Bord Iascaigh Mhara
Irish Sea Fisheries Board

Assessment of Diamond Cod-end Mesh Size on Catch Composition in a Celtic Sea *Nephrops* Trawl Fishery

Ronán Cosgrove, Daragh Browne, Daniel McDonald, Peter Tyndall, BIM

Key Findings

- **The 100 mm cod-end outperformed other smaller mesh cod-ends in terms of reducing landings of undersize *Nephrops*.**
- **The effective discard rate of below minimum landing size *Nephrops* in the 100 mm cod-end was 64% lower than the discard rate in the 70 mm cod-end.**
- **No significant difference was observed in quantities of above minimum landing size *Nephrops* across cod-ends with different mesh sizes.**
- **Substantial reductions in whiting, moderate reductions in haddock and small reductions in cod discards were observed in larger cod-end mesh sizes.**
- **The performance of the 100 mm diamond cod-end mesh should be further assessed under normal commercial fishing conditions, in a range of different trawl rig configurations.**

MFV Celtic Warrior II (Photo courtesy of William Power)

February 2015

1. Introduction

The new Common Fisheries Policy[1] is likely to incentivise uptake of technical solutions to deal with the impending requirement to land catches which were formerly discarded. Recent studies carried out by BIM have demonstrated the potential benefits of quad-rig configurations and large meshed square mesh panels in significantly reducing discards of cod, haddock and whiting in *Nephrops* trawl fisheries (BIM, 2014a; BIM, 2014b; Revill *et al*., 2009)

However, issues in relation to discarding of small *Nephrops* persist: Discard rates by weight of small *Nephrops* onboard Irish trawlers range from 9% in the Smalls in the Celtic Sea, to 18% in the Eastern Irish Sea (MI, 2013). A range of factors including time, area, market and handling requirements, mesh size and shape, catch size, trawl-rig configuration eg. quad v twin-rig, and presence of lifting bags are known to affect *Nephrops* discard rates. From January 2016, landings of small *Nephrops* will likely be counted against quota allowances, potentially resulting in major economic losses in the *Nephrops* fishery.

A variety of potential solutions including increased cod-end mesh size, sorting grids, and square mesh cod-ends or panels have been tested in a range of different fisheries (eg. Briggs, 1986; Catchpole and Revill, 2008; Graham and Ferro, 2004; ICES, 2007; Sala *et al*., 2015). It is clear from these studies that there are pros and cons to each of these measures depending on the fishery in question and the desired catch composition. Ireland's *Nephrops* trawl fisheries are diverse in nature with a variety of trawl configurations utilised and species targeted, and it is unlikely that any one potential solution will work in all cases.

BIM are, therefore, currently engaged in a programme of research to assess a range of technical solutions in relation to *Nephrops* discard rates. In this study, we aim to compare the catches of above and below minimum landing size *Nephrops* in a range of diamond cod-end mesh sizes in a *Nephrops* trawl fishery. Effects of cod-end mesh size on catches of fish species are also examined.

1 Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy, amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and repealing Council Regulations (EC) No 2371/2002 and (EC) No 639/2004 and Council Decision 2004/585/EC.

2. Methods

2.1 Fishing operations

Table 1. Gear specification

Trawl type	Quad-rig
Trawl Manufacturer	Pepe Trawls
Head-line Length (m)	33
Foot-line Length (m)	38
Sweep Length (m)	70
Warp Diameter (mm)	20
Door Spread (m)	97
Door Type	Tyboron
Door Weight (kg)	500
Clump Weight (kg)	500
Clump Type	Roller

The trial was carried out onboard the MFV Celtic Warrior II (DA8), a 25 m trawler from Clogherhead, County Louth. Fishing gear consisted of a Quad–rig trawl using a triple warp and centre clump arrangement. Test cod-ends consisted of 70, 80, 90, and 100 mm diamond mesh cod-ends, constructed with single 5.5 mm twine. Mean omega mesh gauge measurements in relation to these cod-ends were 75.2, 81.9, 93.7 and 106.3 mm respectively, although the previous mesh size descriptors are used for the purposes of this report. The mesh size in the top and bottom panels behind the head-line and in the lower wing ends was 80 mm, while meshes in the upper wing ends were 120 mm. The vessel employed 120 mm knotless nylon square mesh panels located 9 - 12 m from the cod-line in accordance with technical conservation requirements.

