Trawl selectivity studies on *Nephrops norvegicus* (L.) in the eastern Mediterranean Sea*

CHRYSSI MYTILINEOU, CHRISSI-YIANNA POLITOU and ANNA FOURTOUNI

National Centre for Marine Research, Ag. Kosmas 16604, Helliniko, Athens, Greece.

ABSTRACT: The trawl codend selectivity on *Nephrops norvegicus* was studied using diamond meshes of 16 mm, 20 mm, 24 mm and 26 mm nominal side mesh size. The cover codend method was applied for the sampling. The logistic function for the probability of retention by the codend was used for the estimation of selectivity parameters from all data combined. The results indicated that the 16 mm mesh size was not selective and that almost all individuals were retained. The 24 mm and 26 mm mesh size showed quite similar results and were a little more selective than the 20 mm mesh size. None of the experimental mesh sizes proved to be adequate for *N. norvegicus*, since all estimated values of length of 50% retention (*L*50) were lower than the length at first maturity and those of length of 25% retention (*L*25) were lower than the legislated minimum landing size. It is suggested that mesh size should be much larger than 20 mm, the size legislated by E.U. for the Mediterranean.

Key words: Selectivity, trawl, mesh size, Crustacea, *Nephrops norvegicus*, Norway lobster, Eastern Mediterranean, Greece.

RESUMEN: Estudio de la selectividad de *Nephrops norvegicus* (L.) para el arte de arrastre en el Mediterráneo oriental. – La selectividad de *Nephrops norvegicus* para el copo de arrastre se ha analizado utilizando mallas de 16 mm, 20 mm, 24 mm and 26 mm (de lado). Para el estudio de la selectividad se utilizó el método del sobrecopo. Se utilizó la ecuación logística para conocer la probabilidad de retención del copo y los parámetros de selectividad. Los resultados indican que la malla de 16 mm no es selectiva y que no deja escapar casi ningún ejemplar. Las mallas de 24 mm y de 26 mm presentan resultados parecidos entre sí y son un poco más selectivas que la malla de 20 mm. Aunque la proporción de individuos retenidos aumenta con la luz de malla, ninguna de las mallas utilizadas se considera adecuada para *N. norvegicus*, ya que todos los valores estimados de *L*50 fueron menores que la talla de primera madurez y, que todos los valores de *L*25 fueron menores que la talla mínima de captura legislada. Se recomienda que la malla del copo debe ser mucho más que 20 mm, la cual es la malla legislada por la E.U. para el Mediterráneo.

Palabras clave: Selectividad, arrastre, luz de malla, Crustacea, *Nephrops norvegicus*, cigala, Mediterráneo oriental, Grecia.

INTRODUCTION

*Nephrops norvegicus* is one of the most commercially important products of the multi-species trawl fisheries exercised in the Mediterranean waters. Studies on the trawl selectivity of *N. norvegicus* in the Northeast Atlantic are numerous, and *ICES* presents, on a regular basis, comparative data from the different countries (e.g. Anon., 1991, 1995a). On the contrary, information concerning the Mediterranean is very scarce (in the Western Mediterranean: Sardà et al., 1993; in the Eastern Mediterranean: Stergiou et al., 1997). Nevertheless, some studies on the biology of this species in the Greek waters exist (Mytilineou et al., 1992; 1993a, b; 1995).

*Received 17 January 1997. Accepted 19 November 1997.*
In the North Euboikos Gulf (Greece), the selected study area, about 30 t of *N. norvegicus* are fished by the trawlers every year (Fisheries Development Company - ETANAL data, 1990-1994) during a strict fishing period of only five months (January to March and November to December). The above quantity corresponds to about 3.8% of the total trawl landings in the area (15% of their economical relevance) (ETANAL data, 1990-1994). However, when fishery is exercised in the main *Nephrops* grounds, it represents in terms of weight 16% of the total catch and 24% of the commercial catch of the area (Mytilineou *et al.*, 1998). In any case, the by-catch in terms of numbers or in terms of weight is important.

