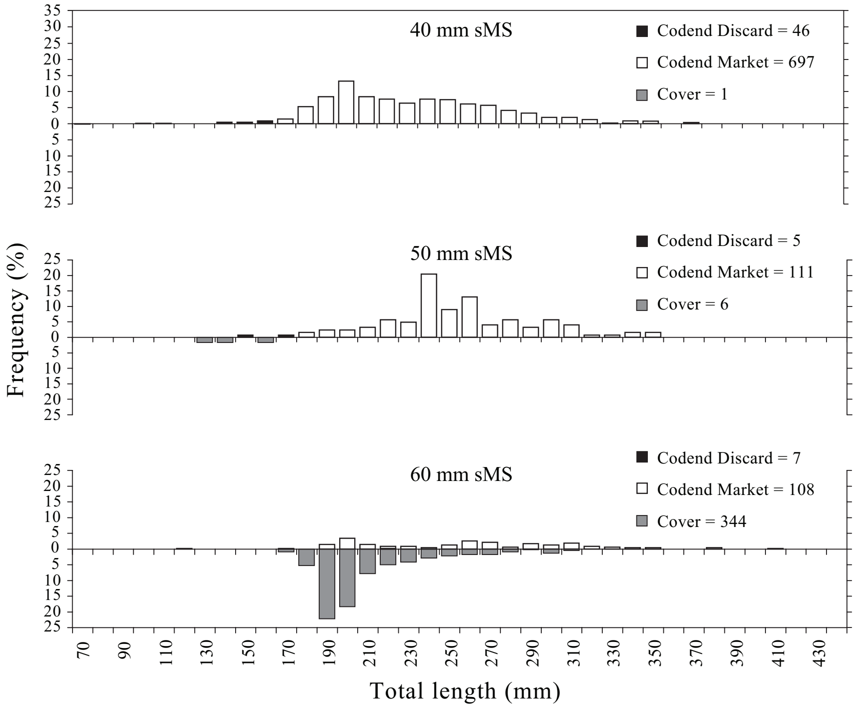

Fig. 14. Length frequency distribution of *Micromesistius poutassou* collected in the codend (40, 50 and 60 mm sMS) and cover with indication of discarded and marketable fraction.

