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Escapement from the main body of the bottom trawl used for the Mediterranean international trawl survey (MEDITS)

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Abstract — Escapement through the body or under the footrope of the sampling trawl used for the Mediterranean international trawl survey programme (MEDITS) was assessed i) by means of visual observations performed with a towed operating vehicle equipped with a high-sensitivity video camera, and ii) by attaching small bags to the outside of the trawl body and under the footrope. Due to the small size of most of the individuals present in the study area and to the towing speed, fish behaviour in front of the trawl could not be frequently observed. In contrast, their behaviour was easily observed inside the net, especially upstream and inside the codend. Some species, such as horse mackerel (*Trachurus* sp.), showed greater swimming endurance compared with others such as annular seabream (*Diplodus annularis*). In three fishing trips conducted in different seasons in 1996 and 1997 to obtain data on several species in different areas of the Adriatic, six small net bags were mounted outside the body of the MEDITS trawl to quantify escapement through the trawl belly and under the footrope. Significant escapement of many species occurred in the near-bottom part of the side panels. Norway lobster (*Nephrops norvegicus*) had the highest rate (64 %), mainly represented by small-size individuals. The escapement of greater forkbeard (*Phycis blennoides*) was also high (53 %). For hake (*Merluccius merluccius*), common pandora (*Pagellus erythrinus*) and poor cod (*Trisopterus minutus capelanus*), rates ranged from 10 to 16 %. The escapement of red mullet (*Mullus barbatus*) was very low despite their great abundance. Blue whiting (*Micromesistius poutassou*) escaped mainly through the mid-height part of the side panel. This great variability of escapement values could affect the proportion rates of the species sampled during a standard survey. Different escape behaviours among size classes were observed for *M. poutassou*, *T. minutus capelanus* and *P. erythrinus*, with smaller individuals tending to escape towards the bottom and larger ones towards the higher parts of the trawl body. In the species where the escape rate was size-dependent, therefore, the size-frequency distributions obtained from the codend catch may not reflect actual size-frequency distributions. © Ifremer/Cnrs/Inra/Ird/Cemagref/Elsevier, Paris

Survey trawl selectivity / trawl escapement / bottom trawls / experimental fishing / underwater observations / Mediterranean

Résumé — Échappements à travers le corps du chalut de fond utilisé pour le programme international d'évaluation par chalutage des ressources halieutiques de Méditerranée (MEDITS). L'échappement à travers le corps ou sous le bourrelet du chalut d'échantillonnage utilisé dans le cadre du programme MEDITS a été estimé : i) au moyen d'observations sous-marines faites à partir d'un véhicule remorqué équipé d'une caméra vidéo haute sensibilité, et ii) en fixant des petites poches de filet à l'extérieur du corps du chalut ainsi que sous le bourrelet. La petite taille de la plupart des individus présents sur les fonds de pêche étudiés, ainsi que la vitesse de chalutage, n'ont pas permis d'observer fréquemment le comportement des poissons devant l'entrée du chalut. Leur comportement à l'intérieur du filet a pu, en revanche, être régulièrement observé, notamment dans la poche et les pièces situées en amont de celle-ci. Certaines espèces, comme les chinchards *(Trachurus* sp.*)*, ont montré une meilleure résistance que d'autres, par exemple le sparaillon *(Diplodus annularis)*, quant à leur capacité de nage vers l'avant à l'intérieur du chalut. Trois campagnes de pêche ont été conduites durant différentes saisons de 1996 et 1997 en vue de récolter des données concernant différentes espèces halieutiques et différentes zones de la mer Adriatique ; durant ces campagnes, six petites poches de filet ont été fixées à l'extérieur du corps du chalut MEDITS en vue de quantifier les phénomènes d'échappement à travers les mailles du corps de ce chalut ainsi que sous son bourrelet. Pour de nombreuses espèces, un échappement significatif est survenu dans la partie basse des faces de côté du chalut. Le plus fort taux d'échappement noté (64 %) concernait *Nephrops norvegicus*, phénomène principalement lié à la petite taille des individus présents sur la zone. L'échappement des mostelles *(Phycis blennoides)* a également été élevé (53 %). Les taux d'échappement du merlu *(Merluccius merluccius)*, du pageot *(Pagellus erythrinus)* et du capelan *(Trisopterus minutus capelanus)* ont été compris entre 10 et 16 %. L'échappement du rouget *(Mullus barbatus)* s'est avéré particulièrement faible, en dépit de la forte abondance de l'espèce sur les zones de pêche. Les fuites de merlan bleu *(Micromesistius poutassou)* se sont produites principalement vers le milieu de la hauteur des faces latérales du chalut. La variabilité importante des échappements observés peut affecter les valeurs des proportions relatives d'espèces échantillonnées durant une campagne d'évaluation standard. Des comportements d'échappement différents selon la taille ont été

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notés pour *M. poutassou*, *T. minutus capelanus* et *P. erythrinus*, les plus petits individus tendant à fuir vers le bas et les plus grands vers le haut du corps du chalut. Pour les espèces ayant présenté un échappement lié à la taille, la distribution des fréquences de longueur des individus trouvés dans la poche du chalut peut donc ne pas refléter exactement la distribution réelle des longueurs sur la zone.

Sélectivité du chalut / échappement du chalut / chalut de fond / pêche expérimentale / observation sous-marine / Méditerranée

1. INTRODUCTION

A sampling trawl was designed for the Mediterranean international trawl survey (MEDITS) programme based on a series of requirements provided by the biologists involved in the programme [3, 8]. One of these was low selectivity, so as to provide as complete a picture as possible of the species captured. To do this, the full mesh size of the codend was limited to 20 mm.

However, the codend is not the only part of the trawl from which fish escape. The escapement from trawls used for survey purposes has been extensively studied. Engås and Godø [6] observed considerable length-dependent escapement of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) under a Norwegian sampling trawl. Walsh [13] showed the vulnerability of a groundfish survey trawl to be size-dependent in Atlantic cod (*G. morhua*), American plaice (*Hippoglossoides platessoides*) and yellowtail flounder (*Limanda ferruginea*). Ehrich [5] studied escapement under the GOV trawl (*chalut à grande ouverture verticale*) used for the present international bottom trawl surveys in the North Sea, Skagerrak and Kattegat, and concluded that young cod (*G. morhua*) are considerably underestimated when the trawl is rigged with a heavy bobbin footrope.