In the framework of the present paper, trawl cod-end selectivity was studied for *N. norvegicus*, using nets of nominal side mesh sizes 16 mm, 20 mm, 24 mm and 26 mm. Although, during the present study, the legal mesh size for the Greek trawl fisheries was 14 mm, the 16 mm mesh in codend was often used by the fishermen for *Nephrops* grounds and for tows on sandy and muddy bottoms. The 20 mm mesh size was used in the present study because it is actually legislated by the E.U. as the minimum size for the trawl cod-end. The two larger mesh sizes (24 mm and 26 mm) have been used for comparative purposes and as information for future perspectives.

**MATERIAL AND METHODS**

Sampling was conducted in the North Euboikos Gulf (eastern continental Greece) during May 1995 (Fig. 1). A commercial trawler (26 m length) equipped with two engines (250 HP each) was hired for the experimental surveys. This stern type trawler was outfitted by a trawl (the characteristics of which are shown in Fig. 2) and two rectangular metallic otter-boards (weight: 180 kg and size: 2.2 m x 1.3 m each).

The cover cod-end method (Pope *et al.*, 1975) was applied in order to study trawl cod-end selectivity for *N. norvegicus*. The following nominal side sizes of diamond mesh were used for the codend: 16 mm, 20 mm, 24 mm and 26 mm. Side and stretched measurements of the meshes were also taken by tape measurements and a mean size was calculated for each net (Table 1). The application of the Student’s t test showed (Table 1) that the mean side measurements were statistically different from the nominal mesh sizes, except in the case of the 24 mm mesh. This was also true for the mean stretched measurements, with the exception of the case of the 32 mm mesh. The analysis of variance (ANOVA) and the LSD Fisher’s test for the mean measured sizes indicated that the nets differed significantly between them at the 95% significance level (side measurements - ANOVA:

![Fig. 1. – Map of the study area showing the sampling stations. STA, STB, STC: different locations of sampling.](image-url)
$F = 31503.6, \ p < 0.0001$; stretched measurements - ANOVA: $F = 16827.4, \ p < 0.0001$) and that each net was a homogeneous significantly different group. In the present work, the nominal side sizes and the corresponding measured stretched ones were used.

The material of the four cod-ends was braided polyethylene with knots, whereas that of the cover was braided nylon without knots. The cover net was made by diamond meshes of 10 mm nominal size. The different codends were attached to the same trawl net (in Fig. 2 the 16 mm codend is attached to the trawl net). In all cases, the spare edge of the cod-end was tied by a rope as is done in commercial trawl fisheries. The cover was attached to the codend and it was 2 m wider and 2 m longer in order to permit good water circulation and to avoid overlapping of the nets.

Three experimental locations, considered as *Nephrops* grounds, have been selected for the study; Station A in depths from 200 to 350 m; Station B in depths from 110 to 130 m; and Station C in depths from 100 to 150 m (Fig. 1). Two hauls were carried out in each location during daylight, at a speed of 2.9 knots (standard in the commercial trawl fisheries) for all hauls. Each haul lasted 1 hour, in order to prevent distortion of the codend selectivity from the by-catch. The total number and weight per species caught were recorded. For all *Nephrops* caught, the carapace length (CL) was measured to the nearest mm.

For the selectivity study, $L_{50}, L_{25},$ and $L_{75},$ corresponding to the length at which 50%, 25% and 75% of individuals entering the gear are retained, were estimated. The selection range $[S_r = L_{75} - L_{25}]$ and the selection factor $[S_f = L_{50} / \text{mesh size}]$ were also determined. For comparison purposes, the $S_f$ was estimated using the measured stretched mesh sizes.

The selectivity of a net is determined by the relationship between the probability $p$ of a specimen entering the codend to be retained and the length of this specimen (Holden, 1971). A logistic function of this relation was used in order to estimate the selectivity parameters of the different codends. This is presented by the relationship:
which can be transformed to a linear logistic function by the following log transformation: log(p/(1-p)) = \nu_1 + \nu_2 L. As applied by Fryer (1991), the parameters \nu_1 (representing the intercept) and \nu_2 (representing the slope of the curve) were estimated by maximising the log-likelihood

\[
L = \sum_{j=1}^{n} \left\{ y_j \log(p_j) + (n_j - y_j) \log(1-p_j) \right\}
\]

assuming that, if retention of each specimen is independent, the retained \( y_j \) in the codend specimens of length \( l_j \) have a binomial distribution Bi \( (n_j, p_j) \). If the parameters \nu_1 and \nu_2 are represented by the vector

