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Selectivity experiments in the Belgian Norway lobster (*Nephrops norvegicus*) fishery

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ABSTRACT

Two sampling campaigns were carried out on board of a Belgian *Nephrops* trawler currently operating in the Botney Gut - Silver Pit area (central North Sea), to investigate codend selectivity for *Nephrops* and whiting. Three net configurations were tested: a standard *Nephrops* trawl with a 70 mm codend, a standard trawl with a 90 mm codend and the same trawl with a square mesh window in the top panel, in front of a 70 mm codend.

Codend selectivity for *Nephrops* varied widely, with most of the variability being attributable to vessel motion related to the weather conditions. Rather surprisingly, the 90 mm codend was found to be less selective than the 70 mm codend; a phenomenon that could be related to the difference in netting material.

The L_{25}'s of the 70 mm codend for both *Nephrops* and whiting were only slightly above the legal Minimum Landing Sizes (MLS), which indicates that the selective properties of the codend are in agreement with the general principle that the L_{25} should be at, or at least close to, the MLS.

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INTRODUCTION

Until recently the analytical stock assessments and the mesh assessments of the Norway lobster, *Nephrops norvegicus*, in the central and southern North Sea were hampered by the uncertainties on several biological and technical parameters, such as growth, natural mortality, discard survival and codend selectivity. Both assessment working groups and advisory committees, including ACFM and STCF, have recommended further research on stock specific parameters.

The present study aims to fill in the gap in our knowledge on the selective properties of the *Nephrops* trawl currently used in the Belgian *Nephrops* directed fishery. In the margin of these investigations, attention was also paid to its selectivity for whiting, which is known to massively occur on some of the *Nephrops* grounds.

METHODOLOGY

Vessel and fishing grounds

The experiments were carried out during two voyages (viz. 1-13 June and 17-29 June 1993) with a Belgian side trawler (27 m length over all, 98 GT gross tonnage, and 276 kW engine power). The vessel is part of the Belgian trawler fleet which is targeted almost year-round on *Nephrops*.

The fishing grounds were located in the Botney Gut and the Silver Pit, central North Sea (ICES Sub-areas IV_b and IV_c) (Figure 1).

Fishing gear

The *Nephrops* trawl used (Figure 2) was a two panel bottom trawl, with a headline of 28 m and groundrope of 35.5 m. The central part of the groundrope (± 20 m) consisted of wire, winded with netting and rope. The bridles had a length of 6 m. The otter boards were of the traditional rectangular type, made of wood, and had a weight of 430 kg. Depending on the state of the seabed, up to three tickler chains were attached between the otter boards. The net itself was made of polyethylene, with a mesh size of 90 mm throughout (Figure 3). The average towing speed was 3 knots, with a minimum of 2.5 and a maximum of 3.5 knots.

The codends tested (70 and 90 mm) were identical to the ones used in the commercial fishery, and had standard dimensions of 100 meshes round and 50 meshes deep. Codend and cover mesh sizes were measured on several occasions during the experiments, by means of an ICES gauge set at a tension of 4 kg. The mean wet mesh size was 67.3 mm for the "70 mm" polyamide codend, and 79.0 mm for the "90 mm" polyethylene codend. The mean wet mesh size of the codend cover was 37.1 mm. When measured with a wedge gauge, the meshes all proved to be well above the mesh size guaranteed by the manufacturer, viz. 70 and 90 mm for the codends, and 40 mm for the cover. The 70 mm polyamide codends are still used in the commercial fishery, mainly because polyethylene codends, which are generally preferred by the fishermen, are not readily available in that mesh size.

Technical aspects and sampling protocol

All selectivity data were collected by means of the covered codend method. The cover had a length of 7.2 m and measured 320 meshes on the circumference, with 8 full meshes gathered into each selvedge. The netting material consisted of single braided polyamide twine with a nominal mesh size of 40 mm. The top panel of the cover was rigged with two rows of 1 litre floats, to reduce masking of the codend meshes by the cover.

The sampling protocol for the selectivity experiments is summarized in Figure 4. Fractions sampled and measured are marked with a ■.

Shortly after the catch had been sorted by the ship's crew (see REDANT and POLET, 1994, for further details on the catch sorting process on the Belgian *Nephrops* trawlers), the volume of each relevant fraction in the catch (viz. *Nephrops* to be landed whole, *Nephrops* to be tailed, whiting retained for landing, and "trash") was measured in fish baskets (ca. 40 litres) or 20 litre buckets. The discards were then sorted by the scientific crew, from 2 baskets of "trash" taken from each haul. From the codend cover catches, another 1 or 2 baskets were kept, also for sorting by the scientific crew.

Whenever possible, ½ to 1 basket of whole *Nephrops*, and ¼ to ½ basket of *Nephrops* to be tailed were measured, along with the *Nephrops* discards taken from the 2 baskets of "trash" (or a sub-sample thereof), and all the *Nephrops* contained in the samples of the codend cover.

Unless their quantities were too excessive to be measured before the end of the next haul, all whiting retained by the crew, and all whiting from the 2 baskets of "trash" were measured. The whiting samples taken from the cover were sub-sampled when their volume exceeded 20 litres.

The fish were measured with a ruler to the cm below, and the *Nephrops* with callipers to the nearest mm carapace length (CL). *Nephrops* to be tailed were measured whole.

Data processing

For both *Nephrops* and whiting the selection parameters were calculated by means of the symmetrical Logit model (POPE *et al.*, 1975). This link-function is represented by:

$$r(l) = \exp(\alpha * l + \beta)/(1 + \exp(\alpha * l + \beta))$$

where $r(l)$ = the probability for a fish of length l to be retained by the codend,

l = the length class,

α and β = the constants determining the shape of the selection curve.

An iterative maximum likelihood routine, provided by Constat's "CC" software package, was used to calculate the best fitting values for α and β, starting from the numbers retained in the codend and the codend cover.

Apart from the Logit model, which is generally used to calculate selection curves, three other link-functions were tried on the *Nephrops* data, viz. the symmetrical Probit and the asymmetrical Log Log and Complementary Log Log (C Log Log) models. Curve fitting routines for these models are also provided by the "CC" package.

These three curves can be represented by the following link-functions:

Probit : $r(l) = \text{StdNormal}\ (\alpha * l+\beta)$

Log Log : $r(l) = \exp(-\exp\ (-(\alpha * l+\beta)))$

C Log Log : $r(l) = 1- \exp(-\exp\ (\alpha * l+\beta))$

The Log Log curve has a sharper bend between the lengths at 0 % and 25 % retention, and a smoother curvature between the lengths at 75 % and 100 % retention than the Logit or Probit curves. The equally asymmetrical C Log Log curve shows a smoother curvature between the lengths at 0 % and 25 % retention, and a sharp bend between the lengths at 75 % and 100 % retention.

The goodness of fit for each curve was judged from the deviance. Under certain assumptions the deviance is Chi-square distributed, with n-2 degrees of freedom, where n is the number of length classes with at least 5 measurements in both the codend and the codend cover. In general, the goodness of fit of the Probit and the Log Log models was much worse than that of the Logit or the C Log Log models. It was therefore decided to disregard the Probit and the Log Log models in the presentation of the results.

For *Nephrops*, selection curves were calculated for each haul separately but the goodness of fit of these curves varied widely. Selection curves for combined hauls, calculated by the variance component model (FRYER, 1991), also available in the "CC" package, on the other hand, gave a much better fit. Mean selection curves were derived from hauls made under similar conditions, particularly with respect to weather and sea state.

For whiting, the retention rates for single hauls were too dispersed to allow the calculation of individual selection curves, mainly because the numbers of larger fish (lengths > 30 cm) in the catches were too low. Only the combined data sets were used to determine the selectivity parameters.

The mesh size of the cover was large enough to let some smaller *Nephrops* and fish escape. As a consequence the numbers in the cover, especially for the smallest length classes, were under-estimated, as compared to the real numbers of animals escaping from the codend (FONTEYNE, 1991). This, in turn, would have resulted in pushing down the L_{25}'s and in increasing the selection ranges. To compensate for this, the numbers-at-length retained by the cover were raised by means of the expected retention rates for the cover. These were calculated from the following equation:

$$r(l) = \frac{1}{1+e^{-(\alpha * l+\beta)}}$$

After transformation this equation becomes:

$$\ln\left(\frac{r(l)}{1-r(l)}\right) = \alpha * l + \beta$$

and α and β can be calculated as:

$$\beta = \frac{2 \ln 3}{L_{75}-L_{25}} \qquad \text{and} \qquad \alpha = \beta * L_{50}$$

where L_{25}, L_{50} and L_{75} are the lengths at 25, 50 and 75 % retention. L_{75}-L_{25} is the selection range, and L_{50} can be derived from L_{50} = selection factor * mesh opening.

The selectivity parameters used in these calculations were taken from WILEMAN (1991):

Nephrops :	selection factor:	0.37
	selection range :	12 mm
Whiting :	selection factor :	3.12
	selection range :	7.3 cm

RESULTS AND DISCUSSION

In technical terms, the codend cover performed well under different conditions with respect to weather, sea state, etc., and no data sets had to be rejected for reasons of inconsistency. However, despite the floats on the top panel of the cover, masking of the codend meshes by the cover could not completely be avoided, and, as a consequence, the selection factors might be slightly under-estimated.

NEPHROPS

Table 1 summarizes the selectivity parameters for *Nephrops* for individual hauls, and the "mean" selectivity parameters for the combined hauls.

The Complementary Log Log compared to the Logit model

The retention rates for *Nephrops* usually show an asymmetrical pattern; rather smooth in the lower, and sharp in the upper part of the size range. The Logit model, which produces a symmetrical ogive, never gave a good fit above the L_{75} and therefore does not seem to be the most appropriate link-function to represent *Nephrops* selectivity. For most hauls, the C Log Log model gave a better fit to the observed retention rates, as shown by the deviance, as well as by Pearson's Chi-square. When carrying out e.g. mesh assessments, the use of the Logit model may cause errors, particularly in the calculation of the numbers of escapers-at-length above the L_{75} (Figure 5).

Below the L_{25} the Logit curve is usually sharper than the C Log Log curve. Unfortunately, however, the numbers of small *Nephrops* caught were very low, which made it difficult to decide which model is best for the lower length classes.

Within the selection range, the curves for the two models are almost identical, and the selectivity parameters never differed significantly. The two functions are equally satisfactory for selectivity calculations. For calculations requiring close estimates of the retention rates outside of the selection range, the Logit model may result in errors, and the C Log Log function could be a better alternative.

Haul by haul comparison

Each single haul contained sufficient numbers of *Nephrops* to obtain reliable retention rates, particularly for the sizes within the selection range. Sometimes, both the smallest and the largest size classes of *Nephrops* were, however, caught in very low numbers. This resulted in a considerable degree of scattering for the retention rates in the outer parts of the size range. Especially the smallest *Nephrops* may have escaped underneath the footrope or through the trawl wings and body, long before they could reach the codend (HILLIS and EARLEY, 1982).