During acoustic surveys, net bags were applied by Nakashima [12] to the outside of a midwater trawl to quantify escapement and to determine its effect on composition and length-frequency estimates. Quantitative evidence was provided that midwater trawls may produce biased observations, with the smaller capelin (*Mallotus villosus*) and species such as Arctic cod (*Boreogadus saida*) and sand lance (*Ammodytes dubius*) being under-represented in the codend catch.

In a similar study, four small bags were attached to the outside of a typical commercial Italian trawl [9]. No fish were found in the two bags mounted on the upper part of the trawl, while only small benthic fish species, such as scaldfish (*Arnoglossus laterna*), were found in the bags attached to the lateral part of the body. No specimens of the experiment's target species, red mullet (*Mullus barbatus*), were found in the bags despite large catches in the codend.

Selectivity experiments on Norway lobster (*Nephrops norvegicus*) showed that substantial selection can occur in the main body of the trawl [11].

The aim of the work presented in this paper was to assess the escapement through the body or under the footrope of the MEDITS trawl. The first two sections of the body of this trawl have a relatively larger mesh (140 and 120 mm) than those normally used in many commercial Mediterranean trawls [8]. Such mesh sizes have been chosen in order to avoid, in a good compromise, an avoiding behaviour of larger individuals as well as an escapement behaviour of smaller ones. Our object was to observe whether this mesh size herded all the fish to the codend or whether some escaped through these large meshes: i) for the main fish species caught in the area, to see if they all behave in the same way; and ii) for the different size classes, to see if the length-frequency distributions obtained from codend catches reflect those in the sea.

Two methodologies were applied. Trawl-fish interactions were studied by visual inspection during two trips conducted with a towed operating vehicle equipped with a high-sensitivity video camera. In addition, during three fishing trips conducted to assess the efficiency of the MEDITS trawl [8], some small bags were attached to the outside of the trawl to estimate fish escapement through the meshes and under the footrope.

2. MATERIALS AND METHODS

2.1. Visual observations

2.1.1. Instrumentation

The EROC (*engin remorqué d'observation des chaluts*) was used for underwater visual observations. This is a towed underwater vehicle equipped with a TV camera which dives up to 120 m in depth. Its position in the water is controlled through a console on the vessel. Its longitudinal position is controlled by shooting or hauling the towing cable. The transversal and vertical positions are controlled by four rotors (Magnus effect) placed in front of the vehicle. The camera can be rotated in all directions. The towing cable contains the electronic connections that drive the rotors, control the camera and receive the TV signals.

2.1.2. Sampling areas

The two visual-observation trips were made between the second and the third fishing trip. The first was carried out in May 1997 in the Tyrrhenian Sea on board the French research vessel *L'Europe*. The fishing station lay between La Spezia and Viareggio at a depth ranging from 22 to 55 m. The second was

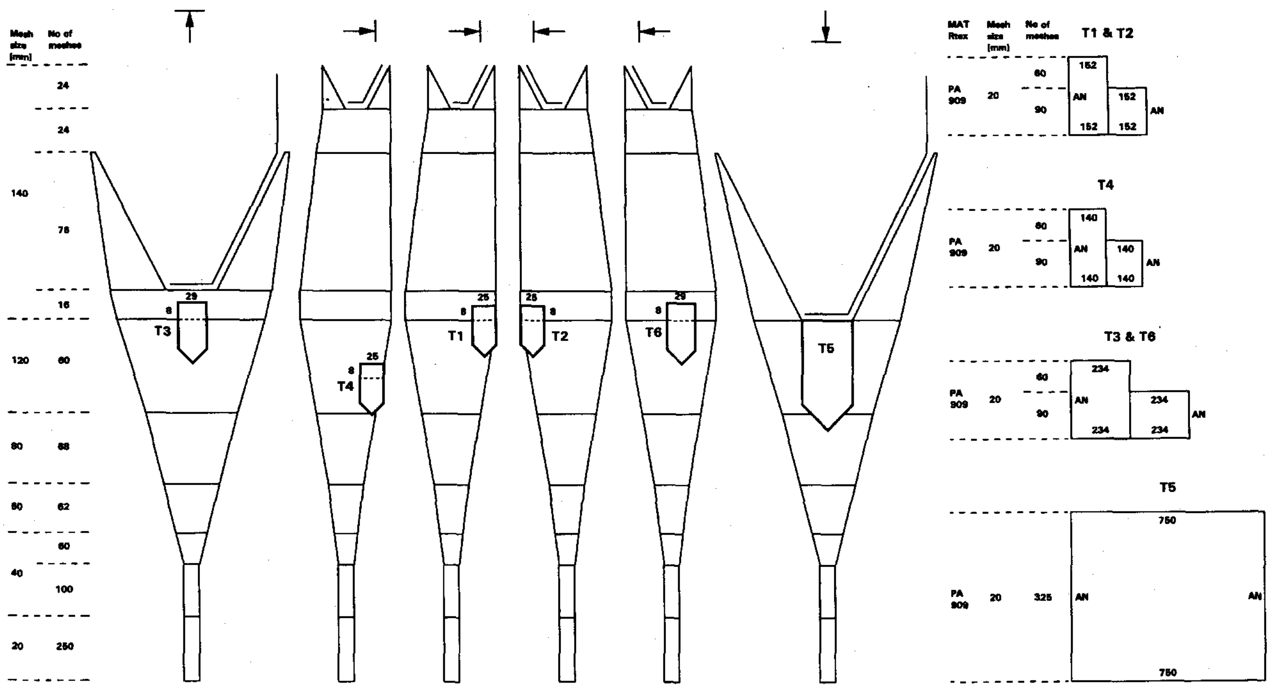

Figure 1. Position and dimensions of the small net bags mounted on the different parts of the MEDITS trawl: the near-bottom part of the side panels (T1, T2 and T4), the upper panel (T3), the mid-height part of the side panel (T6) and under the footrope (T5).

conducted in June 1997 in the Adriatic on board the Italian research vessel *S. Lo Bianco*. The poor visibility close to the bottom off the coast of Ancona made it necessary to move towards the southern Adriatic. An area was selected north of the Gargano promontory at a depth of approximately 15 m. One haul was performed at a depth of 50 m. Tows were performed with the MEDITS trawls in both trips, and also with a commercial Italian trawl in the second.

