Bord Iascaigh Mhara
Irish Sea Fisheries Board

Assessment of square mesh cod-ends in an Irish *Nephrops* fishery

Ronan Cosgrove, Daragh Browne, Peter Tyndall, BIM

Key findings:

- The smallest 45 mm mesh performed the best of the three square mesh cod-ends tested in terms of improving the catch profile of *Nephrops*.
- Smaller scale reductions in undersize *Nephrops* and increased catches of undersize whitefish were observed in the 45 mm square mesh cod-end compared with a previous assessment of an increase in diamond cod-end mesh size from 70 to 80 mm. This suggests that an increase in diamond cod-end mesh is a better option for reducing catches of undersize *Nephrops* in the Irish fishery.
- Substantial reductions of undersize whiting and haddock with marginal losses of marketable fish in the 65 mm square mesh cod suggests that larger square mesh cod-ends have major potential to improve the selectivity of these species in trawl fisheries.

May 2016

Introduction

Worth around €45 million annually at first point of sale, *Nephrops* is Ireland's most commercially important demersal species. Numerous gear modifications have been developed over the years to reduce fish discards in the *Nephrops* fishery with a particular emphasis on cod in response to management plans for that species. Until recently, however, remarkably little work had been carried out on reducing catches of small *Nephrops*. This raised a key challenge for Industry given relatively high discard rates of small *Nephrops* and the fact that this species was phased in under the landing obligation from 2016.

BIM set about testing three different gear options to effectively reduce the quantities of *Nephrops* retained < 25 mm carapace length (CL), the minimum conservation reference size (MCRS) in Irish waters outside the Irish Sea and the size at which discarding commences in the Irish Sea (MI, 2015). A 45% reduction by weight of *Nephrops* < 25 mm CL was achieved by increasing the size of the diamond mesh in the cod-end from 70 to 80 mm leading to improvements in the length composition and value of catches over the course of a season. A 30% reduction in the quantity of mixed flatfish was an additional benefit of this increase in diamond cod-end mesh size (Cosgrove *et al.,* 2015). This work led to a public consultation by the Department of Agriculture, Fisheries and the Marine (DAFM) on a national increase in minimum cod-end mesh size from 70 to 80 mm. Next we tested a *Nephrops* sorting grid which consisted of relatively small 15 mm spacings in the bottom half to allow small *Nephrops* to escape, and a reinforced gap in the top half to allow fish and large *Nephrops* to pass into the cod-end. A 35% reduction in *Nephrops* < 25 mm CL was obtained using the *Nephrops* sorting grid compared with a standard 70 mm diamond mesh cod-end without a grid (Cosgrove *et al.,* 2016).

Here, we tested a third option, the square mesh cod-end. Previous studies have demonstrated improvements in *Nephrops* selectivity when using square mesh cod-ends compared with diamond mesh. Depending on the size of the mesh used and the *Nephrops* MCRS, cod-ends or ventral net panels constructed with square mesh can also, however, be associated with loss of marketable *Nephrops* and increased retention of small flatfish (Catchpole and Revill, 2008; Frandsen *et al.,* 2010; Frandsen *et al.,* 2011). We endeavoured to address these issues by testing a range of different square mesh sizes in an Irish *Nephrops* fishery.