The haul by haul variability of the selection factor appeared to be quite large (Table 1) but close examinations of the data revealed that at least part of this variability was attributable to the weather conditions (see next section). Special attention was also paid to the volume of the catches, and to the amount of "trash" therein, but no correlation could be found between the selection factor or range, and the volume of the catches.

Effect of sea state on selectivity

The appreciation of the sea state was based on Douglas' sea scale. During the experiments five states of sea were recorded, viz. calm, smooth, slight, moderate and rough, and the selectivity data were combined accordingly. The selectivity parameters for these combined data were calculated using Fryer's variance component model (FRYER, 1991).

The selection curves, calculated for each sea state, are compared in Figure 6. The graph shows that sea state, which affects vessel motion, has a critical effect on selectivity: the rougher the surface of the sea, the better the selectivity. Figure 7 shows the L_{50}'s for the five sea states, together with their 95% confidence limits. There is an overlap of confidence intervals, and hence no significant difference, for several "neighbouring" states of sea. However, the differences between calm and slight, slight and rough, and moderate and rough are significant at the 95% level. The same trend was, however, not evident for the selection range.

BRIGGS and ROBERTSON (1993) found that *Nephrops* is largely inactive during the catching process and that it makes no active attempts to escape from a trawl. External factors, however, such as pumping movements of the net, which may provoke the opening and closing of the meshes, could induce the escapement of *Nephrops* from the codend. Vessel motion, which clearly depends on sea state, will certainly create such an effect. This is particularly the case during the hauling operation, when the trawl is heaving up and down alongside the vessel. The present data seem to confirm this hypothesis. Under calm weather conditions, the selection was very poor (SF = 0.37, sea state "calm") but as soon as the waves grew higher, selection started to improve (SF = 0.57, sea state "rough").

Selectivity parameters of the 70 mm codend

The data for all hauls with the 70 mm codend were combined to produce a "mean" selection curve (Figure 8). The L_{50} thus obtained was 31.6 mm, the selection factor 0.47, and the selection range 15.2 mm.

Since the weather conditions have a major impact on the selection factor, it seemed reasonable to tune the selectivity according to the prevailing weather conditions in the Botney Gut - Silver Pit area. Wind speed data for the Botney Gut - Silver Pit area, based on recordings from the "Viking Alpha" platform, were obtained from the UK Meteorological Office, Marine Advisory and Consultancy Service. From these data "moderate" appeared to be the prevailing sea state in the area. The selectivity parameters corresponding to this sea state, viz. an L_{50} of **33.8 mm**, a selection factor of **0.50** and a selection range of **14.7 mm**, are therefore a far more realistic estimate of the "true" selectivity parameters, than the ones derived from the "mean" selection curve.

The L_{25} of **26.4 mm** is very close to the legal MLS (25 mm), which indicates that the selective properties of the standard codend are in line with the general principle that the L_{25} should be at, or at least close to, the MLS. It should, however, be emphasized that selection by the 70 mm codend is far from being knife-edged. The selection ogive has a very gentle slope, resulting in a wide selection range, and retention rates of 100 % are being reached from a size of about 50 mm CL onwards only.

The square mesh window

The selection factors and ranges for the combined hauls with (Figure 9) and without (Figure 8) square mesh window were 0.46 and 16.1 mm, and 0.47 and 14.8 mm respectively. The data do not indicate that *Nephrops* would escape through the window. These findings are in line with the results of previous studies (THORSTEINSSON, 1991; TUMILTY, 1991; ULMESTRAND and LARSSON, 1991; BRIGGS, 1992; BRIGGS and ROBERTSON, 1993).

Comparison between the 70 mm and the 90 mm codends

The L_{50} and the selection range for the 90 mm codend were 28.9 mm and 16.8 mm (Figure 10) as compared to 31.6 mm and 15.2 mm for the 70 mm codend. Contrary to what might be expected, an increase of the mesh size would not improve the escapement of small *Nephrops*.

The most likely explanation for this phenomenon is that the material used for the 90 mm codend (double braided polyethylene) is much more rigid than the single braided polyamide used for the 70 mm codend, which may have adversely affected the opening of the meshes.

It is important to notice that the choice of the netting materials for the two codend mesh sizes was based on the knowledge that fishermen will definitely choose for double braided polyethylene if the minimum mesh size were increased. The consequence being that an increase of the codend mesh size to reduce discard mortalities in this fishery (REDANT and POLET, 1994) would worsen the problem, rather than solve it.

Comparison with other *Nephrops* selectivity parameters

The selection factors published for *Nephrops* codends used in other ICES Sub-areas show a wide range of variability, even within one ICES Sub-area (BRIGGS, 1986 and WILEMAN, 1991). The selectivity of the standard 70 mm codend compared fairly well with the mean of these data. The selection factor of the 90 mm codend was, however, low as compared to the others.

WHITING

Table 2 summarizes the selectivity parameters for the combined hauls for each net configuration.

Selectivity parameters of the 70 mm codend

The L_{50} of the standard 70 mm codend was 27.2 cm, the selection factor 4.04 and the selection range 6.1 cm. The size frequency plot in Figure 11 clearly shows that almost all fish below the MLS (23 cm) escaped from the codend.

The L_{25} was 24.2 cm, which is slightly above the MLS. As for *Nephrops*, the selective properties of the 70 mm codend for whiting comply reasonably well with the general principle that L_{25} and MLS should be at the same length.

The square mesh window

The L_{50} for the trawl with a square mesh window in the top panel and a 70 mm codend was 33.6 cm, the selection factor 4.99 and the selection range 11.6 cm. Below the MLS roughly the same proportions of fish were retained in both the standard trawl (Figure 11) and the trawl with the square mesh window (Figure 12). Above the MLS, however, more whiting seemed to escape from the configuration with the window. Similar conclusions can be drawn from the selectivity parameters. The L_{25}, the L_{50} and the L_{75} increased by 3, 6 and 9 cm respectively, upon the insertion of a square mesh window, and, as a consequence, the selection range for the window trawl was considerably larger than that for the standard trawl.

Several previous studies (e.g. BRIGGS, 1992; TUMILTY, 1991; ULMESTRAND and LARSSON, 1991) have shown that square mesh windows are particularly effective in reducing the roundfish by-catches in the *Nephrops* fisheries. It should, however, be kept in mind that, at least in this case, the extra escapes included mainly marketable fish, and that the usefullness of square mesh windows as a conservation tool for juvenile whiting may therefore be limited.

Comparison between the 70 mm and the 90 mm codends

From the size frequency plots (Figures 11 and 13) and the selection curves (Figure 14) for the 70 mm and the 90 mm codends, it is clear that selection does not improve with the use of a 90 mm codend. On the contrary: particularly in the lowest part of the length range (below the MLS) relatively more whiting were retained by the 90 mm codend than by the 70 mm codend. The L_{50} for the 90 mm codend was 26.6 cm, and the selection factor 3.37. The slope of the selection ogive was comparable to the one for the 70 mm codend, with a selection range of 8.0 cm.

Again, however, it must be emphasized that the netting material of the 90 mm codend was double braided polyethylene. Owing to its low flexibility, it seems logical that it has a worse selectivity than single braided polyamide.

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Table 1: *Nephrops* selectivity parameters - separate hauls