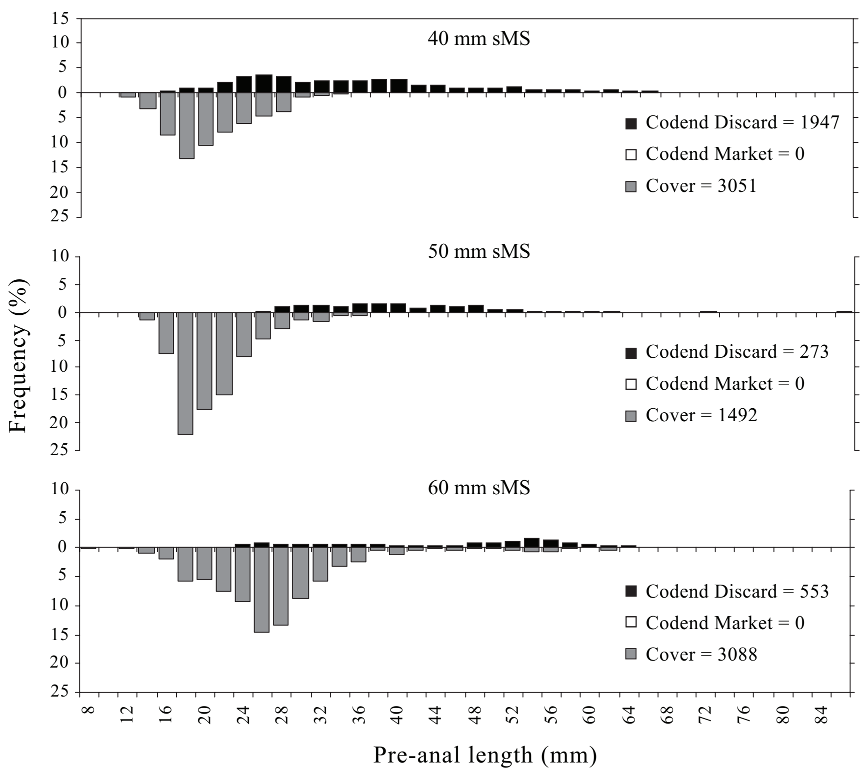

Fig. 15. Length frequency distribution of *Caelorhynchus caelorhynchus* collected in the codend (40, 50 and 60 mm sMS) and cover with indication of discarded and marketable fraction.

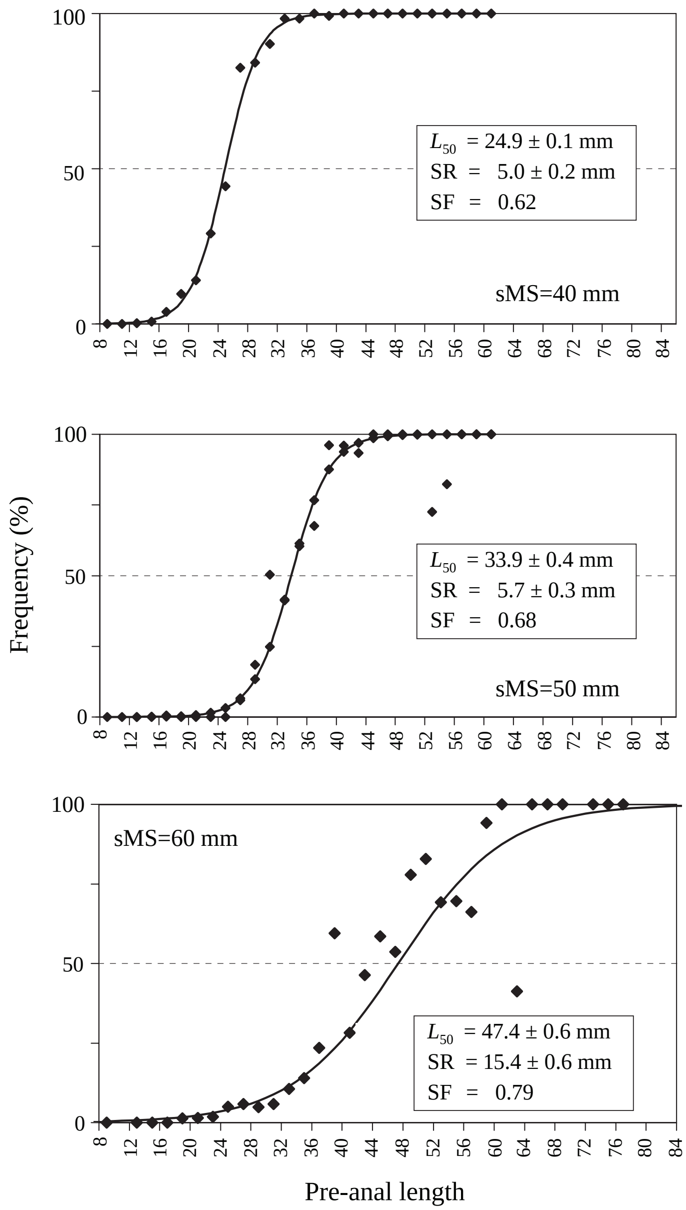

Fig. 16. Estimated selectivity curves for *Caelorhynchus caelorhynchus* by stretched mesh sizes (sMS).

fraction of small specimens of by-catch and unwanted species to escape. Ragonese *et al.* (1994, 2001) reported that the adoption of a larger mesh size (28 mm side) reduces the capture of low value or undersize specimens, minimizing the sorting time and improving the catch quality. However, considering that nothing is known about the survival of escaped specimens during deep shrimp trawling, it is not yet possible to quantify the reduction of juvenile mortality or of the impact on the deep-sea living resources. Several studies have shown that fish escaping from gears are seriously damaged and unable to make a complete recovery (in Chopin and Arimoto, 1995). Individuals would be subjected to capture stress and physical injuries both in the cod-end due to contact with other organisms and debris, and when passing through the mesh. Unfortunately, very little is known about the survival of crustacean species (e.g. Smith and Howell, 1987; Hill and Wassenberg, 1990; Stevens, 1990) and nothing about *A. antennatus*.