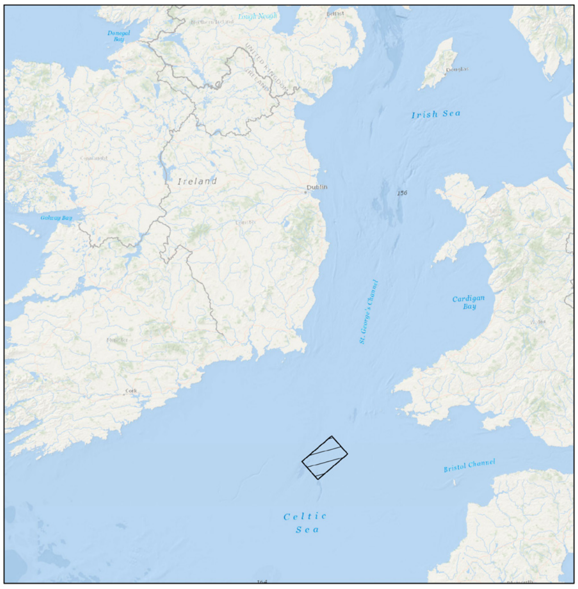

Figure 1. Gear trial location (striped area)

The trial took place on the Smalls fishing grounds in the Eastern Celtic Sea in ICES Division VIIg (Figure 1). A total of 27 hauls were carried out over a 5 day period commencing 19th July 2014. Haul duration, towing speed and depth of ground fished averaged one hour, 3 knots and 106 m respectively. Haul duration was kept short in order to facilitate effective sampling across the four test cod-ends.

2.2 Sampling

Total catches were separated to species level and weighed to the nearest kg. All commercial fish species were measured to the nearest cm below. Total catches of *Nephrops* were weighed and random subsamples were chosen from each test gear at haul level. Subsamples were weighed and measured to the nearest mm below (carapace length (CL)). Digital calipers linked wirelessly to a toughbook pc were used to measure a total of 49,052 *Nephrops* which were raised to a total catch of 267,017 individuals during the trial.

2.3 Analysis

Length frequency charts were constructed for the main commercial species. *Nephrops* data were categorised in relation to the minimum landing size (MLS) of >= 25 mm carapace length as >= MLS or < MLS *Nephrops*. Mean *Nephrops* CL and catch weight were obtained for each test cod-end. Mixed Effects Models (MEM) were used to analyse potential differences in sizes and catch weights of *Nephrops* across test gears. A mixed effects model is any model that has a mix of random and fixed effects (Gelman, 2005; Thorson and Minto, 2014). In this case, we assume that observed hauls are essentially a random sample from a very large population of potential hauls whereas the four different mesh sizes tested within each haul correspond to a fixed effect.

Haul duration under normal commercial fishing conditions would typically be around 4 hours compared to one hour in this study. Increased haul duration should result in larger catches of all species. The opening of diamond mesh used in cod-ends is known to be affected by increased catch accumulation (Herrmann et al., 2006; Robertson and Stewart, 1988). We tested the potential effect of increased mesh opening on *Nephrops* catches in this trial by plotting scatterplots of categorised *Nephrops* catches in 70 and 100 mm cod-ends with the total catches (fish and *Nephrops*) in these cod-ends. Next, General Liner Model (GLM) runs tested differences in correlations. Categorised *Nephrops* catch weight was included as the dependent variable, with the covariate, total catch in each test cod end, and the mesh size factor included as independent variables. An interaction between total catch weight and mesh size was included to test if the slopes of observed regression lines were significantly different. All statistical analyses were carried out using R version 3.1.2 (R_Core_Team, 2013).

3. Results

3.1 *Nephrops*

A length frequency distribution of the total *Nephrops* catch is outlined in Figure 2. Other than a slightly increased catch around 30 mm CL in the 70 mm cod-end, little difference in the size distribution of *Nephrops* >= MLS occurred. The main difference occurred for < MLS *Nephrops* where the larger 90 and 100 mm cod-ends caught less *Nephrops* than the 70 and 80 mm cod-ends.