\[
\nu = \begin{pmatrix} \nu_1 \\ \nu_2 \end{pmatrix}
\]

and if there is a sufficient number of length classes and a sufficient number of retained and escaped specimens, then the maximum likelihood estimator of \nu is normally distributed with mean \nu and variance matrix \( R \) (McCullagh and Nelder, 1989; in Fryer, 1991). An approximate test for the examination of overdispersion in data was also applied, by comparing the deviance statistic \( \Delta \) to a \( \chi^2 \) distribution on \( N - 2 \) degrees of freedom. \( R \) and \( \Delta \) were estimated as described by Fryer (1991). Moreover, the standard errors of \nu_1 and \nu_2, and the 95% confidence intervals of the estimated value of \( L50 \) were also calculated as described in Fryer (1991). Fryer’s (1991) model incorporates between haul variation; however, this was not attempted here, since between haul variation was not the aim of the present study, but it may be examined in a future work. Hence, length data from all hauls were combined per net and a mean selectivity was estimated from all the data (Sparre and Venema, 1992). For the analysis, a DOS algorithm for PC developed in our laboratory (Petrakis, pers. com.) was used.

In order to check the fitting of the method applied for each net, the residuals from the selectivity curves were examined. Moreover, since the data used included a large number of length classes with retention probability 1, the influence of these data was examined. For this purpose, for each net, the data for classes up to 40.5 mm CL were re-analysed with the same method. Finally, for the comparison of the selectivity curves between the three larger mesh sizes, two logistic models with common regression coefficients were applied to all the data and deviances were compared between models.

The selectivity parameters of the 16 mm mesh size were impossible to estimate by this model, hence an approximate value of the \( L50 \) was estimated using the selection factor of 20 mm mesh size (Stergiou et al., 1997).

RESULTS

The carapace length frequency distributions of the total number of entered, retained and escaped Nephrops individuals for the codends of 16, 20, 24 and 26 mm mesh size are presented in Figure 3, whereas in Figure 4 the selectivity curves and the original data of retention

<table>
<thead>
<tr>
<th>Nominal side mesh size</th>
<th>Mean size mesh size (SD)</th>
<th>t</th>
<th>Mean stretched mesh size (SD)</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>16.6 (0.29)</td>
<td>2.02</td>
<td>32.2 (0.25)</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td>(t0.05(2),69=1.99)</td>
<td></td>
<td>(t0.05(2),29=2.01)</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>20.9 (0.13)</td>
<td>7.13</td>
<td>40.8 (0.19)</td>
<td>4.14</td>
</tr>
<tr>
<td></td>
<td>(t0.05(2),51=2.01)</td>
<td></td>
<td>(t0.05(2),29=2.01)</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>24.3 (0.16)</td>
<td>1.64</td>
<td>47.0 (0.42)</td>
<td>2.42</td>
</tr>
<tr>
<td></td>
<td>(t0.05(2),51=2.01)</td>
<td></td>
<td>(t0.05(2),58=2.00)</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>26.8 (0.07)</td>
<td>11.13</td>
<td>51.8 (0.76)</td>
<td>3.04</td>
</tr>
<tr>
<td></td>
<td>(t0.05(2),50=2.01)</td>
<td></td>
<td>(t0.05(2),54=2.01)</td>
<td></td>
</tr>
</tbody>
</table>
for each type of codend are shown. The results of the selectivity analysis are presented in Table 1.

16 mm nominal side or 32 mm stretched mesh size

The carapace length frequency distribution of the entered and retained Nephrops individuals for the 16 mm net presented one mode between 33 and 36 mm (Fig. 3a). The number of entered specimens was the highest among the various types of codend (Fig. 3). Overall, 1.7% of the entered individuals were undersized (minimum landing size for the species, MLS: 20 mm).

The number of the retained specimens by this net was the highest among the various codends (Fig. 3). Practically, almost all specimens were retained by the 16 mm codend (99.6%). Overall, 1.6% of the retained individuals were undersized. This was the highest percentage of undersized retained individuals among the various nets.