2.2. Fishing trips

For a description of the materials and methods used during the fishing trips see Fiorentini et al. [8]. Additional information on specific materials and methods used for escapement data analysis is presented in the following sections.

2.2.1. Fishing gear

During the last three of four fishing trips conducted to assess the efficiency of the MEDITS trawl [8], five small net bags (T1, T2, T3, T4 and T6) were attached to the outside of the first two belly panels of the trawl to assess fish escapement through their relatively large meshes (140 and 120 mm, respectively). A sixth bag (T5) was attached under the trawl between the footrope and the chains to assess escapement under the footrope. The mesh size of the bags was 20 mm as in the codend. Their position along the net and their dimensions are shown in *figure 1*.

The fishing trips follow the numeration adopted in Fiorentini et al. [8] and are thus numbered from 2 to 4. Three bags (T1, T2 and T4) were employed in all three fishing trips, bags T3 and T5 were mounted only in the second trip, and bag T6 was employed in the third and the fourth trip.

2.2.2. Sampling methodology

Data on the species caught by the net bags and by the codend were collected according to the MEDITS protocol [1, 2, 8].

2.2.3. Data processing

To evaluate escape rates, the number and size-frequency distributions computed for each net bag were multiplied by different coefficients according to the part of the trawl to which the bags had been attached.

To obtain these coefficients, one possibility was to subdivide the trawl body into the truncated conic sections having equal mesh size and to consider each bag as representative of the escape rate occurring through the section to which it was attached. This possibility was rejected because the species composition in the bags mounted in the near-bottom part of the belly (T1, T2 and T4) was quite different from that observed in the bags mounted at mid-height (T6) or on the upper part (T3), which had the same mesh size.

An alternative choice, and the one adopted, was to consider all the bags except T5 as representative of the

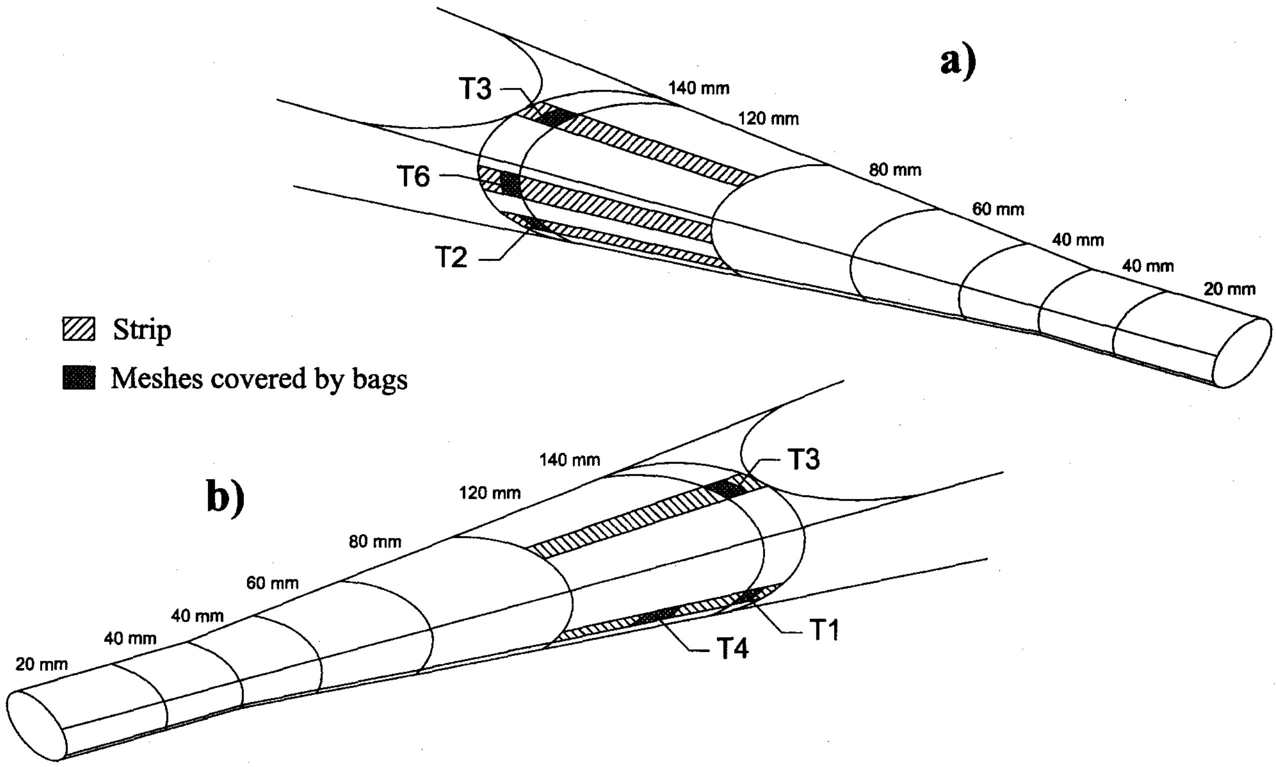

Figure 2. Port (a) and starboard (b) views of the MEDITS trawl with bag positions and trawl strips through which escapement is assumed to be homogeneous.

escapement occurring through a hypothetical longitudinal net strip (*figure 2*), measuring 76 meshes in length (the overall length of the two panels, 16 + 60 meshes) and 25 or 29 meshes in width (the number of the transversal meshes covered by each bag; *figure 1*). Because the bags covered 8 meshes along the strip, the coefficient was 9.5 (76/8) for the T3 bag, considered representative of the upper panel of the trawl, and 19 (9.5 × 2) for the T6 bag, representative of the two mid-height (MH) side panels.

The T1, T2 and T4 bags were considered representative of the near-bottom (NB) part of the side panels. The escapement data obtained from these bags were averaged to obtain mean escapement per bag. This value was then multiplied by the coefficient (19) used for the T6 bag. The T5 bag data were considered representative of the fish escaping under the central part of the footrope and were not multiplied.

For each species, the escape rate was computed as the ratio between the average number of individuals found in the bags per haul, raised to the whole strip, and the average number of those caught in the codend [4].