Campaign	Haul no.	L25 *logit*	L50 *logit*	Conf. int.		L75 *logit*	Sel. factor *logit*	Sel. range *logit*	L25 *c.loglog*	L50 *c.loglog*	Conf. int.		L75 *c.loglog*	Sel. factor *c.loglog*	Sel. range *c.loglog*	Mesh size	Seastate
1	2	27.8	36.5	35.4	37.9	45.2	0.54	17.4	28.0	36.8	33.1	40.6	43.7	0.55	15.6	67.3	mod
1	4	28.4	35.5	34.5	36.8	42.7	0.53	14.4	28.3	36.0	32.7	39.4	42.1	0.54	13.7	67.3	mod
1	7	27.3	34.6	33.6	35.7	42.0	0.51	14.7	27.0	35.1	31.5	38.7	41.6	0.52	14.6	67.3	sli
1	9	13.3	24.9	23.1	26.3	36.6	0.37	23.2	9.7	24.9	17.9	31.3	36.8	0.37	27.2	67.3	smo
1	12	-17.0	7.4	-50.7	17.3	31.9	0.11	48.8	-30.1	4.6	-52.1	20.9	32.0	0.07	62.1	67.3	cal
1	13	20.5	28.7	26.4	30.4	36.9	0.43	16.5	18.0	28.8	23.0	33.7	37.3	0.43	19.3	67.3	cal
1	15	23.7	31.4	30.1	32.6	39.1	0.47	15.5	22.2	31.8	27.4	35.9	39.3	0.47	17.2	67.3	cal
1	18	28.5	34.1	32.8	35.5	39.8	0.51	11.4	28.0	34.8	31.6	38.0	40.2	0.52	12.3	67.3	smo
1	19	24.8	30.5	29.7	31.3	36.3	0.45	11.6	23.3	31.0	27.6	34.3	37.0	0.46	13.7	67.3	smo
1	20	25.5	28.4	26.9	29.6	35.3	0.42	13.8	18.9	28.5	23.9	32.6	36.0	0.42	17.1	67.3	cal
1	23	23.3	30.3	29.5	31.4	37.3	0.45	14.0	21.1	30.6	26.4	34.7	38.1	0.45	16.9	67.3	smo
1	24	23.5	29.5	28.4	30.4	35.4	0.44	11.9	22.2	29.8	26.5	33.1	35.8	0.44	13.6	67.3	sli
1	25	22.4	29.0	27.9	30.0	35.7	0.43	13.3	18.9	29.0	24.2	33.4	36.9	0.43	18.0	67.3	sli
1	29	17.8	26.0	25.0	26.9	34.3	0.39	16.4	15.1	26.1	21.3	30.7	34.7	0.39	19.6	67.3	cal
1	31	8.6	19.2	13.1	22.6	29.8	0.29	21.2	0.1	17.0	6.1	24.8	30.4	0.25	30.3	67.3	cal
1	32	12.2	20.9	18.8	22.4	29.7	0.31	17.5	4.3	18.9	11.3	25.2	30.4	0.28	26.1	67.3	cal
1	39	16.9	26.7	24.9	28.1	36.5	0.34	19.6	12.9	26.5	20.2	32.3	37.2	0.34	24.3	79	smo
1	41	15.5	22.1	20.0	23.6	28.7	0.28	13.2	8.2	20.0	13.3	25.2	29.2	0.25	21.0	79	smo
1	42	10.2	21.6	17.9	24.0	33.1	0.27	22.9	3.1	20.2	10.9	27.6	33.7	0.26	30.6	79	sli
1	43	20.7	29.3	26.2	31.5	38.0	0.37	17.3	19.1	29.7	23.9	34.5	38.1	0.38	19.0	79	sli
1	47	22.7	32.9	31.3	34.6	43.2	0.42	20.5	21.6	33.4	28.0	38.7	42.7	0.42	21.0	79	smo
1	49	18.5	27.9	13.7	32.1	37.3	0.35	18.9	16.5	28.3	13.8	34.3	37.5	0.36	20.9	79	smo
1	50	25.1	30.6	29.7	31.5	36.1	0.39	11.1	24.0	31.1	27.8	34.2	36.8	0.39	12.8	79	smo
1	51	23.3	32.5	30.8	34.2	41.6	0.41	18.3	21.8	33.2	27.9	38.5	42.2	0.42	20.4	79	cal
1	52	27.4	35.1	33.6	36.7	42.7	0.44	15.3	27.0	35.9	31.8	39.9	42.9	0.45	15.9	79	cal
2	25	26.9	34.6	32.6	36.9	42.4	0.51	15.5	26.1	35.2	30.5	39.8	42.3	0.52	16.3	67.3	sli
2	27	16.0	26.8	23.0	29.1	37.5	0.40	21.5	11.3	26.3	18.2	32.9	38.1	0.39	26.8	67.3	mod
2	30	29.2	33.9	32.6	35.1	38.6	0.50	9.4	28.5	34.4	31.3	37.2	39.1	0.51	10.6	67.3	mod
2	32	25.9	31.6	29.6	33.2	37.3	0.47	11.4	24.6	32.1	27.9	35.6	38.1	0.48	13.5	67.3	mod
2	35	27.9	36.6	35.1	38.3	45.2	0.54	17.3	27.6	37.1	32.9	41.4	44.5	0.55	16.9	67.3	rou
2	36	34.4	39.9	38.9	41.0	45.3	0.59	10.9	34.8	40.7	38.1	43.4	45.4	0.61	10.6	67.3	rou
2	37	25.9	38.3	36.3	41.1	50.7	0.57	24.8	25.9	38.4	32.9	44.3	48.3	0.57	22.5	67.3	rou
2	40	20.4	31.5	29.5	33.4	42.6	0.47	22.3	19.3	32.0	26.1	37.5	41.9	0.47	22.8	67.3	mod
2	41	25.0	33.1	31.0	35.0	41.1	0.49	16.0	34.3	33.6	29.0	37.8	40.9	0.50	16.5	67.3	mod
2	42	23.8	31.0	29.7	32.1	38.2	0.46	14.4	22.0	31.3	27.0	35.4	38.7	0.47	16.6	67.3	sli
2	45	24.3	30.3	29.1	31.3	36.3	0.45	12.0	23.0	30.7	27.1	34.1	36.8	0.46	13.8	67.3	sli
2	47	24.7	35.1	30.0	44.7	45.6	0.52	20.9	24.8	35.5	28.2	43.1	43.9	0.53	19.0	67.3	mod
2	48	32.6	38.1	36.2	40.5	43.6	0.57	11.0	33.1	38.8	36.1	41.6	43.4	0.58	10.3	67.3	mod
2	49	23.5	32.0	30.7	33.3	40.5	0.48	17.0	22.8	32.6	28.2	36.8	40.3	0.48	17.5	67.3	sli
2	51	26.4	32.9	32.0	33.8	39.5	0.49	13.1	25.7	33.5	30.1	36.9	39.7	0.50	14.0	67.3	sli
2	52	17.8	26.1	21.9	28.5	34.3	0.39	16.4	14.0	25.7	18.2	31.1	34.9	0.38	20.9	67.3	sli
2	54	18.5	27.4	22.7	30.1	37.3	0.41	17.8	13.7	26.7	17.0	32.8	37.0	0.40	23.3	67.3	mod
2	55	28.6	34.1	33.4	34.8	39.5	0.51	10.9	28.4	34.6	31.9	27.3	39.5	0.51	11.2	67.3	mod
2	57	31.2	38.3	37.1	39.8	45.4	0.57	14.3	31.0	38.8	35.3	42.6	45.0	0.58	13.9	67.3	mod

Table 2 : *Nephrops* selectivity parameters - combined hauls

Data set	L25	L50	L75	Mesh size	Sel. factor	Sel. range
Square mesh window (70mm)	23.2	31.1	39.2	67.3	0.46	16.1
No window (70mm)	24.4	31.9	39.2	67.3	0.47	14.8
No window (90mm)	20.4	28.9	37.2	79.0	0.37	16.8
Sea state calm	16.1	25.2	34.4	67.3	0.37	18.2
Sea state smooth	23.7	30.6	37.6	67.3	0.45	13.9
Sea state slight	24.1	31.2	38.1	67.3	0.46	14.0
Sea state moderate	26.4	33.8	41.1	67.3	0.50	14.7
Sea state rough	30.6	38.6	46.6	67.3	0.57	16.0
All hauls (70mm)	24.0	31.6	39.2	67.3	0.47	15.2

Table 3 : Whiting selectivity parameters - combined hauls

Data set	L25	L50	L75	Mesh size	Sel. factor	Sel. range
Square mesh window (70mm)	27.8	33.6	39.4	67.3	4.99	11.6
No window (70mm)	24.2	27.2	30.3	67.3	4.04	6.1
No window (90mm)	22.6	26.6	30.6	79.0	3.37	8.0