The number of escapes from the 16 mm net was very low (11 specimens), the lowest among the various types of codend (Fig. 3). The lengths of escapes ranged between 17 and 26 mm CL. Overall, 18.0% of the escapes of this net were undersized, which was the highest percentage among the various nets. The undersized escapes of the 16 mm codend constituted 5% of the undersized specimens that entered into this codend.

Since the retention probability of the 16 mm codend was very high at all size classes (from 13 mm and over it was almost 1) (Fig. 4a), the selectivity parameters could not be estimated. A rough estimate of the L50 was obtained by the selection factor of the 20 mm codend and this was found to be 14.2 mm.

20 mm nominal side or 40.8 mm stretched mesh size

The carapace length frequency distribution of the entered and retained Nephrops individuals for this net presented one main mode between 33 and 36 mm and some others of less importance (Fig. 3b). The number of entered specimens was lower than that of the 16 mm codend (Fig. 3). Overall, 2.5% of the entered individuals in the 20 mm codend were undersized. This was the highest percentage of undersized entered specimens among the various codends.

The number of retained specimens by the 20 mm net was lower than that of 16 mm codend (Fig. 3). However, the retained proportion (97.5%) was not very different than that of the 16 mm codend (Table 1). Overall, 1.2% of the retained individuals were undersized. This was the lowest percentage of undersized retained individuals among the various codends.

Since the retention probability of the 20 mm codend was high at all size classes (from 13 mm and over it was almost 1) (Fig. 4b), the selectivity parameters could not be estimated. A rough estimate of the L50 was obtained by the selection factor of the 20 mm codend and this was found to be 14.2 mm.

---

**Fig. 3.** – Length distribution of the total number of entered, retained and escaped individuals of *Nephrops norvegicus* in the N. Euboikos Gulf for different mesh sizes. a: 16 mm, b: 20 mm, c: 24 mm, d: 26 mm nominal side mesh sizes; N: number of individuals.
were undersized. This percentage was lower than that of the 16 mm net.

The number of escapes from the 20 mm net was generally low (62 specimens). It was higher than that of the 16 mm codend (Fig. 3), although it was not very different. The lengths of escapes ranged between 14 and 39 mm CL, although the main bulk was found to be between 16 and 25 mm. Overall, 51.6% of the escapes of this net were undersized, which was the highest percentage among the various codends. The undersized escapes of the 20 mm codend constituted 51.6% of the undersized specimens that entered into this codend.

The estimates of the selectivity parameters (Table 1) were generally low. The selectivity of the 20 mm codend was poor, whereas the net was not selective at all for lengths greater than 27 mm (Fig. 4b). From Figures 3b and 4b, it was obvious that a part of the smallest length sizes (much bigger than that of the 16 mm) escaped through the 20 mm codend. The estimate of the selection factor was the highest and that of the selection range the lowest comparing with the two larger studied nets.

24 mm nominal side or 47.0 mm stretched mesh size

The carapace length frequency distribution of the entered and retained Nephrops individuals for this net presented an almost unimodal distribution, with a mode between 33 and 35 mm (Fig. 3c). The number of entered specimens was lower than that of the 20 mm codend (Fig. 3). Overall, 1.6% of the entered individuals in the 24 mm codend were undersized, which was lower than the percentage of undersized specimens entered in the 20 mm codend, but similar to the percentage of 16 mm and 26 mm nets.

The number and the proportion (95.6%) of the retained specimens by the 24 mm net were lower but not very different from those of the 20 mm codend (Fig. 3, Table 2). Overall, 0.6% of the retained individuals were undersized. This percentage was lower than that of the 20 mm net.

The number of escapes from the 24 mm net was generally low (110 specimens). It was higher than that of the 20 mm codend (Fig. 3), although it was not remarkably different. The lengths of escapes ranged between 16 and 35 mm CL, but the main bulk was found to be between 18 and 27 mm. Overall, 21.6% of the escapes of this net were undersized, which was lower than the percentages of the 20 mm and 26 mm codends, but higher than that of the 16 mm net. The undersized escapes of

![Fig. 4. – Probability of retention and selectivity curves of *Nephrops norvegicus* in the N. Euboikos Gulf for different mesh sizes. a: 16 mm, b: 20 mm, c: 24 mm, d: 26 mm nominal side mesh sizes.](image-url)
the 20 mm codend constituted 61.5% of the undersized specimens that entered into this codend.