According to Ragonese *et al*. (1994, 2001), the introduction of a larger mesh size would cause minimal economic loss (due to the very small unit value of small-size specimens which would escape). However, the adoption of such a regulation becomes questionable for those fisheries because, as in this case, they are based on shelf and upper slope multispecies assemblages (Caddy, 1990). In particular, in the study area the trawlers fish over a wide depth range. The same trawlers can fish both on deepwater shrimps (*A. foliacea* and *A. antennatus*) on the upper slope, and on the rose shrimp and hake on the shelf edge and upper slope. Depending on sea state or weather conditions and the varying availability of the resources they can also fish in very shallow waters targetting red mullet and other coastal species. Thus, the adoption of a larger mesh than 40 mm stretched would appear to be feasible as part of the regulation of an almost monospecific fishery targetting deep-water shrimps on the slope, but only after the assessment of its long-term effects on stock levels and catches.

Acknowledgements

This work was supported by DG XIV of the European Commission as part of the project "Developing deep-water fisheries: data for their assessment and for understanding their interaction with and impact on a fragile environment" (DEEP-FISHERIES CT 96-0655).

References

ALVERSON, D. L., M. H. FREEBERG, S. S. MURASKI, and J. G. POPE. 1994. A global assessment of fisheries by-catch and discards. *FAO Fish. Tech. Pap*., **339**: 233 p.

BRIGGS, R. P. 1986. A general review of mesh selection for *Nephrops norvegicus*. *Fish. Res*., **4**: 59–73.

CADDY, J. F. 1990. Options for the regulation of Mediterranean demersal fisheries. *Nat. Resour. Modeling*, **4**: 427–475.

CARBONELL, A., P. MARTIN, S. DE RANIERI, and WEDIS team. 1998. Discards of the Western Mediterranean trawl fleet. *Rapp. Comm. int. Mer Médit*., **35**: 392–393.

CHOPIN, F. S., and T. ARIMOTO. 1995. The condition of fish escaping from fishing gears – a review. *Fish. Res*., **1**, 315–327.

D'ONGHIA, G., F. MASTROTOTARO, P. MAIORANO, and M. BASANISI. 1998a. Selettività della rete a strascico utilizzata sui fondi di scarpata (250–750 m) dello Ionio (Mediterraneo Centrale). *Biol. Mar. Medit*, **5**(2): 437–448.

D'ONGHIA, G., A. TURSI, A., M. BASANISI, and F. MASTROTOTARO. 1997. Commercial trawling, discards and recruitment from a fishery of the north-western Ionian Sea. *Biol. Mar. Medit.,* **4**(1): 291–297.

D'ONGHIA, G., A. TURSI, P. MAIORANO, A. MATARRESE, and M. PANZA. 1998b. Demersal fish assemblages from the bathyal grounds of Ionian Sea (middle-eastern Mediterranean). *Ital. J. Zool. Suppl*., **65**: 287–292.

FIORENTINI, L., G. COSIMI, A. SALA, and V. PALUMBO. 1994. Caratteristiche e prestazioni delle attrezzature a strascico impiegate per la Valutazione delle Risorse Demersali in Italia. *Biol. Mar. Medit.*, **1**(2): 115–134.

HILL, B. J., and T. J. WASSENBERG. 1990. Fate of discards from prawn trawlers in Torres Strait. *Aust. J. Mar. Fresh. Res*., **41**: 53–64.