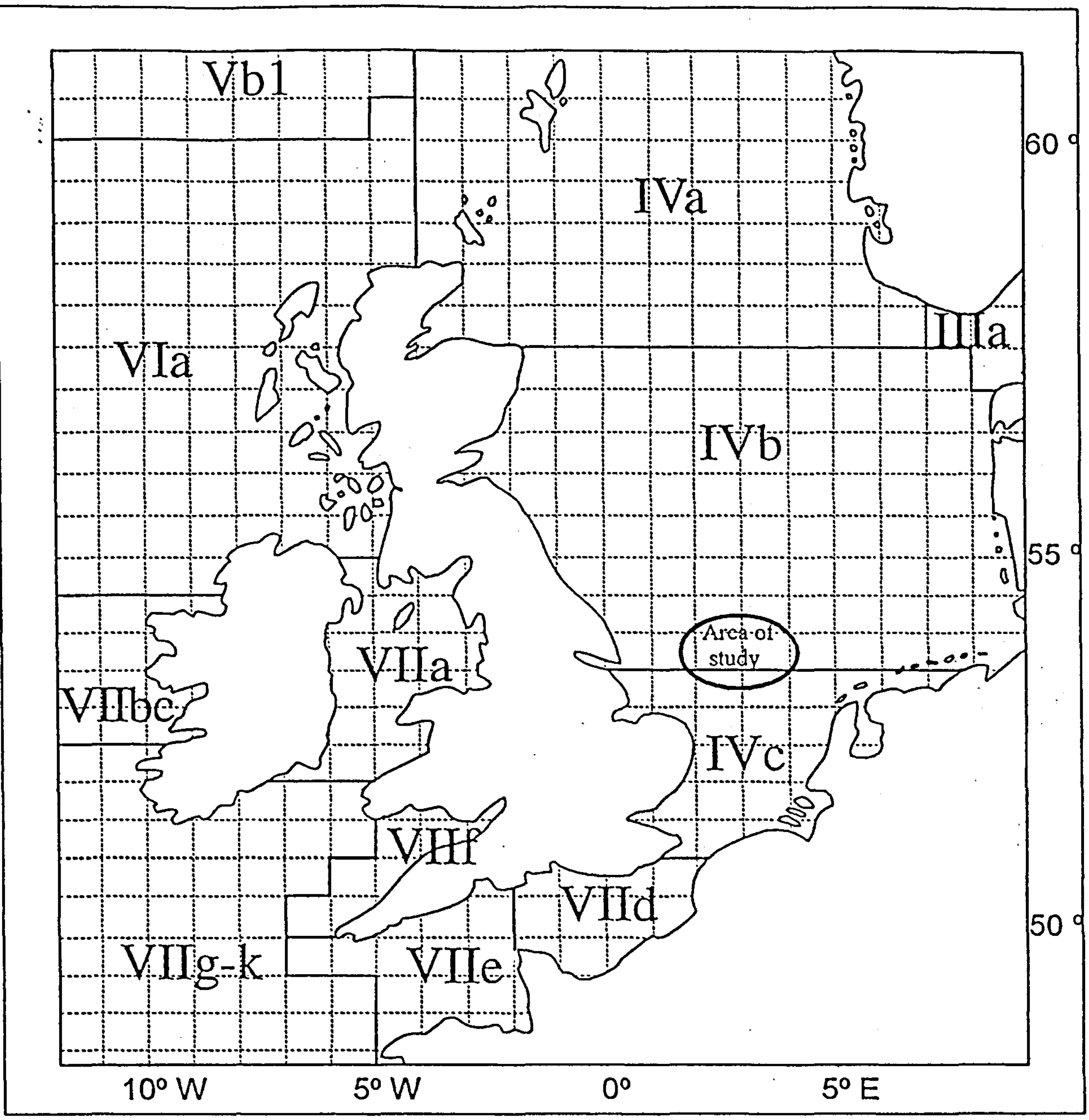


Figure 1 - Location of fishing areas

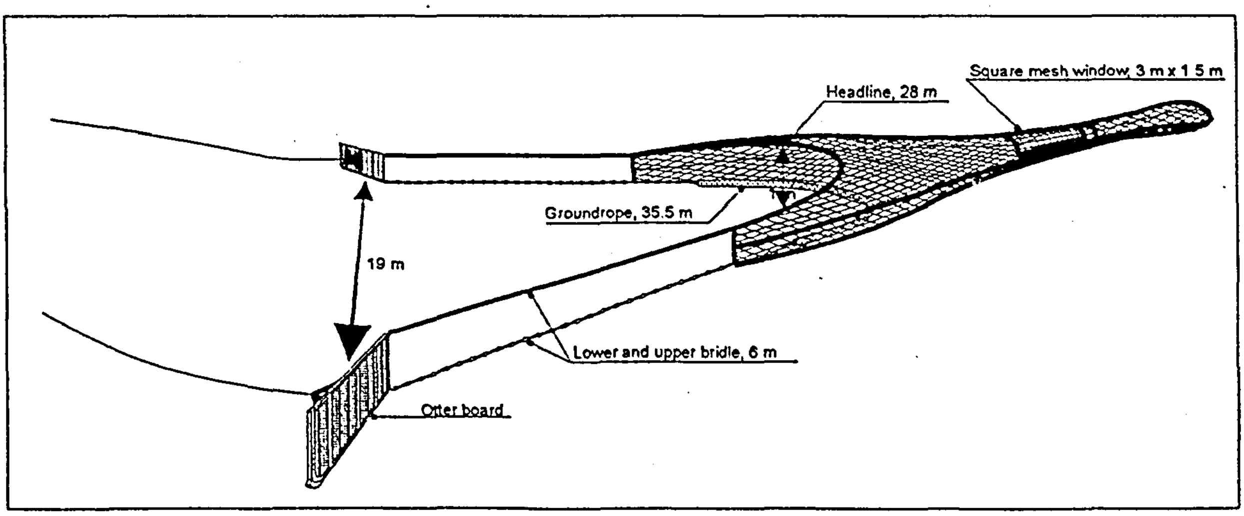
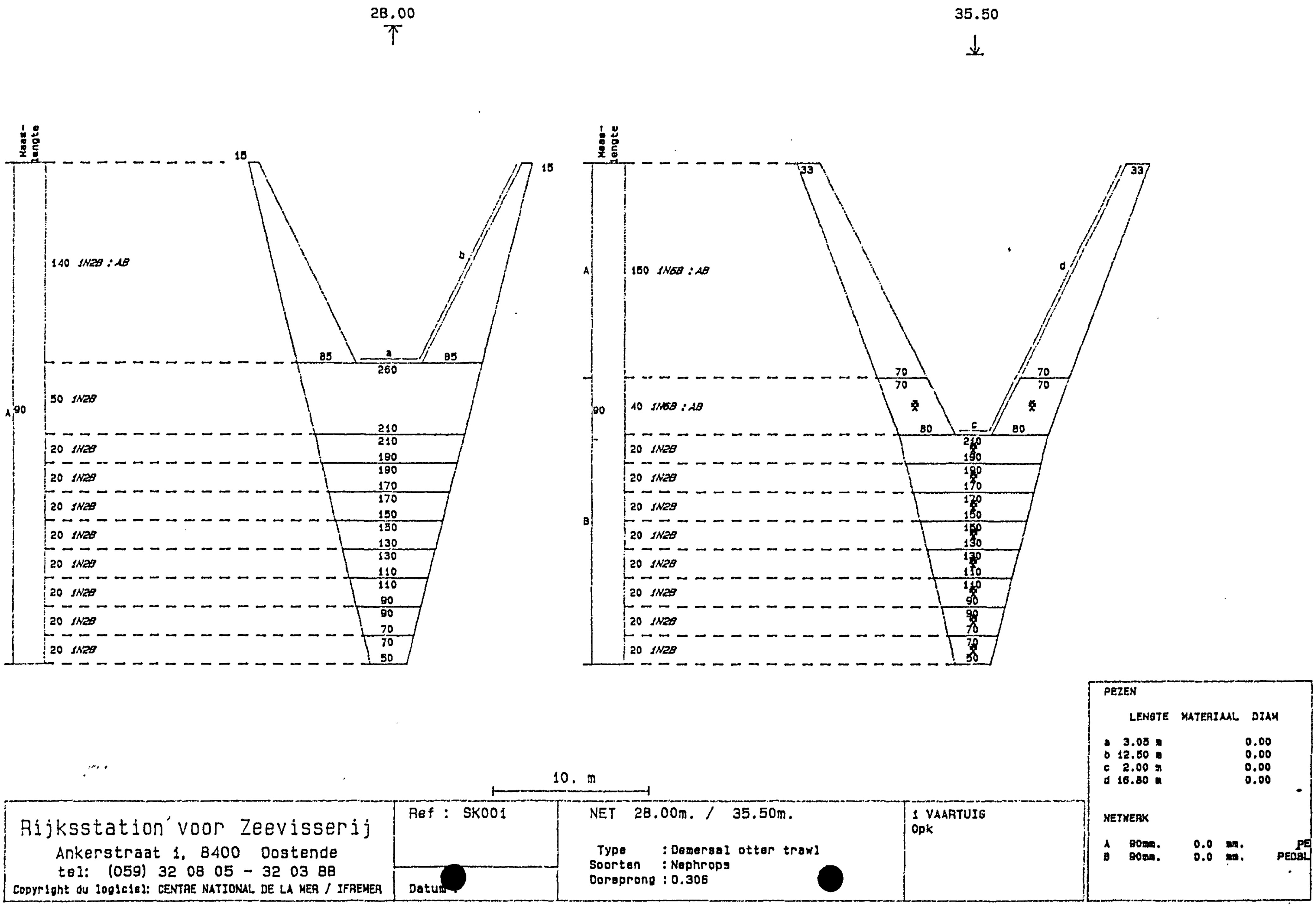


Figure 2 - The Belgian *Nephrops* trawl