The estimates of the selectivity parameters (Table 2) were generally low. The 24 mm codend was not selective for lengths greater than 37 mm (Fig. 4c). The smallest length sizes escaped through the 24 mm codend (Fig. 4c); however, some of the small individuals were also retained (Fig. 4c). The values of the selection factor and that of the selection range were intermediate, between those of 20 and 26 mm codends.

26 mm nominal side or 51.8 mm stretched mesh size

The carapace length frequency distribution of the entered and retained *Nephrops* individuals for this net presented an almost unimodal distribution, with a mode between 33 and 36 mm (Fig. 3d). The number of entered specimens was the lowest among the various nets (Fig. 3). Overall, 1.8% of the entered individuals in the 26 mm codend were undersized, which was similar to the percentage of undersized specimens entered in the 24 mm and 16 mm codends, but lower than that of the 20 mm net.

The number and the proportion (94.3%) of retained specimens by the 26 mm net were lower but not very different than that of the 24 mm codend (Fig. 3, Table 2). Overall, 0.4% of the retained individuals were undersized. This percentage was the lowest among the studied nets.

The number of escapes from the 26 mm net was generally low (139 specimens). It was a little higher than that of the 24 mm codend (Fig. 3). Their lengths ranged between 11 and 38 mm *CL*, although the main bulk was found to be between 16 and 30 mm. Overall, 25.7% of the escapes of this net were undersized, percentage which was higher than that of the 24 mm codend. The undersized escapes of the 26 mm codend constituted 81.8% of the undersized specimens that entered into this codend, the highest percentage among the studied nets.

The estimates of the selectivity parameters (Table 2) were low. This net was not selective for lengths greater than 39 mm (Fig. 4d). From Figure 4d, it was obvious, that the smallest length sizes escaped through the 26 mm codend. The value of the selection factor was the lowest and of the selection range the highest, among the three larger studied nets.

### Statistical analysis

For the 20 mm, 24 mm and 26 mm mesh sizes, the deviance statistic $\Delta$ and the $X^2$ values showed that the data were not overdispersed (Table 2). In addition, for these three mesh sizes, the 95% confidence interval for $L_{50}$ was found to be very narrow (Table 2). The examination of the size and pattern of the residuals from each selectivity curve indicated that the model generally fitted well the data derived from the above nets (maximum estimated residual for 20 mm, 24 mm and 26 mm: -2.13, -2.41 and -2.90 respectively). The only problem was found for the 26 mm net, for the length classes 16.5 - 17.5 mm and 18.5 - 20.5 mm, characterized by low residuals but on opposite sides of the curve.

### Table 2.

Selectivity parameters for *Nephrops norvegicus* in the N. Euboikos Gulf using different mesh sizes (20 mm, 24 mm, 26 mm nominal side size or 40 mm, 47 mm, 51.8 mm stretched mesh size). *value estimated using the stretched mesh size. str., stretched mesh size.

<table>
<thead>
<tr>
<th>Mesh size</th>
<th>Retention (%)</th>
<th>$\nu_1$</th>
<th>$\nu_2$</th>
<th>Standard error of $\nu_1$</th>
<th>Standard error of $\nu_2$</th>
<th>$L_{25}$</th>
<th>$L_{50}$</th>
<th>$L_{75}$</th>
<th>Confidence interval of $L_{50}$</th>
<th>Deviance statistic $\Delta (x^2, p)$</th>
<th>Degrees of freedom</th>
<th>Selection factor</th>
<th>Selection range</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 mm (or 40.8 mm str.)</td>
<td>97.53</td>
<td>-7.81</td>
<td>0.44</td>
<td>0.92</td>
<td>0.04</td>
<td>15.32</td>
<td>17.83</td>
<td>20.34</td>
<td>16.63-18.76</td>
<td>(30.01 (65.17, 0.05)</td>
<td>48</td>
<td>0.44*</td>
<td>5.02</td>
</tr>
<tr>
<td>24 mm (or 47 mm str.)</td>
<td>95.58</td>
<td>-6.7</td>
<td>0.33</td>
<td>0.63</td>
<td>0.02</td>
<td>16.77</td>
<td>20.06</td>
<td>23.35</td>
<td>18.92-20.98</td>
<td>(21.72 (67.51, 0.05)</td>
<td>50</td>
<td>0.43*</td>
<td>6.58</td>
</tr>
<tr>
<td>32 mm (or 51.7 mm str.)</td>
<td>94.29</td>
<td>-5.91</td>
<td>0.29</td>
<td>0.52</td>
<td>0.02</td>
<td>16.71</td>
<td>20.53</td>
<td>24.35</td>
<td>19.33-21.52</td>
<td>(33.67 (70.99, 0.05)</td>
<td>53</td>
<td>0.40*</td>
<td>7.64</td>
</tr>
</tbody>
</table>
Nephrops reason for the differences in the number of tion that the gear met seems to be the more proba-
mesh sizes. Therefore, differences in the popula-
tions for the species with increasing number of
entered specimens from the 14 mm to the 20 mm
tern for the species with increasing number of