The escape data obtained for the main and the other MEDITS reference species [1] are reported (*table I*) only for the species that reached the threshold of 50 individuals caught per trip. *Table I* also reports the percentage of their catch per trip as the ratio between the number of hauls in which they were caught and the total number of hauls made in that trip, as well as the mean size and total number of the individuals found in the codend and in the bags.

The size selection occurring in the main body of the trawl was computed by the method normally used in codend-cover experiments. In the present case, cover size-frequency distribution was simply replaced with that of the bags raised to the whole strip. Selection curves were fitted by the maximum-likelihood method [14]. Goodness of fit and between-haul variation were also computed [10].

3. RESULTS

3.1. Visual observations

Fishing stations were preliminarily tested for visibility conditions. Unfortunately, the areas selected on this basis did not provide high fish abundance. Medium-large size specimens were particularly few in the catches.

Therefore, very few fish were observed in front of the trawl entrance. Moreover, probably because of their small size, those fish that were observed were unable to swim for long at the trawl's speed (about

Table I. Escapement through different parts of the MEDITS trawl: percentage of presence in the hauls per trip; mean size (total length for fishes in cm; carapace length for crustaceans in mm; mantle length for molluscs in cm); No: total number of individuals caught in the codend or escaped (bag data were extropolated as explained in the text); escape percentage (ratio between the average number per haul of the specimens found in the bags and those found in the codend) and 95 % confidence interval. – Bag not mounted on the trawl for that trip or no data available.

		Codend			Near-bottom part of side panels (T1 + T2 T4)						Mid-height part of side panels T6						Upper panel T3						Under the footrope T5					
Species	Trip	Presence (%)	Size	No.	Presence (%)	Size	No.	Escape (%) Mean	Low L.	Up.L.	Presence (%)	Size	No.	Escape (%) Mean	Low L.	Up.L.	Presence (%)	Size	No.	Escape (%) Mean	Low L.	Up.L.	Presence (%)	Size	No.	Escape (%) Mean	Low L.	Up.L.
MEDITS main reference species																												
Merluccius merluccius	3	100	19.4	248	13	17.0	32	13	4	22	0	–	0	0	0	0	–	–	–	–			–	–	–	–		
	4	100	17.0	446	22	9.2	44	10	– 3	23	0	–	0	0	0	0	–	–	–	–			–	–	–	–		
Micromesistius poutassou	3	100	15.5	1 741	3	13.5	6	0	0	1	62	17.4	228	13	6	20	–	–	–	–			–	–	–	–		
Mullus barbatus	2	100	2.6	70 401	68	12.7	1 571	2	0	4	–	–	–	–			0	–	0	0	0	0	30	10.7	14	0	0	0
Pagellus erythrinus	2	100	7.4	2 267	37	8.0	253	11	7	15	–	–	–	–			0	–	0	0	0	0	85	5.9	66	3	2	4
Phycis blennoides	3	92	–	119	21	–	63	53	18	88	0	–	0	0	0	0	–	–	–	–			–	–	–	–		
Spicara flexuosa	2	95	–	933	0	–	0	0	0	0	–	–	–	–			5	–	10	1	– 1	3	0	–	0	0	0	0
Trachurus mediterraneus	2	100	10.1	9 514	3	10.5	32	0	0	1	–	–	–	–			0	–	0	0	0	0	5	9.5	1	0	0	0
Trisopterus minutus capelanus	4	100	9.3	1 464	59	6.9	241	16	8	25	11	11.5	19	1	– 2	4	–	–	–	–			–	–	–	–		
Eledone cirrhosa	3	100	7.4	59	3	2.5	6	11	– 13	34	0	–	0	0	0	0	–	–	–	–			–	–	–	–		
	4	100	3.9	95	19	3.8	38	40	3	77	0	–	0	0	0	0	–	–	–	–			–	–	–	–		
Illex coindetii	4	100	9.8	764	0	–	0	0	0	0	0	–	0	0	0	0	–	–	–	–			–	–	–	–		
Loligo vulgaris	2	100	6.2	1 239	3	7.8	13	1	– 1	3	–	–	–	–	–	–	0	–	0	0	0	0	10	3.0	2	0	0	0
Sepia officinalis	2	100	5.8	3 001	30	4.9	146	5	2	8	–	–	–	–	–	–	0	–	0	0	0	0	50	5.2	21	1	0	1
Nephrops norvegicus	3	100	25.7	974	87	22.8	621	64	44	83	0	–	0	0	0	0	–	–	–	–			–	–	–	–		
Other MEDITS reference species																												
Boops boops	2	100	–	5 709	0	–	0	0	0	0	–	–	–	–			0	–	0	0	0	0	5	–	1	0	0	0
Diplodus annularis	2	70	–	105	0	–	0	0	0	0	–	–	–	–			0	–	0	0	0	0	0	–	0	0	0	0
Engraulis encrasicolus	2	100	–	33 062	2	–	6	0	0	0	–	–	–	–	–	–	35	–	95	0	0	1	0	–	0	0	0	0
	4	100	–	4 229	4	–	13	0	– 1	1	11	–	133	3	1	5	–	–	–	–			–	–	–	–		
Lepidopus caudatus	3	100	–	265	0	–	0	0	0	0	8	–	19	7	– 8	22	–	–	–	–			–	–	–	–		
Sardina pilchardus	2	95	–	600	0	–	0	0	0	0	–	–	–	–	–	–	15	–	38	6	– 2	15	0	–	0	0	0	0
	4	89	–	70	0	–	0	0	0	0	0	–	0	0	0	0	–	–	–	–			–	–	–	–		
Squilla mantis	2	100	–	2 615	25	–	108	4	2	6	–	–	–	–	–	–	0	–	0	0	0	0	30	–	8	0	0	0

1.5 m·s^{-1}) and remained very briefly in the area covered by the TV camera, preventing the clear identification of specific behaviours. The only general observation concerned the herding effect: some fish tried to keep clear of the solid part of the trawl (especially the footrope) and tended to concentrate in the middle of the netting cone.

In contrast, fish behaviour was easily observed in the last sections of the trawl body and in the codend. Some species, such as horse mackerel (*Trachurus* sp.), showed greater swimming endurance compared with others such as annular seabream (*Diplodus annularis*). Some fish may have escaped when the vessel stopped for hauling operations. However, since the towed vehicle must be hauled before the fishing gear, observations for this phase are not available.