Figure 3 - Netplan of the Belgian *Nephrops* trawl



Selectivity studies *Nephrops* fishery

Fractions sampled are marked with ▪

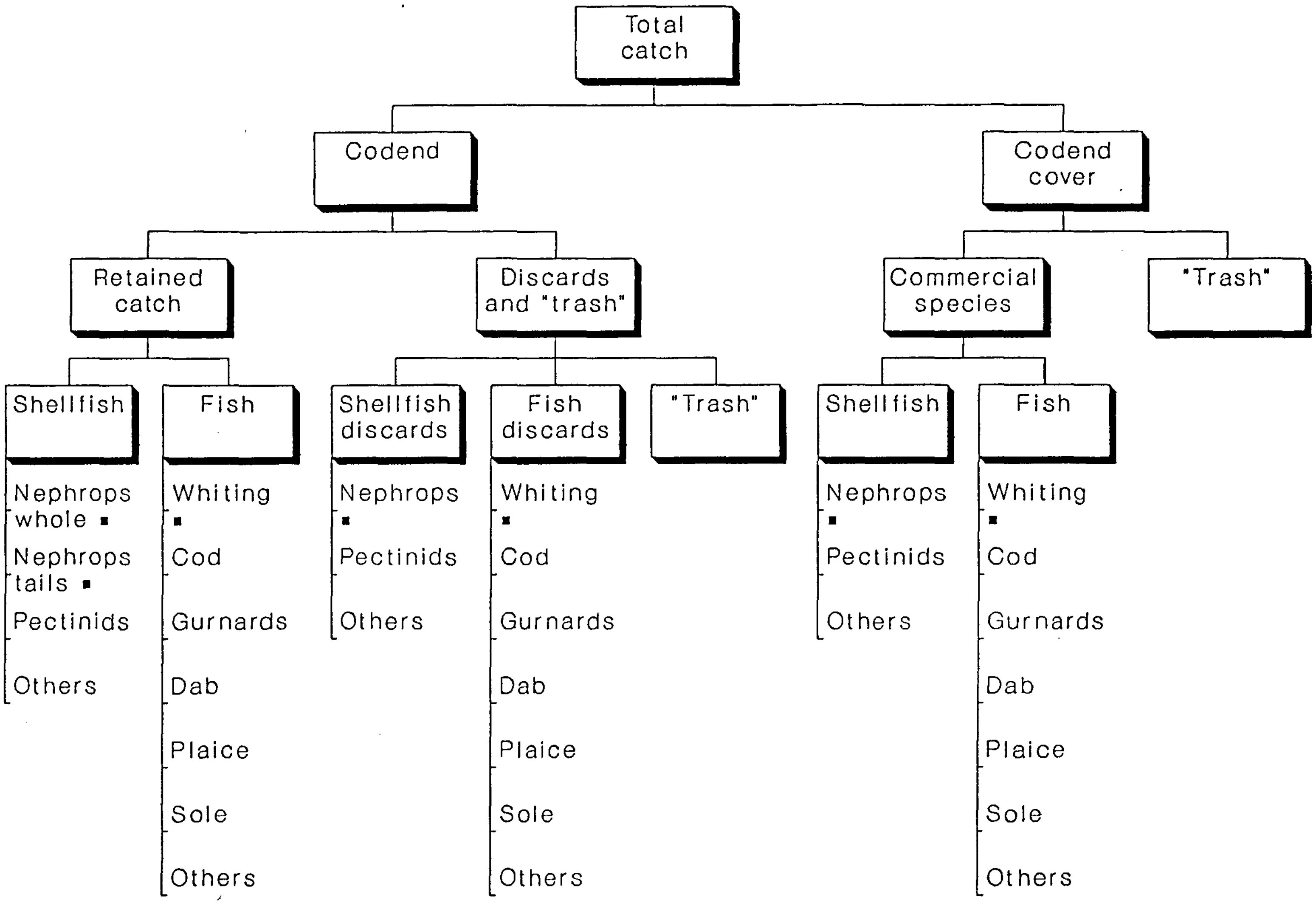
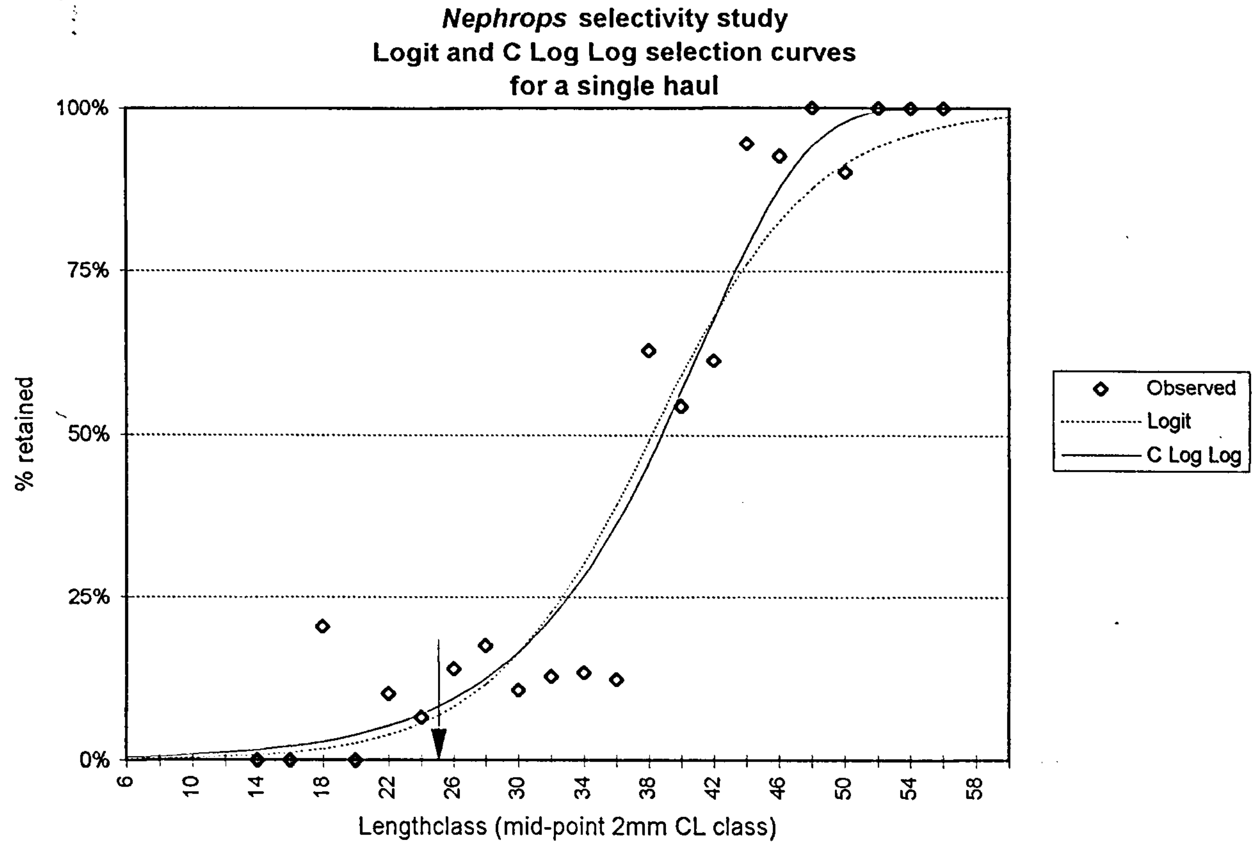
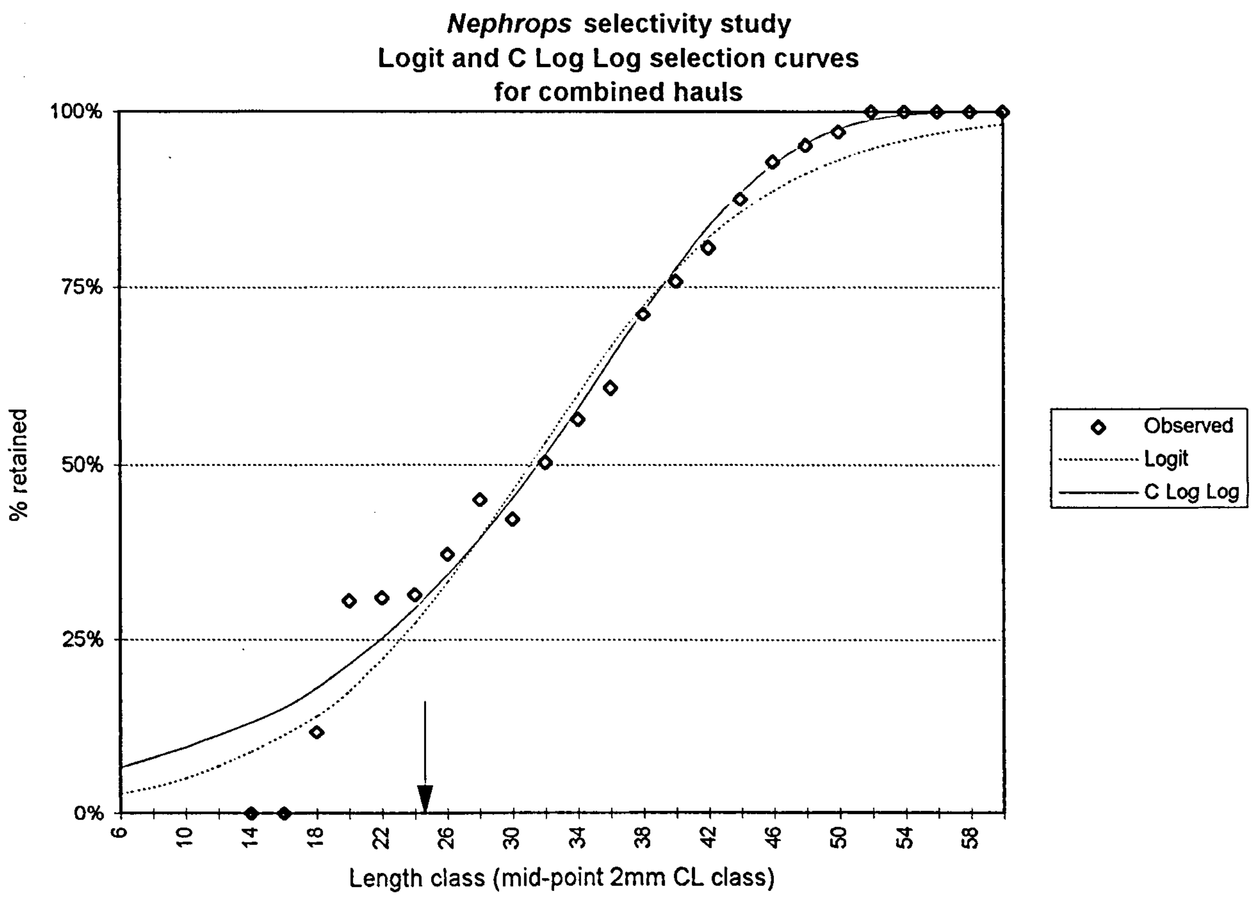