MACHIAS, A., V. VASSILOPOULOU, D. VATSOS, P. BEKAS, A. KALLIANIOTIS, C. PAPACONSTANTINOU, and N. TSIMENIDES. 2001. Bottom trawl discards in the northeastern Mediterranean Sea. *Fish. Res*., **53**: 181–195.

MATARRESE, A., G. D'ONGHIA, A. TURSI, and M. BASANISI. 1996. New information on the ichthyofauna of the south-eastern Italian coasts (Ionian Sea). *Cybium*, **20**(2): 197–211.

MORANTA, J., E. MASSUTÌ, and B. MORALES NIN. 2000. Fish catch composition of the deep-sea decapod crustaceans fisheries in the Balearic Islands (western Mediterranean). *Fish. Res*., **45**: 253–264.

POPE S., A. R. MARGETTS, J. M. HANLEY, and A. F. AKUZ. 1975. Manual of methods for fish stock assessment. Part III. Selectivity of fishing gear. *FAO Fish. Tech. Pap*., **145**: 65 p.

RAGONESE, S., M. L. BIANCHINI, L. DI STEFANO, S. CAMPAGNUOLO, and F. BERTOLINO. 1994. Study of the selectivity and assessment of the coefficient of retention of the trawl nets used for red shrimps fishing (*Aristaeomorpha foliacea* Risso, 1827 and *Aristeus antennatus* Risso, 1816; Crustacea. Aristeidae) in the Sicilian Channel (Central Mediterranean Sea). *Project. MED 92/010, Final report*, 300 p.

RAGONESE, S., M. ZAGRA, L. DI STEFANO, and M. L. BIANCHINI. 2001. Effect of codend mesh size on the performance of the deep-water bottom trawl used in the red shrimp fishery in the Strait of Sicily (Mediterranean Sea). *Hydrobiologia*, **449**: 279–291.

SMITH, E. M., and P. T. HOWELL. 1987. The effects of bottom trawling on American lobsters *Homarus americanus*, in Long Island Sound. *Fish. Bull*. **85**(4): 737–744.

SOKAL, R. R., and F. J. ROHLF. 1969. Biometry. W.H. Freeman and Co., San Francisco, 776 p.

SPARRE, P., and S.C. VENEMA. 1998. Introduction to tropical fish stock assessment. Part 1. Manual. *FAO Fish. Tech. Pap*., **306**.1, Rev. 2, 407 p.

STERGIOU, K. I., A. ECONOMOU, C. PAPACONSTANTINOU, N. TSIMENIDES, and S. KAVADAS. 1998. Estimates of discard in the Hellenic commercial trawl fishery. *Rapp. Comm. int. Mer*, **35**: 490–491.

STERGIOU, K. I., C.-Y. POLITOU, E. D. CHRISTOU, and G. PETRAKIS. 1997. Selectivity experiments in the NE Mediterranean: the effect of trawl codend mesh size on the species diversity and discard. *ICES J. Mar. Sci.,* **54**: 774–786.

STEVENS, B. G. 1990. Survival of King and Tanner crabs captured by commercial sole trawlers. *Fish. Bull*. **88**: 731–744.

TURSI, A., L. SION, P. MAIORANO, and M. PANZA. 1993. Le nurseries di *Micromesistius poutassou* (Risso, 1826) nel Mar Ionio. *Biol. Mar., Suppl*., **1**: 377–378.

TURSI, A., A. MATARRESE, G. D'ONGHIA, P. MAIORANO, and M. PANZA. 1998. Sintesi delle ricerche sulle risorse demersali del Mar Ionio (da Capo d'Otranto a Capo Passero) realizzate nel periodo 1985–1997. *Biol. Mar. Medit*., **5**(3): 120–129.

WILEMAN, D. A., R. S. T. FERRO, R. FONTEYNE, and R. B. MILLAR (eds.). 1996. Manual of Methods of Measuring the Selectivity of Towed Fishing Gears. *ICES Coop. Res. Rep*., No. 215, 126 p.