Gear behaviour could also be observed satisfactorily. The amount of sand and mud lifted from the bottom showed that the footrope of the commercial trawl was in closer contact with the bottom than that of the MEDITS trawl. Moreover, a considerable portion of the lower panel of the commercial trawl seemed to remain in contact with the bottom, while that of the MEDITS trawl rose from the bottom just behind the footrope.

With reference to the bags attached to the trawl belly, the external netting of the one mounted on the upper part of the trawl (T3) appeared to be flattened against the trawl, preventing fish access into the bag. This masking effect was due to the low angle of attack (angle with respect to the water flow) of the first upper panels with respect to the water flow. The bag was removed in the course of the second visual-observation trip and placed in the middle of a side panel (T6 position), whose wider angle of attack allowed the bag to remain distanced from the trawl body, as confirmed by visual observation. The bag was left in this position for the two subsequent fishing trips.

Because of the sand and mud clouds raised by the footrope, the behaviour of the bags mounted on the NB part (T1, T2 and T4) could not be observed, except for the elliptic shape of the belly section and the short distance of these bags from the bottom. As these three bags were attached to the same panels as the T6 bag, and had a similar angle of attack, they were all assumed to behave in the same way as the T6 bag and to be unaffected by the masking effect.

The underwater recordings were employed to produce a video film showing the underwater behaviour of the MEDITS trawl and of the fish in front and inside of it, as well as the methodology and some of the results obtained in these and in the parallel experiments [8]. A copy of the film can be obtained from the corresponding author.

3.2. Escapement from the trawl body

The highest rate of escape into the NB bags (T1, T2 and T4) was shown by *N. norvegicus*, found in these bags in 87 % of the hauls of the third trip. The escape rate in this trip was 64 %, which was significant because the 95 % confidence limits (44–83 %) do not cover 0 (*table I*), and increased with decreasing size. *Figure 3a* shows the size-frequency distributions of this species in the codend and in the NB bags. The proportion of individuals caught by the codend (codend/(codend + bag)) is shown against carapace length in *figure 3b* along with the selectivity curve. The 50 % retention length was 21.9 mm (SE = 0.4), with a selection range of 13.5 mm (SE = 1.2). There was no between-haul variation (P = 1.000). Similar observations were made in the fourth fishing trip, but computations could not be performed owing to the low number of individuals caught.

As regards fish species, the escapement of greater forkbeard (*Phycis blennoides*) into the NB bags was especially high (53 %). In three other species, hake (*Merluccius merluccius*), common pandora (*Pagellus erythrinus*) and poor cod (*Trisopterus minutus capelanus*), it ranged from 10 to 16 %, which was significant except for *M. merluccius* in the fourth trip.

The mean size of *P. erythrinus* was slightly larger in the NB bags than in the codend (*table I*; *figure 3c, d*).

In contrast, the mean sizes of *M. merluccius*, *T. minutus capelanus* and blue whiting (*Micromesistius poutassou*) were larger in the codend. For *T. minutus capelanus*, in particular, escapement was strongly size-dependent (*figure 3e, f*) as for *N. norvegicus*.

M. barbatus, probably because of their high abundance, were found in the NB bags in 68 % of the hauls of the second trip. Nevertheless, their escape rate was low (2 %), with very small differences in mean size between the bags and the codend (*table I*).

The escapement into the NB bags of horned octopus (*Eledone cirrhosa*) was the highest among molluscs (11 %) and not significant in the third trip, when the mean mantle length (ML) of the individuals found in the bags was considerably lower than in the codend (2.5 cm versus 7.4 cm; *figure 4a, b*). Their presence in the hauls was only 3 %. During the fourth trip, when the mean size of the individuals present in the area was smaller (3.9 and 3.8 cm, respectively, in the codend and in the bags; *figure 4c, d*), their escape rate rose to 40 % and their presence in the hauls to 19 %. A moderate escape rate (5 %) was shown by common cuttlefish (*Sepia officinalis*), while broadtail squid (*Illex coindetii*) and European squid (*Loligo vulgaris*) were absent or scarce in bag catches.

The MH bag (T6) showed a high rate of escape only for *M. poutassou* (13 %). This species was found in the bag in 62 % of the hauls of the third trip. The escape rate was lower for silver scabbardfish (*Lepidopus caudatus*; 7 %), anchovy (*Engraulis encrasicolus*; 3 %) and *T. minutus capelanus*. The mean size of the individuals found in this bag was higher than in the codend: for *M. poutassou*, it was 17.4 cm versus 15.5 cm. The larger size classes contributed most to the escapement into the MH bag (*figure 4e, f*).

The only species which escaped through the upper part of the trawl belly was sardine *Sardina pilchardus* (6 %). This result was not significant and *S. pilchardus*