Figure 4



Arrow indicates MLS



Arrow indicates MLS

Figure 5

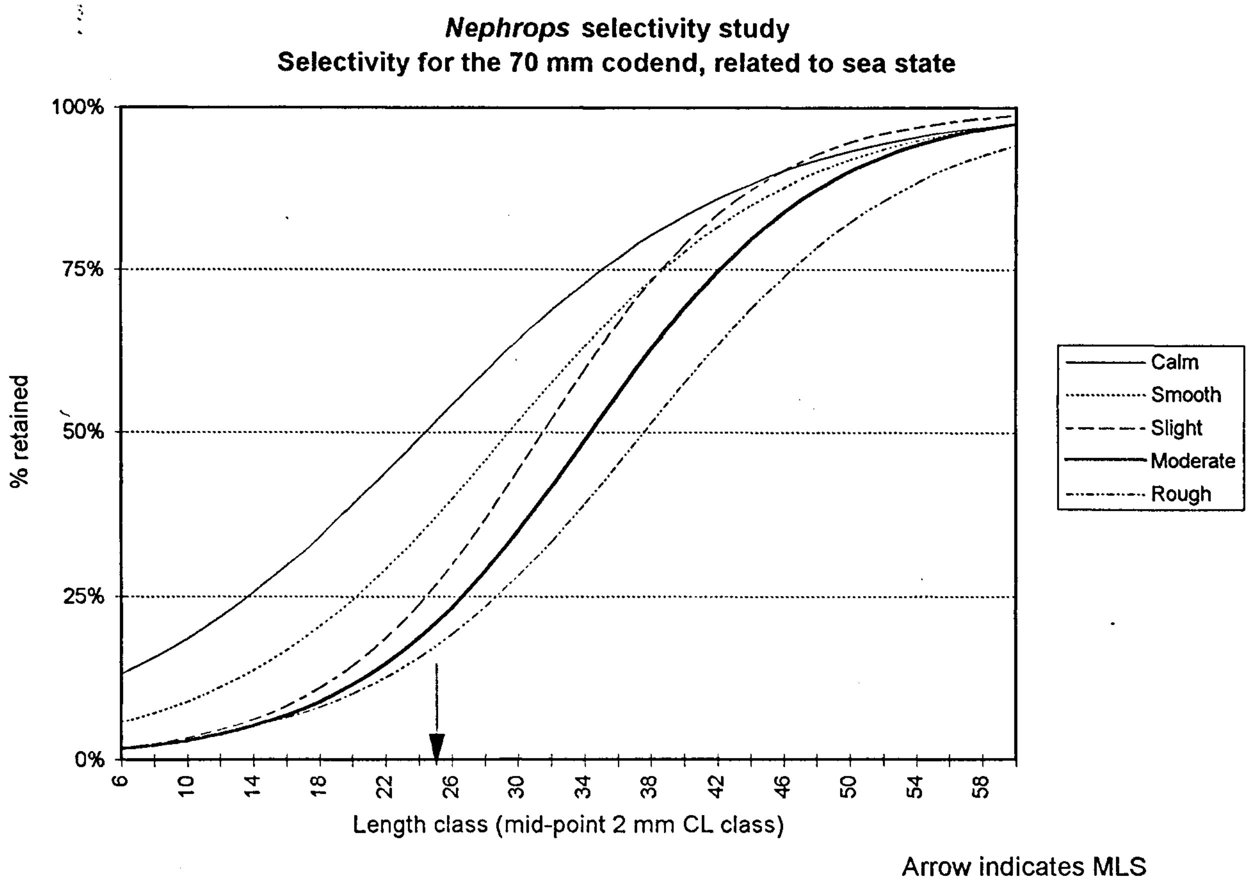


Figure 6

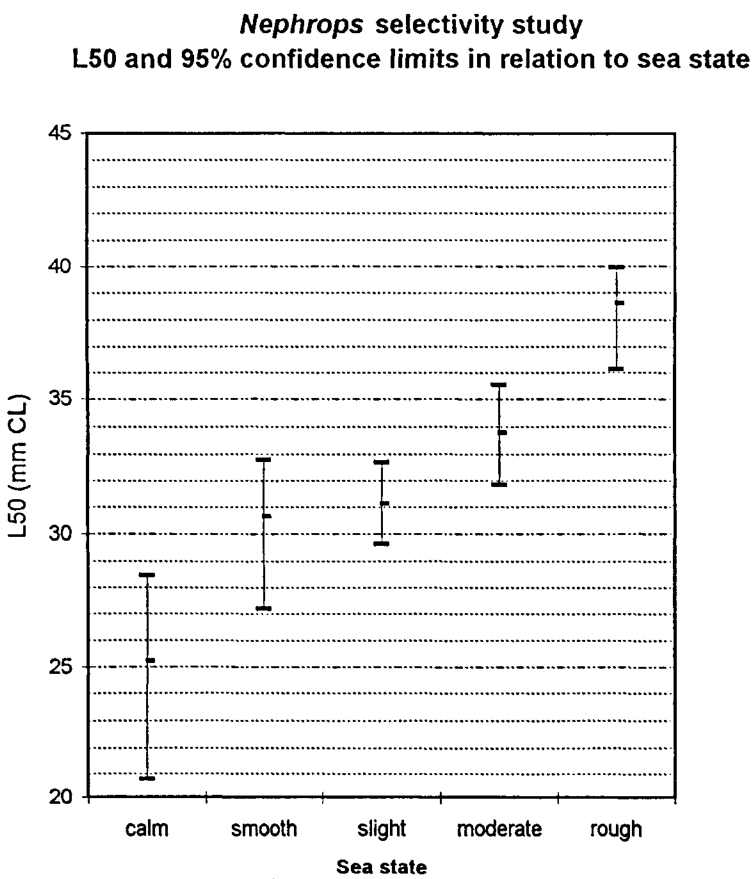
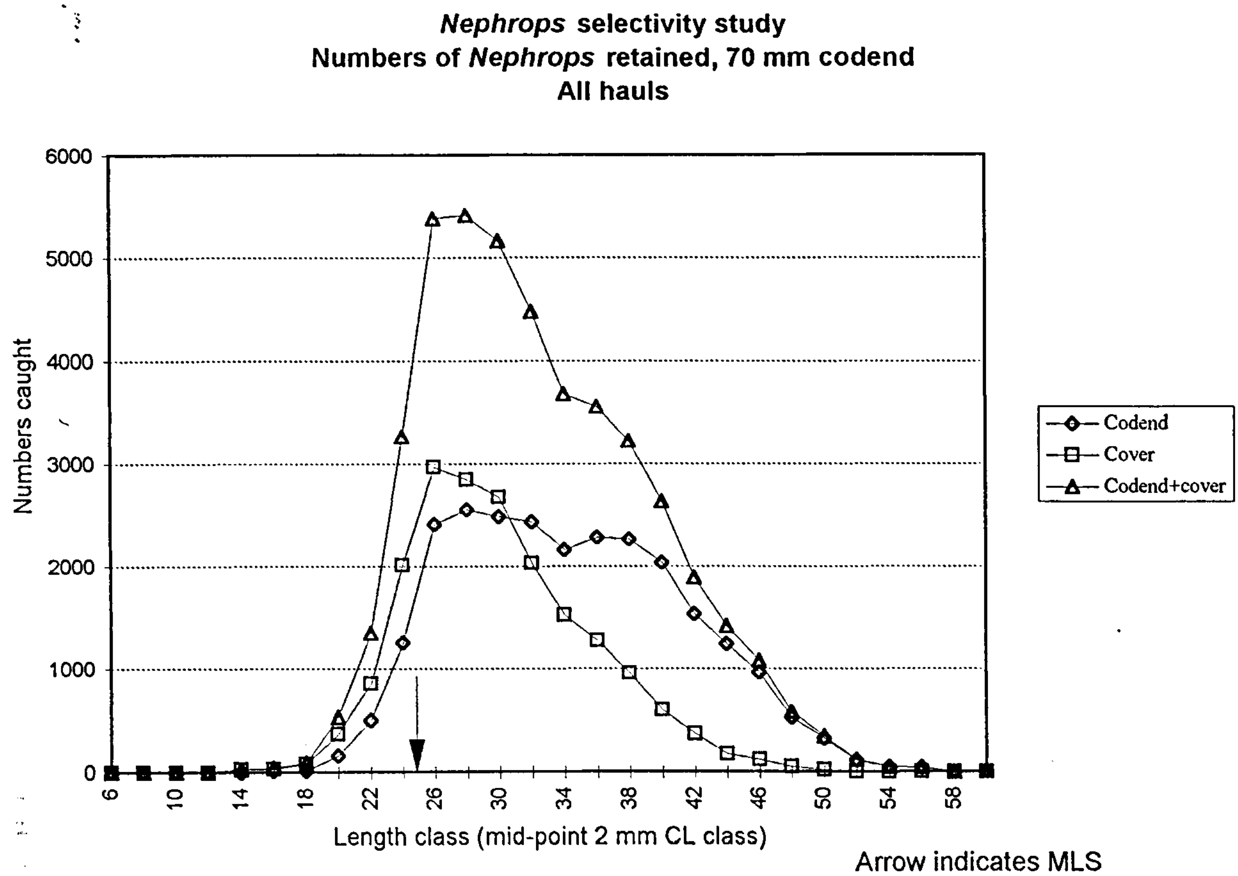
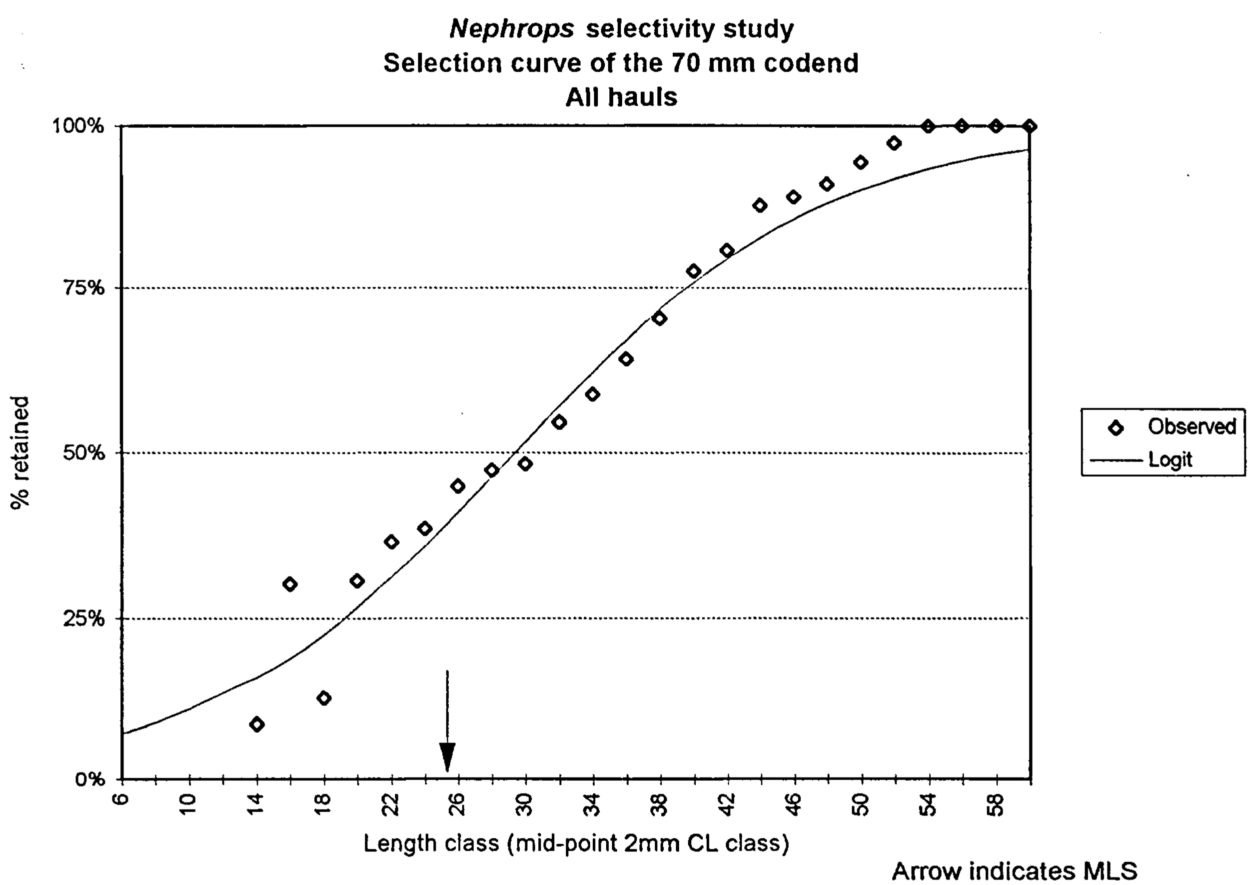


Figure 7

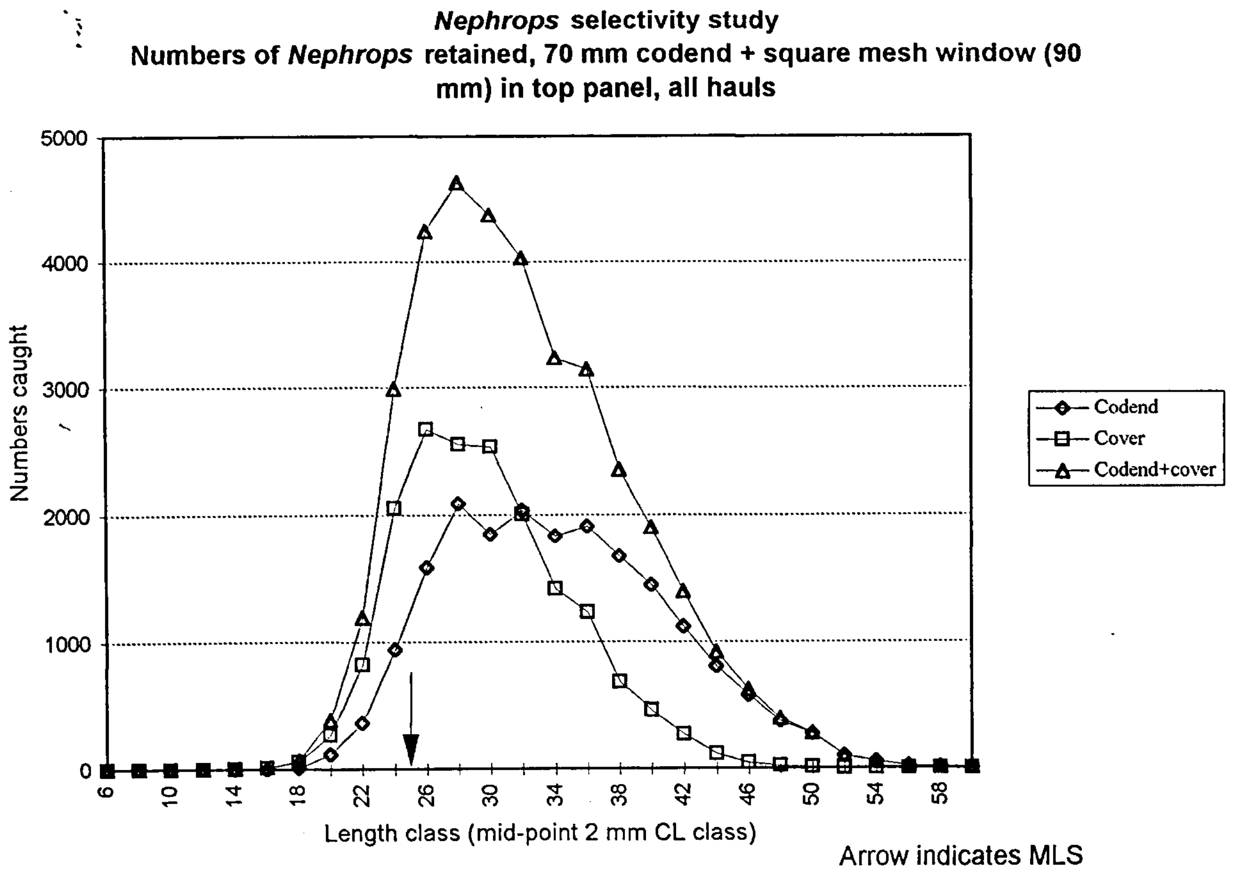


Nephrops selectivity study
Numbers of *Nephrops* retained, 70 mm codend
All hauls
Numbers caught
0
1000
2000
3000
4000
5000
6000
6
10
14
18
22
26
30
34
38
42
46
50
54
58
Length class (mid-point 2 mm CL class)
Codend
Cover
Codend+cover
Arrow indicates MLS