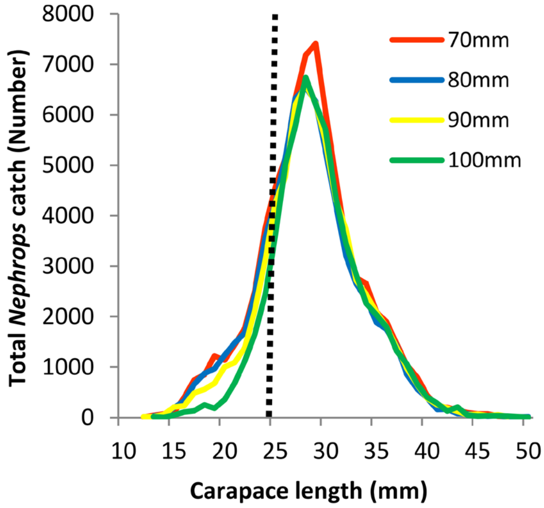

Figure 2. *Nephrops* Length frequency distributions from the four test cod-ends (Dashed line indicates MLS)

This finding is supported in Table 2. where substantial differences in the proportions of < MLS *Nephrops* in relation to different cod-end mesh sizes are outlined. For example, 4.41 % of the total *Nephrops* catch were < MLS in the 100 mm compared to 7.21 % in the 70 mm cod-end. Under current legal requirements, this equates to a difference in discarding rates of < MLS *Nephrops* of 63.53 % between these mesh sizes. Results of the MEM on *Nephrops* catch weights showed a significant difference in < MLS (P < 0.001) and no significant difference for >= MLS (P = 0.131) *Nephrops* across mesh sizes.

Table 2. Total *Nephrops* catch weights and proportion of < MLS and >= MLS *Nephrops* in total catches in relation to cod-end mesh sizes

	< MLS		>=MLS	
Mesh size (mm)	Weight (kg)	∝ Total *Nephrops* catch (%)	Weight (kg)	∝ Total *Nephrops* catch (%)
70	87	7.21	1120	92.79
80	84	7.71	1006	92.29
90	70	6.27	1046	93.73
100	48	4.41	1041	95.59

Mean sizes of categorised *Nephrops* differed little across test cod-ends (Table 3). Results of the MEM showed no significant differences in sizes of >= MLS *Nephrops* (P = 0.81). The size of < MLS *Nephrops* was significantly different (P <0.01) when all mesh sizes were included but not when the 100 mm mesh data were excluded from the model (P = 0.92). This indicates that the 100 mm mesh cod-end retained significantly larger < MLS *Nephrops* than other test cod-ends.

Table 3. *Nephrops* Carapace Length (CL) in relation to cod-end mesh size

	< MLS		>= MLS	
Mesh size (mm)	Mean CL (mm)	SD	Mean CL (mm)	SD
70	19.5	3.1	34.6	6.3
80	19.5	3.1	34.2	6.1
90	19.4	3.2	34.5	6.1
100	20.3	2.8	34.3	6.5

Scatterplots of categorised *Nephrops* catches and total catches in 70 and 100 mm cod-ends are outlined in Figure 3. No significant difference in the slopes of the regression lines was observed for >= MLS *Nephrops* (GLM, P = 0.89). However, a significant difference was observed between the slopes of regression lines in the case of < MLS *Nephrops* (GLM, P < 0.01). This confirms that within the range of observed catches, no difference in the relationships between catch rates of >= MLS *Nephrops* and total catch rates occurred in 70 and 100 mm cod-ends. The 100 mm did, however, catch significantly less < MLS *Nephrops* compared to the 70 mm cod-end as total catches increased.

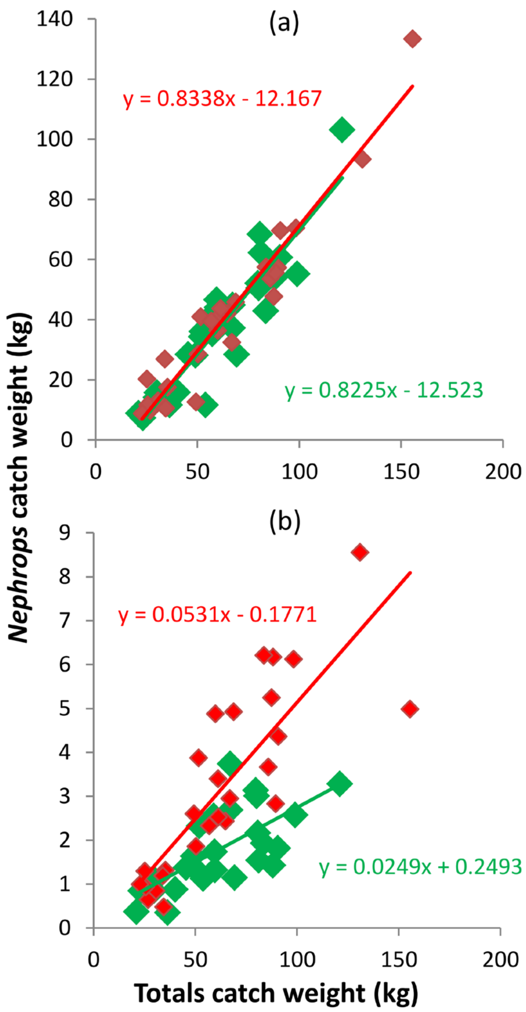

Figure 3. *Nephrops* catch weights plotted against total catch weight (all species) for 70 mm mesh (small red diamonds and red lines) and 100 mm mesh (large green diamonds and green lines) for (a) All, (b) >= MLS, and (c) < MLS *Nephrops*