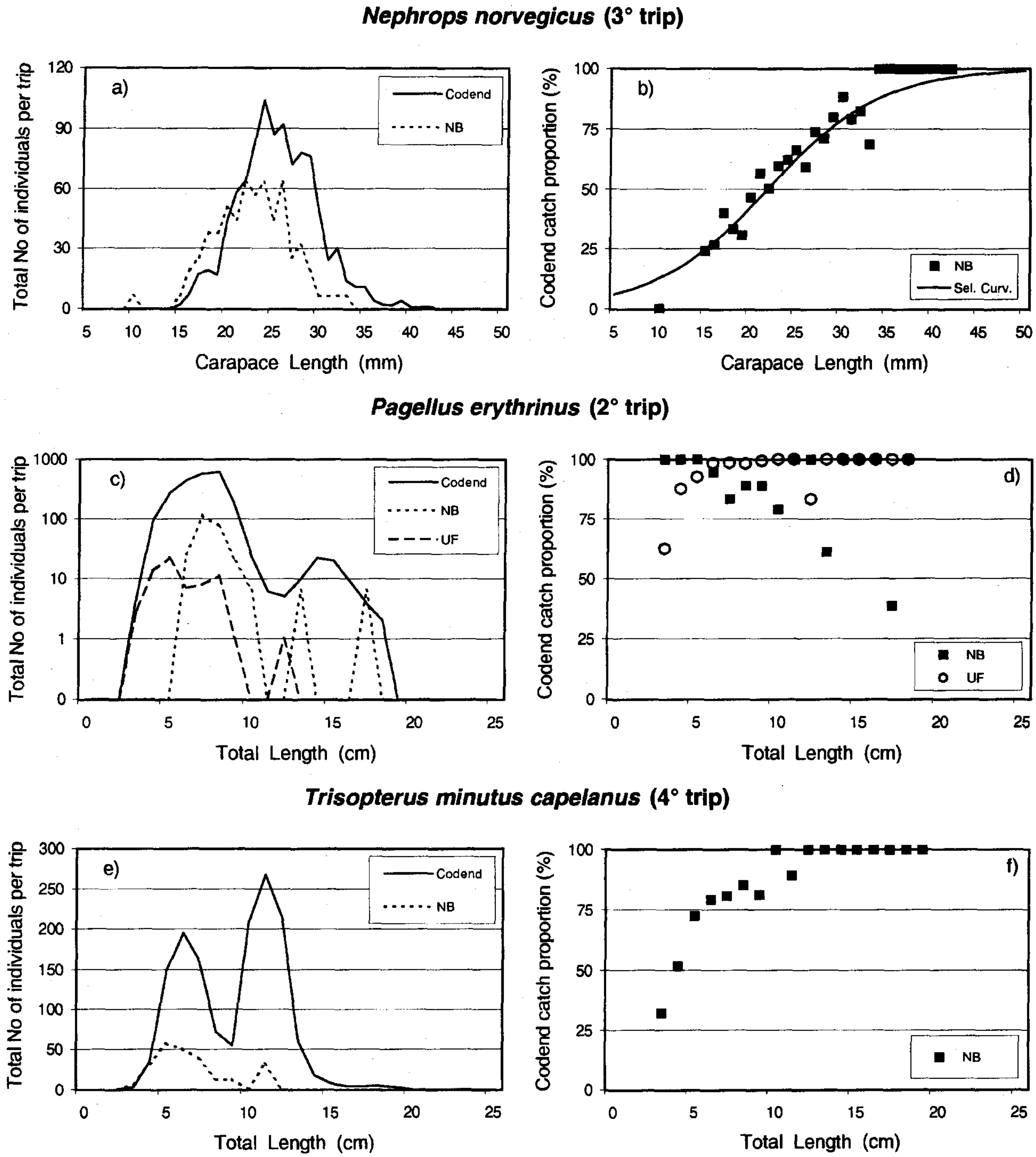

Figure 3. Size-frequency distributions of all the individuals of Norway lobster (*Nephrops norvegicus*) caught by the codend and near-bottom (NB) bags of the MEDITS trawl in the third trip (a), of common pandora (*Pagellus erythrinus*) in the second trip (c), of poor cod (*Trisopterus minutus capelanus*) in the fourth trip (e). The distribution of *P. erythrinus* found in the bag mounted under the footrope (UF) is also shown (c). Bag data were extrapolated as explained in the text. For the three species, the proportions of individuals caught by the codend (codend/(codend + bag)) are shown in graphs b, d and f, respectively. The selection curve of *N. norvegicus* is shown in graph b.