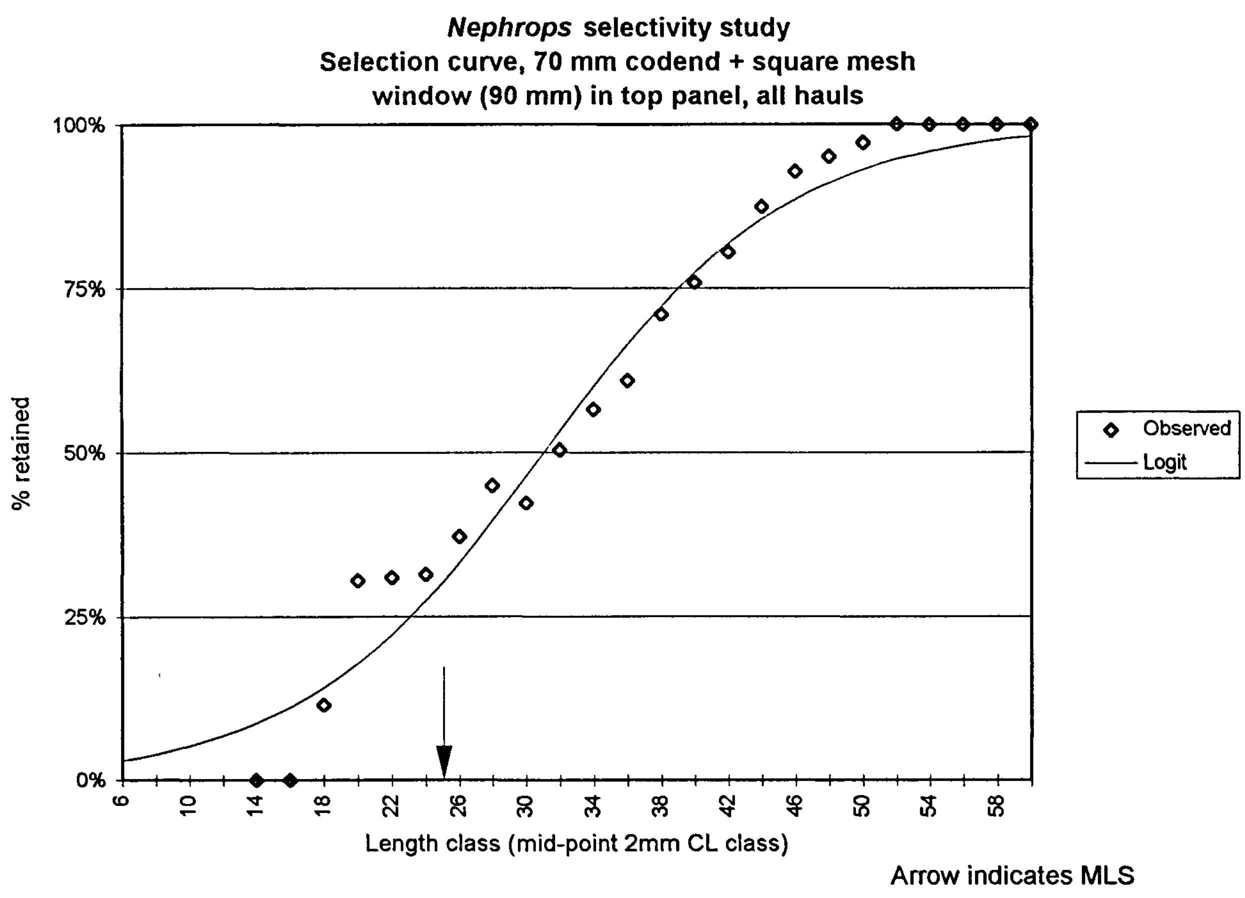


Nephrops selectivity study
Selection curve of the 70 mm codend
All hauls
% retained
0%
25%
50%
75%
100%
6
10
14
18
22
26
30
34
38
42
46
50
54
58
Length class (mid-point 2mm CL class)
Observed
Logit
Arrow indicates MLS

Figure 8



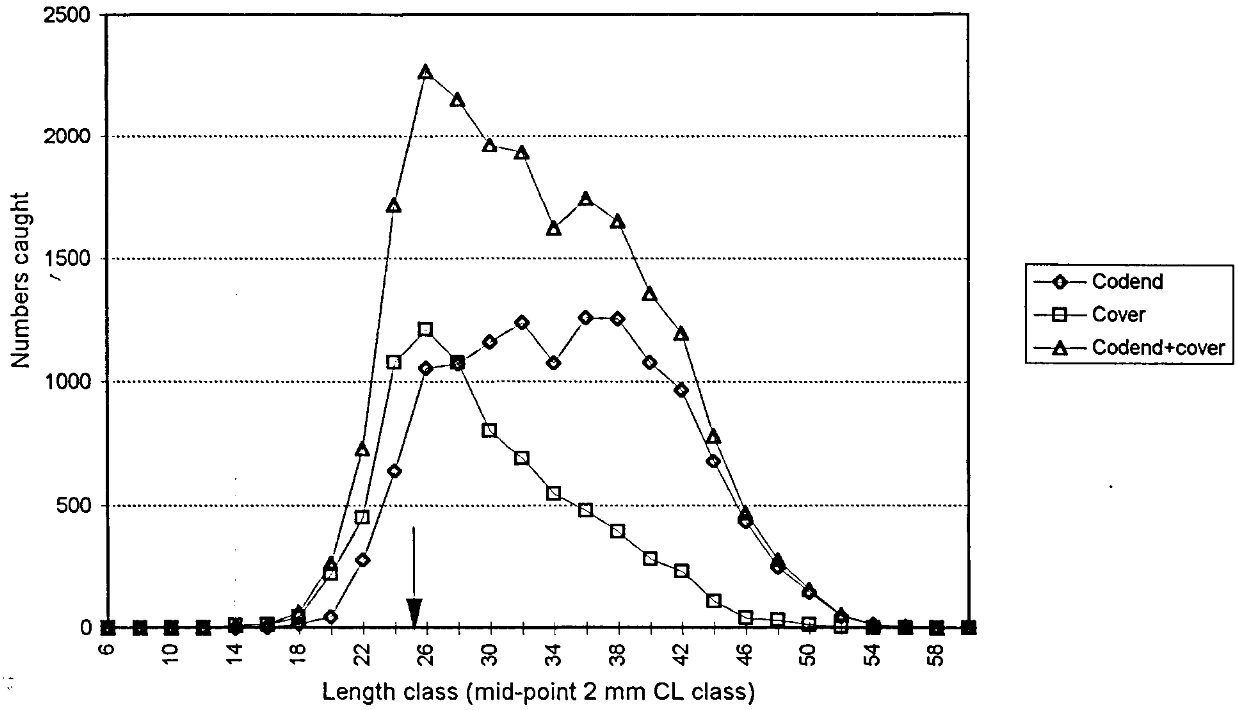
Nephrops selectivity study
Numbers of *Nephrops* retained, 70 mm codend + square mesh window (90 mm) in top panel, all hauls
5000
4000
3000
2000
1000
0
Numbers caught
6
10
14
18
22
26
30
34
38
42
46
50
54
58
Length class (mid-point 2 mm CL class)
Codend
Cover
Codend+cover
Arrow indicates MLS



Nephrops selectivity study
Selection curve, 70 mm codend + square mesh window (90 mm) in top panel, all hauls
100%
75%
50%
25%
0%
% retained
6
10
14
18
22
26
30
34
38
42
46
50
54
58
Length class (mid-point 2mm CL class)
Observed
Logit
Arrow indicates MLS

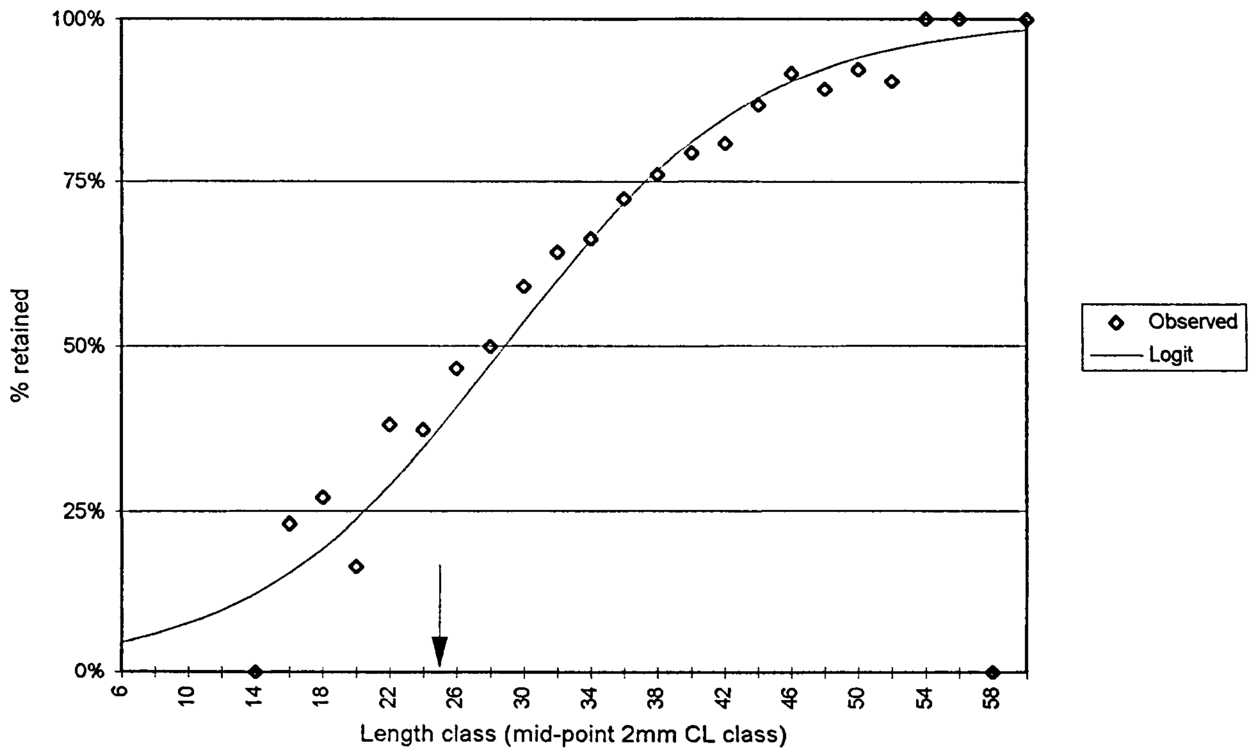
Figure 9

Nephrops selectivity study
Numbers of *Nephrops* retained, 90 mm codend
All hauls