3.2 Fish

Total catch weights of the main commercial species caught during the trial are outlined in Table 4. While no major trends are apparent in the total catch data, proportionally less < MLS whiting (< 27 cm), haddock (< 30 cm) and cod (< 35 cm) were retained in larger meshed cod-ends (Table 5 and Figure 4).

Table 4. Total Fish catch weights (kg) in relation to cod-end mesh size

	Mesh size (mm)			
Species	**70**	**80**	**90**	**100**
Whiting	83	152	72	103
Cod	77	55	48	85
Monk	11	12	26	39
Haddock	17	24	21	16
Flatfish	15	7	17	13
Ling	14	6	8	8
Hake	7	7	2	8

Just 19 % of the whiting retained in the 100 mm cod-end were < MLS compared to 34 % in the 70 mm cod-end. Also, 59 % of the haddock catch were < MLS in the 100 mm compared to 78 % in the 70 mm cod-end. A smaller reduction in < MLS cod was evident (51 % in the 100 mm and 59 % in the 70 mm cod-end). However, the mean size of all cod retained during the trial (38.6 cm) was higher than whiting (29.2 cm) and haddock (28.9 cm). The minimum size of cod retained during the trial (24 cm) was also much higher than whiting and haddock, and hence, these larger cod were likely less capable of escaping through the larger meshes.

Table 5. Proportion of undersize fish (%) retained in relation to cod-end mesh size

	Mesh size (mm)			
Species	**70**	**80**	**90**	**100**
Whiting	34	25	23	19
Cod	59	53	51	51
Haddock	78	78	73	59

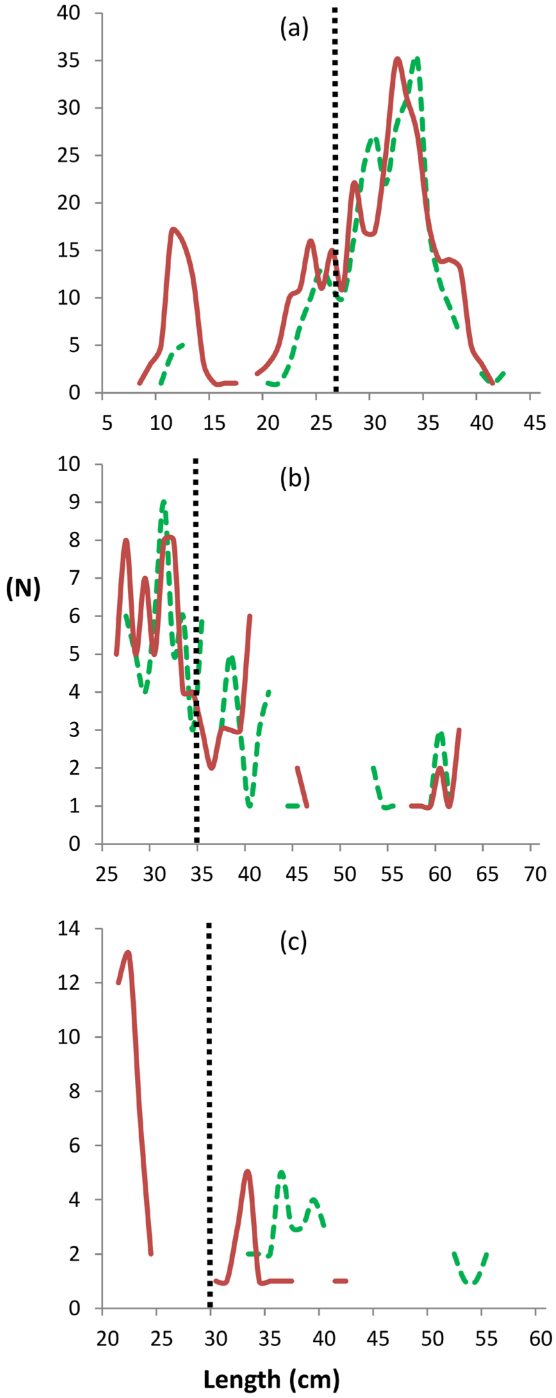

Figure 4. (a) Whiting, (b) Cod and (c) Haddock length frequency distributions from 70 mm (red line) and 100 mm cod-ends (green dashed line). The straight dashed line indicates MLS.