It was also obvious, that the percentage of under-
dimensioned escapes in relation to the undersized entered into the different codends specimens, increased considerably with mesh size. This means that inde-
dependently of the number of small (undersized) Nephrops specimens entered into the different codends, more and more from the undersized spec-
imens will escape through the nets with increasing mesh size. However, this was not considered very important, since generally the percentage of escapes was very low for all the studied mesh sizes.

Among the studied mesh sizes, the 16 mm mesh size was not selective since almost all Nephrops individuals were retained (Fig. 3a). Politou et al. (1998) showed also, that for the most commercially important Nephrops by-catch species (e.g. M. mer-
luccius, L. boscii, E. gurnardus etc.), the 16 mm mesh was not selective either. It is very clear that the use of this mesh size should have been prohibited in the Greek fishery a long time ago, and even more so, the 14 mm mesh size still used by Greek fishermen. The other mesh sizes could be considered slightly more selective than the 16 mm mesh.

In the present study, the applied logistic model, using all the data per net as a single haul, was meaningless for the 16 mm mesh size, but fitted well the data for the three larger mesh sizes. The ICES Working Group on Nephrops stocks (e.g. Anon., 1991) generally used the sigmoidal curve. However, Sardà et al. (1993) found that the lower portions of the selectivity curves for N. norvegicus were truncated, that is, they were not symmetrical, and that curves fall off vertically for the smaller sizes. Millar (1991; 1993) described several other models fitting selectivity data better, and Larsvik and Ulmestrand (1992) applied the isotonic regression to Nephrops selectivity data successfully. Recently, the ICES Fishing Technology and Fish Behaviour Working Group (Anon., 1995a) used Fryer’s (1991) model incorporating between haul variation for Nephrops trawl selectivity, and pro-
duced a manual for methods measuring the selec-
tivity of towing gears (Anon., 1995b), in which all possible models for selectivity data analysis are presented. The application of other models (e.g. asymmetric, complementary log-log, isotonic curve etc.) was beyond the scope of the present work, but could be the subject of a future study.

The results for the selectivity parameters revealed that L50 values increased with mesh size (Table 2), although for the two largest meshes (24 and 26 mm) they were found to be very close. This was in accordance with the results from the comparison of the selectivity curves for the same mesh.

DISCUSSION

The results of the present work showed that the number of entered specimens decreased from the 16 mm to the 26 mm codend. This could be explained by differences between the populations caught by each net or by differences in the catch-
ability of each net. This pattern was not found to be the same for other species accompanying Nephrops catches, such as Merluccius merluccius, Micromesistius poutassou, Trisopterus minutus capelanus, Lepidorhombus boscii and Eutrigla gurnardus (Politou et al., 1998), which showed a great variability in the number of specimens entered among the various nets. Moreover, Stergiou et al., (1997), during selectivity studies for Nephrops norvegicus, found the opposite pattern for the species with increasing number of entered specimens from the 14 mm to the 20 mm mesh sizes. Therefore, differences in the population that the gear met seems to be the more probable reason for the differences in the number of Nephrops individuals entered in the nets. The most important observation was related to the propor-
tions of the individuals retained by the different codends. These did not present remarkable differences between them, ranging from almost 1 for the 16 mm mesh to 0.94 for the 26 mm. A slightly decreasing tendency with the mesh size was apparent (Table 2), reflecting the differences in selectivity among the studied mesh sizes. From our results, it was also obvious, that the percentage of under-
sized escapes in relation to the undersized entered into the different codends specimens, increased considerably with mesh size. This means that inde-
dependently of the number of small (undersized) Nephrops specimens entered into the different codends, more and more from the undersized spec-
imens will escape through the nets with increasing mesh size. However, this was not considered very important, since generally the percentage of escapes was very low for all the studied mesh sizes.