Methods

Fishing operations

Figure 1. The trial vessel

The trial was carried out on board MFV Stella Nova (DA57) a 23.5 m multi-rig *Nephrops* trawler (Figure 1) operating at the Smalls ground in the Celtic Sea, ICES Division VIIg (Figure 2). A total of 12 hauls were carried out over a 4 day period commencing on the 18th of February 2016. Fishing operations approximating normal commercial hauls were carried out with haul duration, towing speed and depth of ground fished averaging 4:05 hours, 2.8 knots and 113 m respectively. Fishing gear consisted of a quad–rigged 23 fathom *Nephrops* trawl set up using a triple warp and centre clump arrangement. The mesh size in the top and bottom panels behind the head-line and in the lower wing ends of the trawl was 80 mm, while meshes in the upper wing-ends were 160 mm. Three 5 m long experimental 4-panel square mesh cod-ends with nominal stretched mesh sizes of 45 (SMC45), 55 (SMC55) and 65 (SMC65) mm were tested against a standard 4 m 2-panel 70 mm (nominal) diamond mesh cod-end (DMC70). The three square mesh cod-ends were constructed using knotted PE mesh turned 45° to form square mesh. The single braided compact PE twine used to construct the experimental cod-ends was made specifically for the trial by Carrymacarry Net Works Ltd. Knotted PE mesh was chosen in preference to knotless nylon because of the twine's greater stiffness and abrasion resistance and because knotless PE is not readily available in the required mesh size range.

Table 1. **Gear specification**

Trawl type	Quad-rig *Nephrops*
Trawl manufacturer	Pepe Trawls Ltd.
Head-line length (m)	37
Foot-line length (m)	42
Fishing circle (mm)	420 x 80
Sweep length (m)	50 + 20
Warp diameter (mm)	20
Door spread (m)	101
Door manufacturer	Thyboron
Door weight (kg)	549
Clump weight (kg)	850 (roller)

The experimental cod-ends were constructed from four panels to stabilise cod-end orientation (Frandsen *et al.*, 2011) and to optimise contact of *Nephrops* and small gadoids with the cod-end meshes. The experimental cod-ends were pre-stretched longitudinally by the net maker to ensure stability of the meshes and selvedges. The control 70 mm (nominal) cod-end was 4m long and constructed, as per commercial fishing practice, using two panels of knotted diamond mesh made from single 5.5 mm braided compact PE twine. Broadhurst and Millar (2009) found that the circumference affects the selectivity of square mesh cod-ends and suggested that minimising the effect of circumference could facilitate a clearer evaluation of the effect of mesh size. Here we used the method suggested by Robertson (1986) to maximise square mesh opening by closely matching the actual fishing circumference of the extension piece to that of each of the square mesh cod-ends. This resulted in different numbers of meshes in circumference in the test cod-ends (Table 4). Cover or strengthening bags were fitted to both control and experimental cod-ends so as to conform to commercial practice and facilitate commercial-like haul durations and catches. No additional selective devices such as square mesh panels were fitted. Control and experimental cod-end mesh size was measured with the Omega gauge (Fonteyne *et al.*, 2007) with outputs presented in Table 2. The protocol for measuring meshes with the Omega gauge requires that 50 N spreading force be applied for meshes < 55 mm, and 125 N for meshes ≥ 55 mm. Experimental and control cod-ends were rotated daily so that each cod-end was attached to each of the 4 nets for a minimum of one day or 3 hauls. Hence, potential differences in fishing power depending on net position could be accounted for in subsequent analyses.

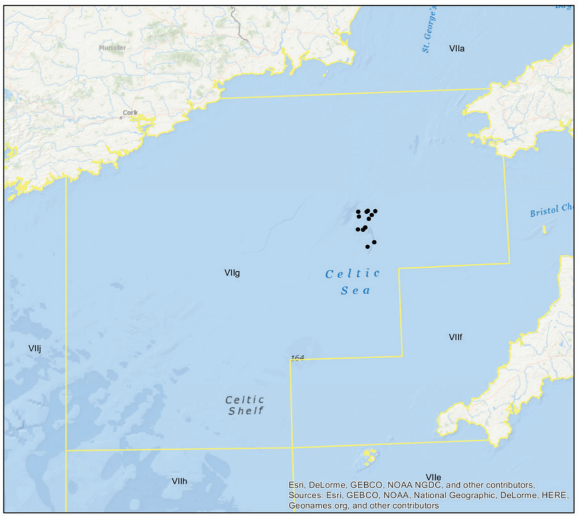


Figure 2. **Haul locations**

Table 2. **Mesh and twine specification**

Nominal mesh size (mm)	**45**	**55**	**65**	**70**
Mesh orientation	Square	Square	Square	Diamond
Measured mesh size (mm)	47.3	56.6	64.8	78.6
Standard deviation (mm)	2.6	1.4	2.4	1.7
Twine thickness (mm)	2.5	3.5	3.5	5.5
Cod-end circumference (mesh no.)	92	84	64	120