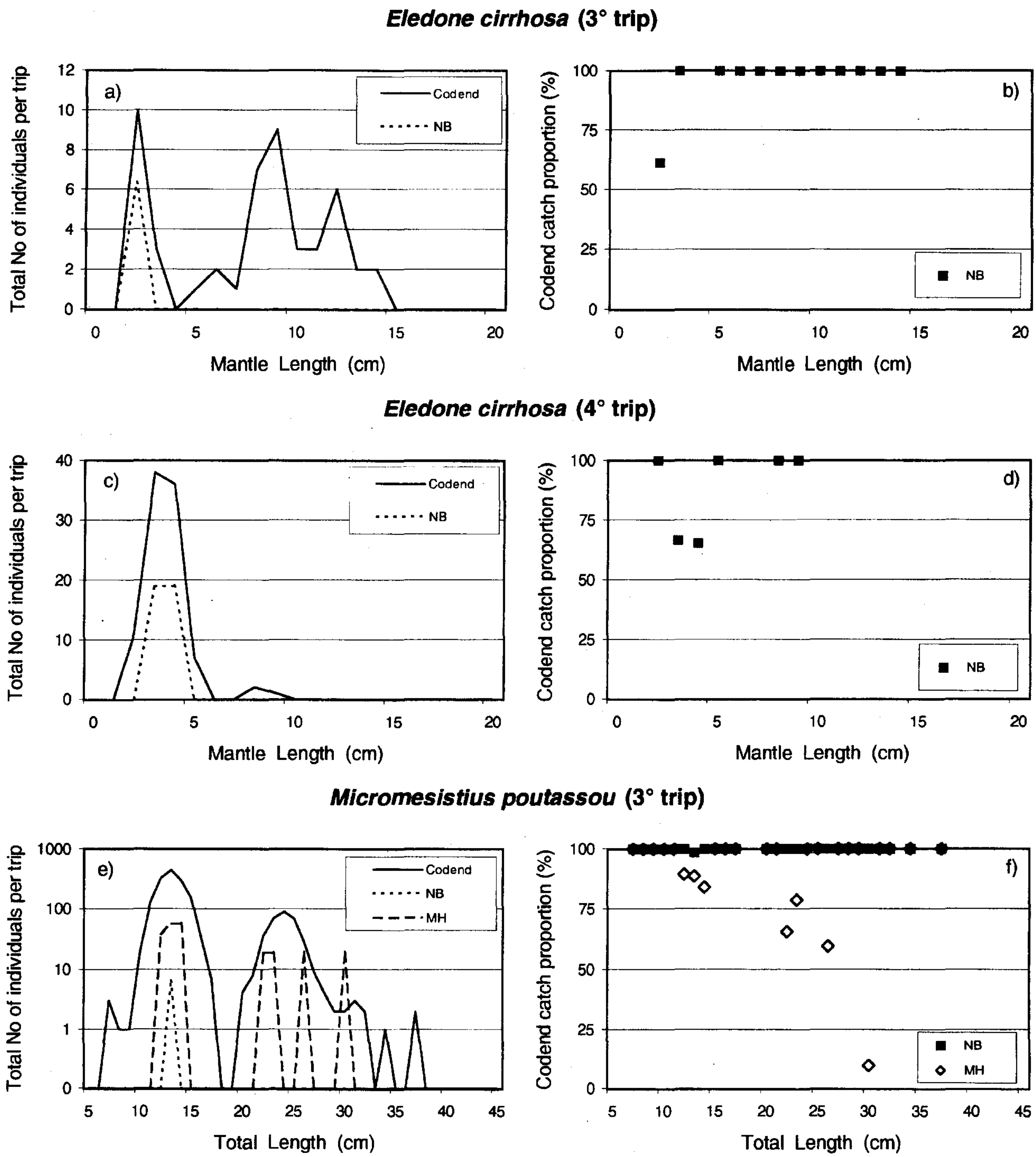

Figure 4. Size-frequency distributions of all the individuals of horned octopus (*Eledone cirrhosa*) caught by the codend and near-bottom (NB) bags of the MEDITS trawl in the third (a) and fourth (c) trip, of blue whiting (*Micromesistius poutassou*) in the third trip (e). The distribution of *M. poutassou* found in the bag mounted on the mid-height (MH) part of the side panel is also shown (e). The bag data were extrapolated as explained in the text. For the two species, the proportions of individuals caught by the codend (codend/(codend + bag)) in the various trips are shown in graphs b, d and f, respectively.

was present in only 15 % of the hauls of the second fishing trip. *E. encrasicolus* was found more regularly (35 %), but their escape rate was low (less than 1 %).

Escapement under the trawl was low. *P. erythrinus* was regularly present (85 %) in the bag mounted under the footrope (T5), with individuals smaller than those found in the codend (5.9 cm versus 7.4 cm; *figure 3c, d*), but their escape rate was significantly low (3 %). Common sole (*Solea vulgaris*), which was not included in *table I* because of their very low catch rates, was occasionally found in the T5 bag during the second trip, as were some individuals of *S. officinalis*.

4. DISCUSSION

Prudent and therefore partial coefficients were adopted to convert bag catches into escape rates. Bag catch data were extrapolated to strips only as large as the bags and as long as the netting panels to which they were attached. The evaluation of whole-trawl escapement was not performed. This could have been calculated by extrapolating bag data in both the longitudinal and the transversal directions with respect to the trawl axis. As regards the longitudinal direction, neither the wings (mesh size 140 mm) nor the last sections ahead of the codend (mesh size 80 and 60 mm) were considered, although escapement there is likely to be similar to that observed in the areas where the bags were mounted. The reason for this decision was that no data were available for these parts of the trawl, which are mainly those where the mesh is smaller and where escapement, even though it probably involved the same species, was likely to be represented by smaller individuals.

As far as the transversal direction is concerned, escapement in the immediate vicinity of the NB bags and in the lower panel was probably similar to that of the NB bags. In this case, the extrapolation was not performed because across the same panel the composition of the species that escaped varied with distance from the bottom. For example, the T2 and T6 bags, mounted on the same panel (*figure 1*) at a short distance, differed considerably in species composition (*table I*). Since it is objectively difficult to determine the extension of the strip where escapement is homogeneous, the strips were assumed to be only as large as the bags.

Similarly, the data collected from the bag attached to the upper part of the trawl were extrapolated only to a longitudinal strip as large as the bag, and not to the whole upper panel.

The coefficients applied in this study allow the risk of overestimating escapement through the trawl body to be avoided. This risk is inherent to the extrapolation process. In the present case, bag data could have been extrapolated to areas for which there were no data and for which it was impossible to know whether and to what extent escapement differed in numbers, species or size.

As a result, escapement was underestimated and we present only the data reflecting the objective part of this phenomenon, which is substantial and does not require exaggeration.

Another source of underestimation could have been produced by the masking effect caused by the flattening of the bag netting against the trawl panels. This effect, observed after the first tests on the bag mounted on the top panel of the trawl (T6), prompted its removal to a position where the angle of attack of the trawl panel was sufficiently wide to keep the netting distanced from the panel. The other bags did not seem to be affected by it.

Escapements through the front part of any bottom trawl may vary significantly with regard to both species and size involved. Starting from no escapement at all, the variation range may reach relatively high values. Few species showed a high escape rate from parts other than the near-bottom side of the trawl (*figure 5*). Pelagic species escaped preferentially through its upper part. In spite of the masking effect observed on T3 bag, and of the consequent possible underestimation of escapement, 6 % of *S. pilchardus* escaped in this direction. This could explain the low catch efficiency of the MEDITS trawl for this species compared with the commercial trawl, which had a smaller mesh size in the front panels of the body [8]. *S. flexuosa* escaped in small numbers (1 %) and only through the upper part. *M. poutassou* showed a higher escape rate through the mid-side than through the near-bottom part (13 % and less than 1 %, respectively). *L. caudatus* escaped (7 %) only through the mid-side part.

For all the other species, escapement mainly occurred through the near-bottom part of the side panels. *P. erythrinus* escaped in small numbers (3 %) under the footrope, but less than in the near-bottom part of the trawl body (11 %). A similar behaviour was shown by *S. vulgaris*.

Escape rates through the NB bags varied widely, from 64 % of *N. norvegicus* and 53 % of *P. blennoides* to the very low values of some species (*M. barbatus* 2 %, *L. vulgaris* 1 %, *Spicara flexuosa* 1 % and even 0 for *I. coindetii*). This variability clearly affects, as for other sampling trawls [5, 6, 12, 13], the species proportion rates resulting from sampling surveys.