Among the studied mesh sizes, the 16 mm mesh size was not selective since almost all Nephrops individuals were retained (Fig. 3a). Politou et al. (1998) showed also, that for the most commercially important Nephrops by-catch species (e.g. M. mer-
luccius, L. boscii, E. gurnardus etc.), the 16 mm mesh was not selective either. It is very clear that the use of this mesh size should have been prohibited in the Greek fishery a long time ago, and even more so, the 14 mm mesh size still used by Greek fishermen. The other mesh sizes could be considered slightly more selective than the 16 mm mesh.

In the present study, the applied logistic model, using all the data per net as a single haul, was meaningless for the 16 mm mesh size, but fitted well the data for the three larger mesh sizes. The ICES Working Group on Nephrops stocks (e.g. Anon., 1991) generally used the sigmoidal curve. However, Sardà et al. (1993) found that the lower portions of the selectivity curves for N. norvegicus were truncated, that is, they were not symmetrical, and that curves fall off vertically for the smaller sizes. Millar (1991; 1993) described several other models fitting selectivity data better, and Larsvik and Ulmestrand (1992) applied the isotonic regression to Nephrops selectivity data successfully. Recently, the ICES Fishing Technology and Fish Behaviour Working Group (Anon., 1995a) used Fryer’s (1991) model incorporating between haul variation for Nephrops trawl selectivity, and pro-
duced a manual for methods measuring the selec-
tivity of towing gears (Anon., 1995b), in which all possible models for selectivity data analysis are presented. The application of other models (e.g. asymmetric, complementary log-log, isotonic curve etc.) was beyond the scope of the present work, but could be the subject of a future study.

The results for the selectivity parameters revealed that L50 values increased with mesh size (Table 2), although for the two largest meshes (24 and 26 mm) they were found to be very close. This was in accordance with the results from the comparison of the selectivity curves for the same mesh.
sizes, which demonstrated significant differences between the intercepts but not between the slopes. One reason explaining this is that a 2 mm mesh difference (or approximately 4 mm stretched mesh difference) is not enough to produce significant differences between the curves. Another reason could be the quantity of the by-catch. Briggs (1983) demonstrated that the retention percentage of *Nephrops* increased with total catch. In the present study, the total catch of the 26 mm codend was found to be higher than that of the 24 mm codend (Table 3); however this difference could not be considered very important.

Comparing our results with those of Stergiou *et al.* (1997) for the same area, some differences arose between them. These authors found, for the 20 mm mesh size, a lower percentage of retained *Nephrops* individuals (79%) and a higher $L_{50}$ value ($L_{50} = 22.82$ mm) than in the present work. Hence, they considered the 20 mm codend to be a selective net. Although the authors pointed out that their value might be an overestimate, another reason explaining the difference from our results could be the structure of the population fished. It must be pointed out that the length frequency distribution of escapes, used by Stergiou *et al.* (1997), contained many small individuals. The sampling period in that study was in March, whereas ours took place in May. March is one of the months with new recruits and one of the main months of *Nephrops* moulting (Gramitto, 1998), when many individuals remain in their burrows. These factors could result in a different population structure met by the net at the moment of sampling, with a consequence of a different selection ogive. Another factor affecting selectivity could be the total catch or by-catch size, as already mentioned above. The total catch using the 20 mm codend was found by Stergiou *et al.* (1994) to be 190513 g, whereas ours was 3.5 times higher (Table 3). Such a situation could justify the reduced number of escaped individuals, determined in our case.