Arrow indicates MLS

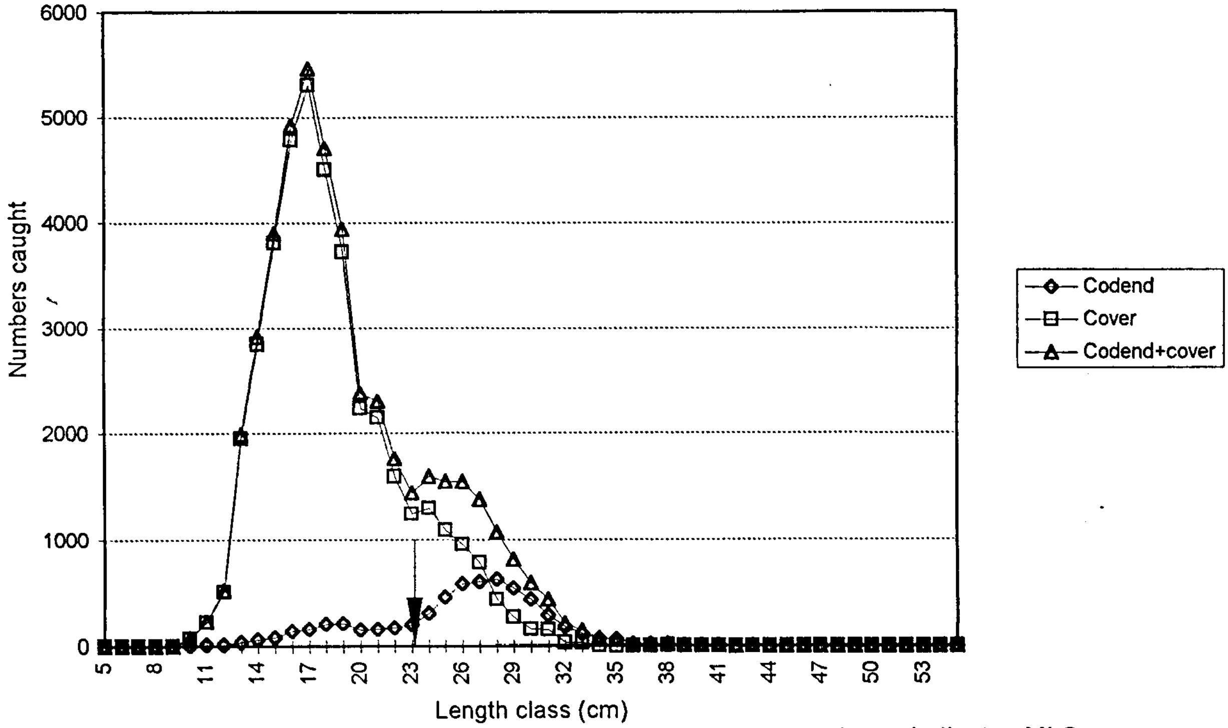
Nephrops selectivity study
Selection curve, 90 mm codend
All hauls



Arrow indicates MLS

Figure 10

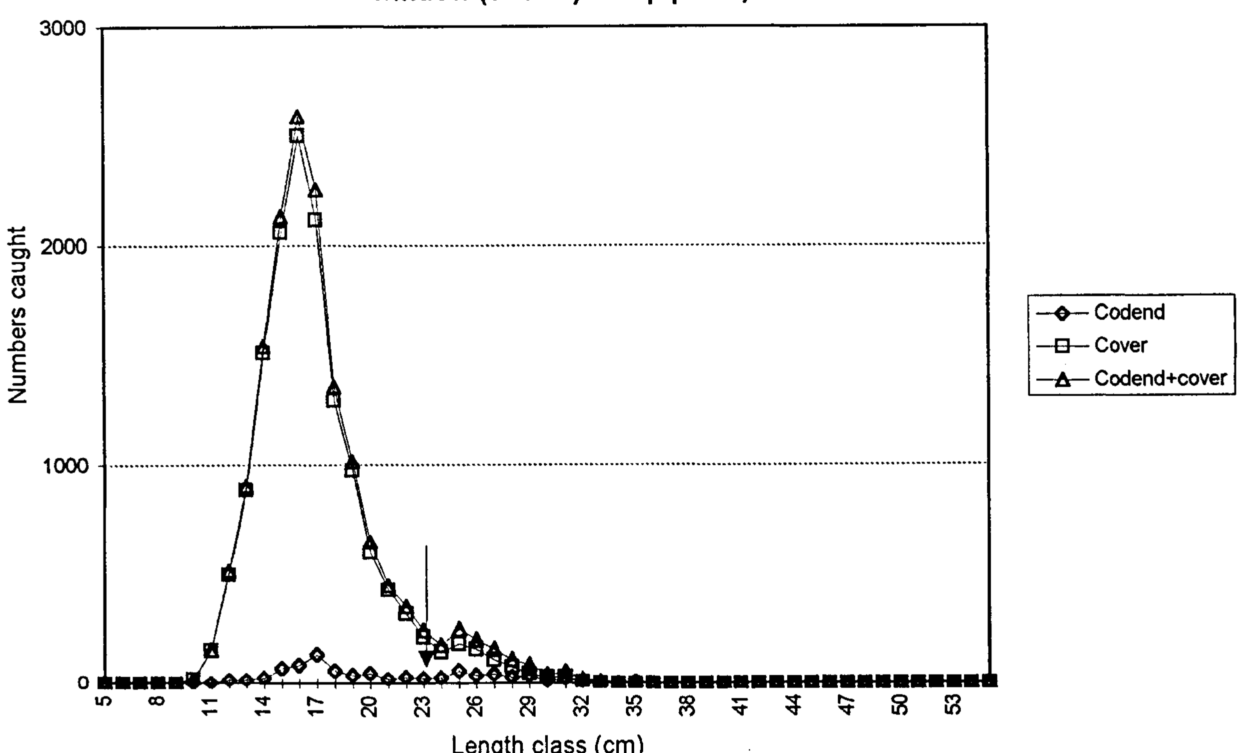
Whiting selectivity study
Numbers of whiting retained, 70 mm codend
All hauls



Arrow indicates MLS

Figure 11

Whiting selectivity study
Numbers of whiting retained, 70 mm codend + square mesh window (90 mm) in top panel, all hauls



Arrow indicates MLS

Figure 12

Whiting selectivity study
Numbers of whiting retained, 90 mm codend
All hauls

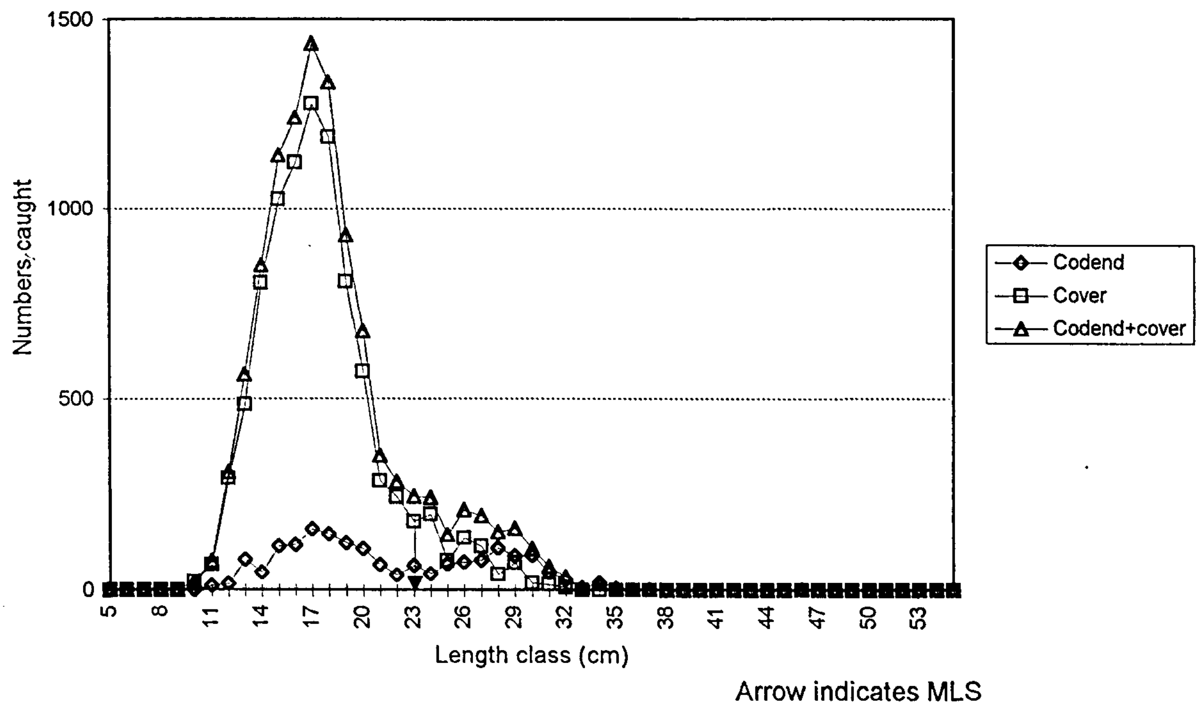


Figure 13

Whiting selectivity study
Selection curves
70 mm and 90 mm codend

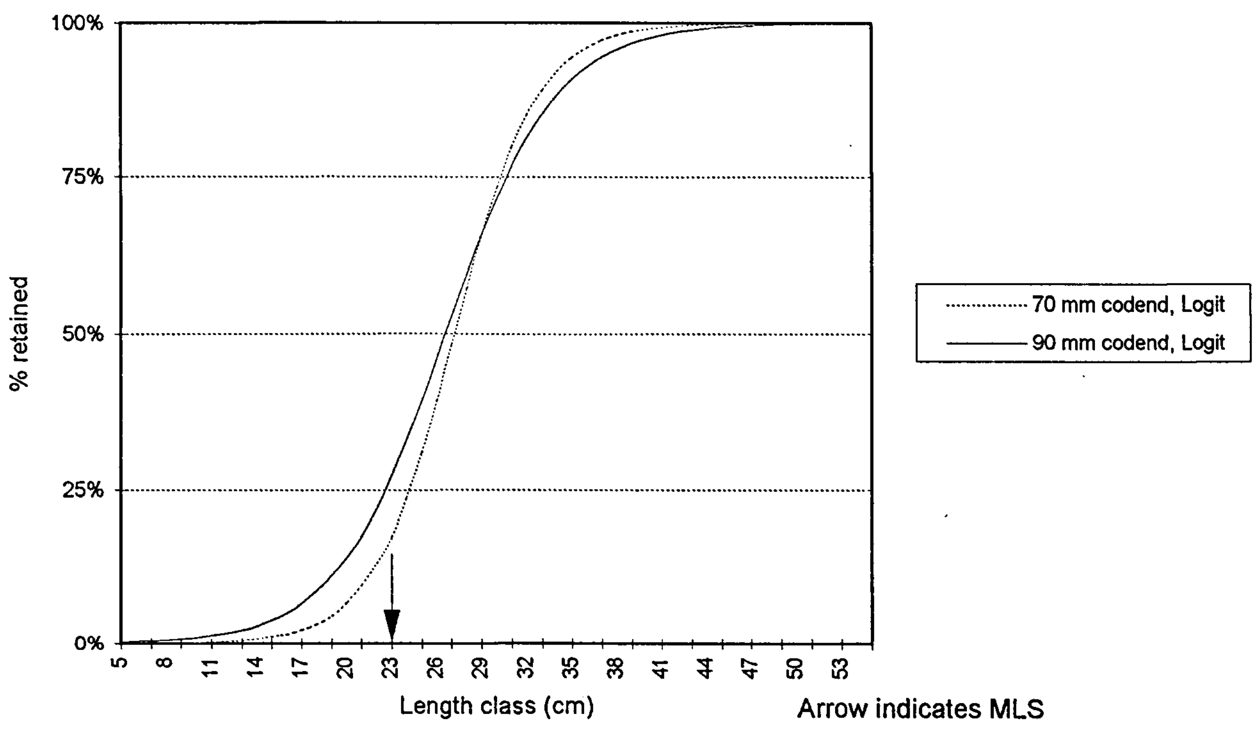


Figure 14