Sampling and analysis

The total catches from each gear were weighed and sorted to species level for *Nephrops* and commercial roundfish species after each haul. Total catch weights and the weights of random representative subsamples were recorded for each of these species to facilitate extrapolation of subsamples. Total catch weight of all species was also recorded to permit inclusion of this variable in subsequent analyses. *Nephrops* were measured to the nearest mm below (Carapace Length (CL)) and commercial roundfish were measured to the nearest cm below (Total Length (TL)). Digital callipers linked wirelessly to a Toughbook pc were used to measure a total of 9,972 *Nephrops* out of a total estimated catch of 180,523 individuals caught during the trial. Although sex sampling was not conducted, the length weight relationship used for males in Briggs *et al.* (1999), $X = 0.00032CL^{3.21}$, was used to obtain estimated *Nephrops* weights in relation to CL for comparative purposes in relation to cod-end mesh size. Plots and tables of raised weights in relation to *Nephrops* sizes and size grades were constructed. In the case of key whitefish species, length frequency plots and a table of the numbers and proportions of fish landed in relation to MCRS were produced. A recently developed mulitinomial modelling approach which facilitates comparison of catches in two or more gears (Browne *et al.,* 2015) was used to examine significant differences in the proportional catches of *Nephrops* across size classes between different gears. Explanatory variables included in the model were carapace length, net configuration and catch weight per cod-end, with random effects added to account for variability attributable to hauls. The predicted retention of *Nephrops* at size, and odds ratio plots were constructed to explore the effect of these variables on *Nephrops* catches across test gears.

Results

Nephrops

Raised weights of *Nephrops* in relation to different test gears and relevant size grades are outlined in Figure 3 and Table 3. A reduction of ~ 10% of undersize (< 25 mm CL) and tail grade (>= 25 & <= 31 mm) *Nephrops*, and an increase of 7% of whole grade *Nephrops* (> 31 mm CL) were observed in SMC45 compared with DMC70. Major losses of *Nephrops* occurred in SMC55 and SMC65 compared with DMC70 e.g. a 29% reduction in whole grade *Nephrops* in SMC55. Modelled proportions of retained *Nephrops* are outlined in Figure 4. Tighter confidence limits in the predicted proportions of *Nephrops* retained in SMC45 are consistent with the observed differences in catches between the two gears but overlap in the predicted trend and in the odds ratio plot shows that these differences are not statistically significant.

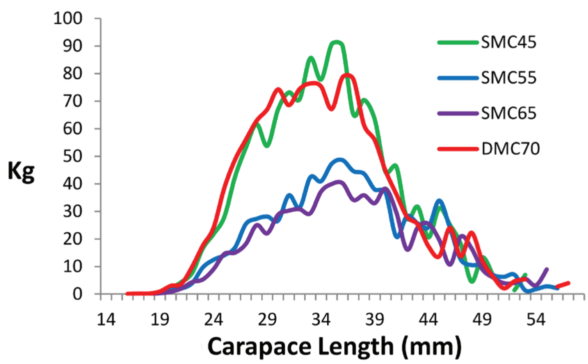
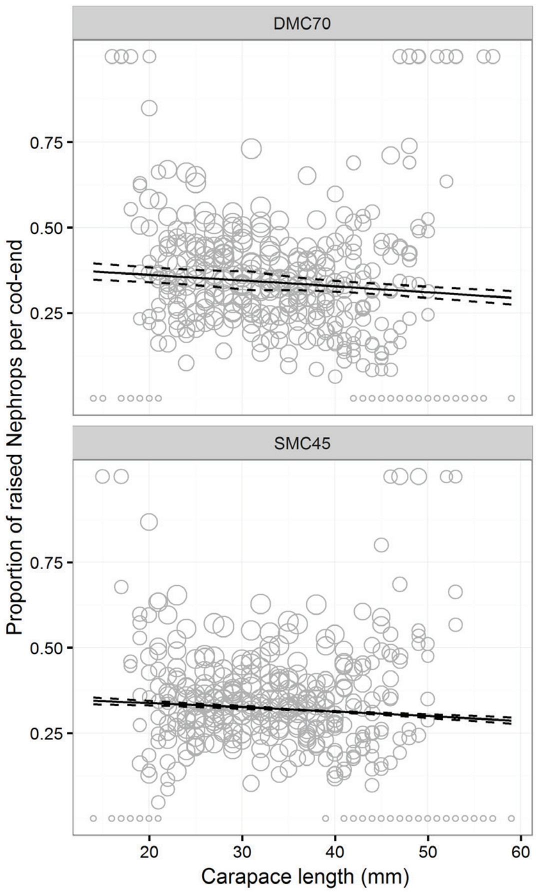