4. Discussion

The results of this study are generally in agreement with available literature on the effects of diamond cod-end mesh size on catch composition. In a general review of this issue, Catchpole and Revill (2008) describe how different diamond cod-end mesh sizes do not generally affect the selection range[2], but do affect the quantities of *Nephrops* retained. This corroborates our results of significant reductions in quantities of undersize *Nephrops* in 90 and 100 mm compared to 70 and 80 mm cod-ends, but less clear differences in the sizes of *Nephrops* retained across mesh sizes. The authors also describe how increases in diamond cod-end mesh size are usually associated with an improvement in selectivity of whiting and haddock, supporting our findings with these species.

The 100 mm cod-end out-performed the other test cod-ends in terms of reducing landings of undersize *Nephrops* with an effective discard rate ~ 64 % lower than the discard rate in the 70 mm cod-end. Although statistically insignificant, the 100 mm mesh was observed to retain slightly lower quantities of >= MLS *Nephrops* compared to the 70 mm cod-end. It is likely, however, that any reduction in marketable *Nephrops* in the 100 mm cod-end, would be at least partially offset by the benefits of catching less undersize *Nephrops*: Under the Landing Obligation, small *Nephrops* will likely be counted against quota allowances. Under this scenario it would take marginally longer to catch the *Nephrops* quota using the 100 mm cod-end, but more marketable *Nephrops* of higher economic value would be landed as part of that allowance.

The significantly larger size of < MLS *Nephrops* retained by the 100 mm compared to the other cod-ends was likely related to *Nephrops* morphology. *Nephrops* have an array of appendages that get caught in the meshes and other organisms in the trawl, causing the retention of a wide size range of animals (Briggs, 1986; Frandsen et al., 2010). However, above 90 mm diamond cod-end mesh size, *Nephrops* can escape from a trawl and the selection is size dependent dependent (Catchpole and Revill, 2008). This suggests that smaller Nephrops were more likely to fall through the 100 mm mesh leading to a slight increase in their mean size.

2 The length range from L25 % to L75 % (mean lengths at which fish have 25 % and 75 % of being captured)

Our analysis of the effect of total catch quantities on *Nephrops* catch rates also supports this size dependent selection of *Nephrops* in larger diamond cod-end mesh sizes. Potentially related to larger mesh openings, higher total catches did not affect catches of large *Nephrops* but were more likely to be associated with higher retention of small Nephrops in the 70 compared to the 100 mm cod-end.

One caveat with this analysis is that the maximum catches observed in this study were small (generally < 80 kg, Figure 3). A previous attempt to simulate the effects of total catch size on *Nephrops* catch rates focussed on larger total catches of 200 to 400 kg in single and twin-rig trawls (ICES, 2007). Quantities of whitefish species retained in such rigs are generally substantially higher than quad-rig trawls. However, quad-rigs have been demonstrated to catch ~ 50 to 100 % more *Nephrops* than twin-rig trawls (BIM, 2014b; Revill et al., 2009). This could result in relatively high total catches in quad-rig trawls under normal fishing conditions which could potentially impact *Nephrops* selectivity.

5. Conclusion

The 100 mm diamond mesh cod-end has major potential to substantially reduce catches of below minimum landing size *Nephrops* and whitefish species in quad-rig trawls. Increasing cod-end mesh size is probably the simplest technical measure that can be adopted for this purpose and can easily be combined with other selective measures such as the 300 mm square mesh panel (BIM, 2014a) without compromising the geometry or overall performance of the net. The combination of these two measures has major potential to improve sustainability and meet new catch requirements under the Landing Obligation in trawl fisheries which principally target *Nephrops*.

Uncertainty regarding the effect of larger total catch quantities on *Nephrops* selectivity, suggests that the 100 mm diamond cod-end mesh should be further tested under normal commercial fishing conditions onboard a quad-rig trawler. This type of assessment should also be extended to twin and single-rig trawls to assess the potential benefits of this simple measure in a range of *Nephrops* fisheries.

6. References

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