For some species, the escape behaviour varied with size, the smaller individuals tending to escape towards the bottom and the larger ones towards higher parts of the trawl body. For example, the mean size of *M. poutassou* escaping through the mid-side part (17.4 cm) was higher than in the codend (15.5) and in the NB bags (13.5). This species seemed to react actively to gear motion, but only the larger individuals were able to escape effectively from the trawl, probably because of their greater swimming endurance. A similar behaviour was shown by *T. minutus capelanus*, even though for this species the highest escape rate was observed in the near-bottom part. For *P. erythrinus*, the mean size of the individuals that escaped

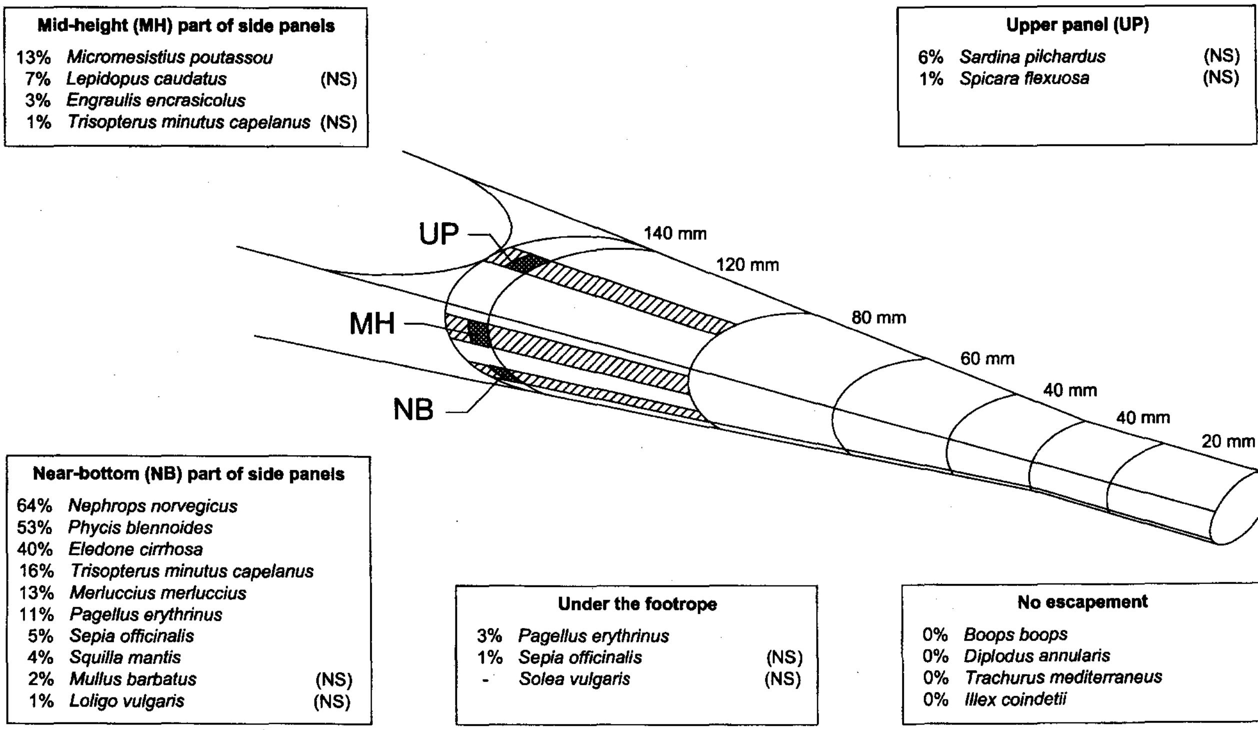

Figure 5. Summary of escapement rates through the different parts of the MEDITS trawl for the main and other reference species: the near-bottom (NB) part of the side panels, the upper panel (UP), the mid-height (MH) part of the side panel and under the footrope. Species which showed a null escapement rate through any part of the trawl are also reported.

under the footrope was lower than in the codend and in the NB bags where large size classes accounted for the majority of escapement.

A loss of fishing efficiency of the MEDITS trawl compared with the Italian commercial trawl was observed for large-size classes of some species (*M. merluccius*, *M. poutassou*, *P. erythrinus* and *L. vulgaris*) [8]. This can be explained by the ability of medium-large individuals to escape through the belly sections of the MEDITS trawl, which are made of larger mesh than those of the Italian commercial trawl. Despite the relatively small mesh size used in the front part of this commercial trawl, some comparative experiments have been conducted during the fourth fishing trip [7]. Four small net bags were attached to the outside of the first two belly panels (60 and 48 mm mesh sizes) of the commercial trawl. These experiments have shown some significant escapements only through the first panel (60 mm mesh size) of the commercial trawl, ranging from 5 % (*Illex coindetii*) to 77 % (*Nephrops norvegicus*) of the total catch in mean values. As regards *M. merluccius* and *T. minutus capelanus*, the mean escapement values through the front body of the commercial trawl were 69 and 49 %, respectively [7].

For the MEDITS trawl, the higher rate of escape of large-size individuals was directly confirmed by the bag data for *M. poutassou* (MH bags) and *P. erythrinus* (NB bags). In contrast, there was no such evidence for *M. merluccius* and *L. vulgaris*. This could mean that if large individuals did escape, this occurred through areas not covered by the bags, possibly the upper panel and the part just ahead of the codend, where some species showed good swimming endurance. But an avoiding behaviour cannot be excluded.

Escapement also varied with size for other species, and the mean size of some species that escaped through the near-bottom part of the trawl was lower than in the codend. The most representative case is *N. norvegicus*, where the escape rate of small-size individuals was particularly high. This size-dependent escapement was confirmed by the comparison of the efficiency of the MEDITS with the commercial trawl [8].

These results show that for *N. norvegicus* a size-selection process occurred in the body of the trawl, as already shown for another trawl type [11]. However, the size-selection curve shown in *figure 3b* cannot represent whole-trawl selection because data were available for only a part of the trawl body.

If data on the escapement through other trawl parts – e.g. the wings or the last sections just ahead of the codend – were available, the escape rate would obviously increase and the codend retention percentage would diminish, the codend catch being constant. This could only increase the 50 % retention length computed.

The selection curve was computed to show the sampling limitations of the MEDITS trawl with *N. norvegicus*. It is intended to be a warning to use the data below the 50 % retention length very carefully, bearing in mind that it is an approximation by defect of whole-trawl selectivity.

5. CONCLUSION

Escapement was demonstrated through the body and under the footrope of the MEDITS trawl. The escapement behaviour was strongly species-dependent and this could affect the proportion rates of the species sampled during a standard survey.

Because the escape rate of some species was size-dependent, their size-frequency distributions obtained from the normal codend catch of the MEDITS trawl may misrepresent, as for any multispecies sampling trawl, the real size-frequency distributions of populations in the area sampled.

The assessment of the escapement of large-size individuals of some species, not detected in the present experiments, and the improvement of whole-trawl selectivity estimates require further experiments with bags applied to all the important parts of the trawl.

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