Figure 3. Plot of total raised weights of *Nephrops* per Carapace Length from four test gears: DMC70 = diamond mesh cod-end with 70 mm nominal mesh size; SMC45 – SMC65 = Square mesh cod-end with nominal mesh sizes of 45 – 65 mm.

Table 3. Estimated total weight (kg) of *Nephrops* size grades in relation to test gears

Test gear	DMC70	SMC45	SMC55	SMC65	Total
Total	1305	1325	797	702	4129
Δ DMC70 (%)		1	-39	-46	
< 25 mm CL	60	53	30	22	165
Δ DMC70 (%)		-10	-49	-63	
>= 25 mm CL	1246	1271	767	680	3963
Δ DMC70 (%)		2	-38	-45	
>= 25 & <= 31 mm (tails)	416	379	174	154	1124
Δ DMC70 (%)		-9	-58	-63	
> 31 mm CL (whole)	830	892	592	526	2840
Δ DMC70 (%)		7	-29	-37	
< 40 mm	1043	1047	542	456	3088
Δ DMC70 (%)		0	-48	-56	
>= 40 mm	262	278	255	245	1041
Δ DMC70 (%)		6	-3	-6	

Δ= Difference from



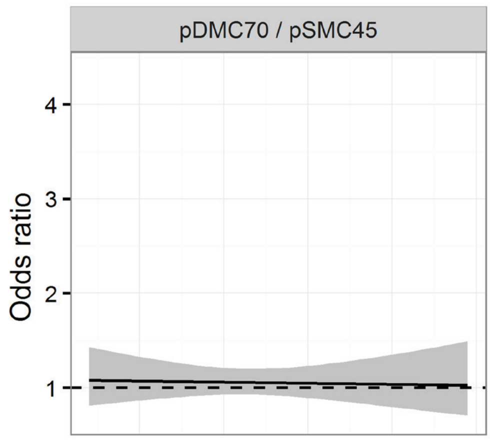


Figure 4. The panels on the left outline the overall predicted proportions of *Nephrops* at length in the 70 mm diamond mesh cod-end (DMC70) and 45 mm square mesh cod-end (SMC45). Solid and dashed lines represent the mean and 95% confidence intervals on the mean respectively. The panel on the right outlines the pairwise odds ratios for these gears obtained by setting cod-end mean weights and equal position effects. 95% confidence intervals are pointwise Bonferroni corrected for the comparison of the two gears.