The results of the present study were also compared with those from the Western Mediterranean and the Atlantic. Although the mesh sizes studied by Sardà *et al.* (1993) were not identical, the $L_{50}$ estimates from both studies were considered quite close. However, it must be taken into account that in this area a different method of closing the codend is applied (it is laced shut along one side), which increases the probability of individuals’ escape. In contrast, in the knotted codend used in the Greek waters, as well as in the Atlantic, the codend meshes become smaller, producing a reduced probability of escape. This fact may explain, apart from all other factors influencing selection ogive, the higher $L_{50}$ value (23.1 mm) found by Sardà *et al.* (1993) for the 26 mm (side) or 52 mm (stretched) mesh size. Briggs (1986) reviewed for the Atlantic all available information for *N. norvegicus* selectivity. The $L_{50}$ values reported by this author for nets similar to ours ranged from 16.8 to 26.8 mm $CL$ for stretched mesh sizes ranging from 40 mm to 55 mm. Our results lie within this range of values. The values of the selection factor estimated by the present work (0.40 - 0.44) were also close to those reported in the above bibliography (0.31 - 0.56). A decreasing tendency of the selection factor with mesh size, observed in our results, was also found by Charuau (1978). However, this was not observed by some other researchers (eg. Alonso-Allende, 1981, Sardà *et al.*, 1993 etc.). On the other hand, the values of selection range estimated from our data showed a tendency to increase with mesh size (Table 2). In the I.C.E.S. Working Group on Fishing Technology and Fish Behaviour (Anon., 1995a), the data presented for *Nephrops* selectivity from the Atlantic and Mediterranean showed that $L_{50}$ and selection range increase with mesh size, whereas a not clear pattern is apparent for the selection factor.

All the estimated $L_{50}$ values in the present work were considerably lower than the length at first maturity of the species in the Greek waters (~32 mm; Mytilineou *et al.*, 1993a; Relini *et al.* 1998). Furthermore, the estimated values of $L_{25}$ were also considerably lower than the minimum landing size (20 mm), legislated by the EU for *N. norvegicus*. From our work it was obvious, that none of the mesh sizes used gave results adequate for *N. norvegicus*. It is probable that the species biology (hiding in burrows) and morphology (presence of

<table>
<thead>
<tr>
<th>Mesh size</th>
<th>Total catch (codend)</th>
<th>Total catch (cover)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>1032015</td>
<td>10483</td>
</tr>
<tr>
<td>20</td>
<td>648095</td>
<td>138890</td>
</tr>
<tr>
<td>24</td>
<td>532320</td>
<td>103175</td>
</tr>
<tr>
<td>26</td>
<td>540230</td>
<td>204885</td>
</tr>
</tbody>
</table>
pincers and spines) make the problem more complex. This was also suggested by Sardà et al. (1993) from the study of N. norvegicus selectivity in the Western Mediterranean Sea. It was also obvious, that a codend of mesh size smaller than 26 mm (52 mm stretched) should not be used in Nephrops fisheries, and even more so, the 20 mm mesh legislated by EU for the Mediterranean. However, it is difficult to make a clear suggestion. Even though the 26 mm mesh size is not the most appropriate for N. norvegicus (present work, Sardà et al., 1993), some of the commercial by-catch species (especially M. poutassou and to a smaller extent T. minutus capelanus and L. bosci) gain better opportunities for reproduction using this net (Politou et al., 1998). On the other hand, the 60 mm (stretched) mesh size produces better results (L50 values close to the length at first maturity) for Nephrops but worse results for the fishermen (lower commercial catches) (Sardà et al., 1993). At this point, it must be emphasized that the minimum landing size (M.L.S.) is much lower than the length at first maturity (Lmat(50)). In our opinion, the M.L.S. should be increased in order to minimize the difference with Lmat(50) and give chance to the species to reproduce. The above discussion implies a research for a special gear taking into account the Nephrops characteristics as well as the by-catch composition because of the multispecies feature of the Mediterranean fisheries.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to Prof. C. Richardson for useful advice on the statistical problems, G. Petrakis for the use of the DOS algorithm for the analysis of selectivity data, to K. Dogrammatzi, P. Chatzinikolaou and K. Anastassopoulos for their assistance in the field work and V. Lambropoulou and S. Kavadas for drawing the figures for the map and the gear. The authors would like also to thank the two reviewers for their useful comments. This study was financed by the EC, DG. XIV (MED92/008).

REFERENCES