Table 4. Estimated total counts of fish species in relation to MCRS

Test gear	DMC70	SMC45	SMC55	SMC65	Total
Whiting	1099	1151	639	481	3370
Δ DMC70 (%)		5	-42	-56	
Whiting < 27 cm	917	986	465	312	2680
Δ DMC70 (%)		8	-49	-66	
Whiting >= 27 cm	182	165	174	169	690
Δ DMC70 (%)		-9	-4	-7	
Haddock	7289	8569	4782	2883	23522
Δ DMC70 (%)		18	-34	-60	
Haddock < 30 cm	7126	8337	4596	2683	22742
Δ DMC70 (%)		17	-36	-62	

Δ = Difference from

Fish

Length frequency distributions and catches in relation to key fish species encountered in the trial are outlined in Figure 5 and Table 4. Increase in catches of < MCRS whiting and haddock of 8% and 17% respectively occurred in SMC45 compared with DMC70. Major reductions in catches of < MCRS whiting and haddock occurred in larger mesh square mesh cod-ends e.g. 66% reduction in < MCRS whiting in SM65 compared with DMC70. Marginal differences in catches of whiting > 27 cm (MCRS) occurred in square mesh cod-ends compared with DMC70 while limited occurrence of > MCRS haddock precluded detailed comparison of that component of the catch across test gears.

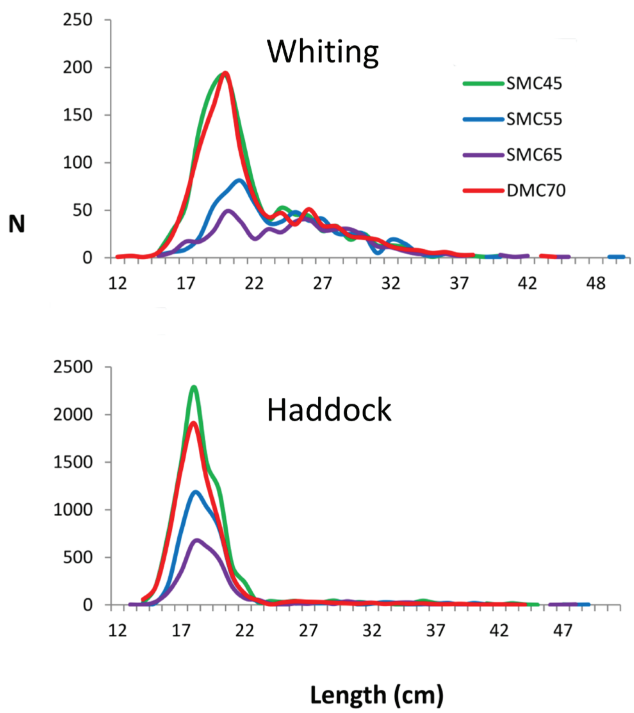


Figure 5. Length frequency distributions of key species retained from four test gears: DMC70 = diamond mesh cod-end with 70 mm nominal mesh size; SMC45 – SMC65 = Square mesh cod-end with nominal mesh sizes of 45 – 65 mm.

Discussion

With a moderate reduction of ~10% of < MCRS and tail grade *Nephrops*, and a 7% increase in whole grade *Nephrops*, SMC45 was the most promising of the square mesh cod-ends tested as a means to reduce quantities of small *Nephrops*. However, in terms of available options, SMC45 performed relatively poorly in comparison with an increase in diamond mesh cod-end from 70 to 80mm. The latter option achieved a 45% reduction in < MCRS *Nephrops* with additional benefits also observed in terms of reduced catches of mixed flatfish (Cosgrove *et al.,* 2015). Increased catches of undersize whiting (8%) and haddock (17%) observed in SMC45 suggest that that gear is less selective and would increase the risk of choking on such whitefish species under the landing obligation compared with DMC70. In addition, square mesh cod-ends are known to be less selective for flatfish species compared with diamond mesh cod-ends (Frandsen *et al.,* 2010). Hence, a small square mesh cod-end of 45 mm would lead to increased retention of low quota flatfish species such as plaice and sole compared with DMC70 which would further increase the likelihood of choking when these species are phased in under the landing obligation.

Major losses of whole *Nephrops* in SMC55 and SMC65 indicate that these square mesh sizes are not commercially viable as options to reduce catches of small *Nephrops* in Irish fisheries. However, they could be of benefit in fisheries with a higher MCRS for *Nephrops*. For example, we achieved a reduction in *Nephrops* < 40 mm of 48 % using the SM55 with a marginal loss in *Nephrops* > 40 mm of 3% which supports findings that square mesh cod-ends or panels can be of benefit in places such as the Skagerrak and Kattegat (ICES IIIa) where the MCRS is 40 mm (Frandsen *et al.,* 2010; Frandsen *et al.,* 2011).

Substantial reductions in catches of undersize whiting and haddock with marginal losses in marketable fish particularly in SMC65, suggest that types of mesh with increased openings such as square mesh or T90, have major potential to improve the selectivity of these species in trawl fisheries. In *Nephrops* fisheries, square mesh or T90 could be incorporated in the upper part of a twin cod-end set up which vertically separates *Nephrops* and whitefish using net panels (Pers. Comm. Mike Montgomerie) or rigid sorting grids (Karlsen *et al.,* 2015). Meshes with increased openings also have major potential to improve selectivity in trawl fisheries which predominantly target mixed whitefish species. Further work in this regard is planned in 2016.

Acknowledgements

BIM is grateful to the owners and crew of the MFV Our Lass II for their assistance with this trial. Thanks also to Coilin Minto and Brain Burke from GMIT for assistance with data analysis. This work was funded by the Irish Government and part-financed by the European Union through the EMFF Operational Programme 2014-2020 under the BIM Sustainable Fisheries Scheme.

References

Browne, D., Minto, C., Cosgrove, R., Burke, B., McDonald, D., Officer, R., and Keatinge, M. 2015. A general catch comparison method for multi-gear trials: application to a quad-rig trawling fishery for *Nephrops* (Accepted). ICES Journal of Marine Science.

Catchpole, T., and Revill, A. 2008. Gear technology in *Nephrops* trawl fisheries. Reviews in Fish Biology and Fisheries, 18: 17-31.

Cosgrove, R., Browne, D., and McDonald, D., 2016. Assessment of rigid sorting grids in an Irish quad-rig trawl fishery for *Nephrops*. Irish Sea Fisheries Board (BIM), Fisheries Conservation Report. 9 pp.

Cosgrove, R., Browne, D., McDonald, D., Curtin, R., and Keatinge, M., 2015. Assessment of an increase in cod-end mesh size in the Irish Sea *Nephrops* fishery. Irish Sea Fisheries Board (BIM), Fisheries Conservation Report. 16 pp.

Fonteyne, R., Buglioni, G., Leonori, I., and O'Neill, F. G. 2007. Review of mesh measurement methodologies. Fisheries research, 85: 279-284.

Frandsen, R. P., Herrmann, B., Madsen, N., and Krag, L. A. 2011. Development of a codend concept to improve size selectivity of *Nephrops (Nephrops norvegicus)* in a multi-species fishery. Fisheries research, 111: 116-126.

Frandsen, R. P., Madsen, N., and Krag, L. A. 2010. Selectivity and escapement behaviour of five commercial fishery species in standard square-and diamond-mesh codends. ICES Journal of Marine Science, 67: 1721-1731.

Karlsen, J. D., Krag, L. A., Albertsen, C. M., and Frandsen, R. P. 2015. From Fishing to Fish Processing: Separation of Fish from Crustaceans in the Norway Lobster-Directed Multispecies Trawl Fishery Improves Seafood Quality. Plos One, 10: e0140864.

MI. 2015. The Stock Book 2015: Annual Review of Fish Stocks in 2015 with Management Advice for 2016. Galway, Ireland, 624 pp.

Bord Iascaigh Mhara
Irish Sea Fisheries Board

Fisheries Development Division,
Bord Iascaigh Mhara,
P.O. Box 12,
Crofton Road,
Dun Laoghaire,
Co. Dublin,
Ireland.
Tel: +353 1 2144 230
Fax: +353 1 2300 564
Web: www.bim.ie