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THE EFFECTS OF SQUARE MESH PANEL MESH SIZE AND POSITION ON THE SELECTIVITY OF HIGH AND LOW POWERED *NEPHROPS* TRAWLERS



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SISP PROJECT NUMBER: 08/08

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SUMMARY

During 2008 experiments were conducted to improve the selectivity of round-fish from gears used by Scottish *Nephrops* trawlers targeting North Sea grounds. The main aims of these selectivity trials were to assess the differences in performance between square mesh panels (SMPs) placed in the straight extension or in the taper, between 110 and 120 mm SMPs, and between gears towed by vessels of different horsepower. Results demonstrated that compared to an 80 mm codend with no SMP, all cases with an SMP improved the selection of haddock and whiting. Increasing the mesh size of the SMP from 110 mm to 120 mm in the straight extension of the net rather than the tapered section improved the selection of whiting and was sometimes shown to improve the selection of haddock. Catches of haddock or whiting were not affected by the power of the vessel.

INTRODUCTION

Under the 2008 EU management measures the Scottish Government has developed a system of conservation credits that rewards vessels with additional days at sea. One way to earn rewards in the Scottish *Nephrops* fisheries is to use more selective gear to reduce the mortality of round-fish, in particular whiting and cod. These fisheries typically use mesh sizes between 70 and 99mm which are sub-optimal for exploiting these species.

The industry and Fisheries Research Services discussed practical and effective technical solutions to discarding problems in Scottish mixed fisheries in a series of meetings in January and February 2008 (*Park et al.*, 2008). Following these discussions, ideas were put forward by industry for funding under the 2nd call for proposals under the Scottish Industry/Science Partnership.

North Sea skippers proposed a study to measure the selectivity of 110mm and 120mm square mesh panels (SMPs) of 3m length in 80mm codends with the aim of improving whitefish selectivity in *Nephrops* trawls. The position of the SMP was the focus of the study. Previous trials (*Kynoch et al.*, 2008b) with 5m long 120mm panels within 15m of the codend in the straight extension had shown significant reductions in haddock and whiting discards. During these industry meetings it became apparent that most skippers now rig their SMP's into the end of the trawls tapered section. This change in position was partly due to concerns about the potential for panels positioned in the straight extension to turn upside down, causing *Nephrops* to be lost. It was further suggested that panels positioned in the taper may be more effective due to possible water turbulence building up at the start of the straight extension. Therefore, it was agreed that the primary objective of this study would be to assess the selectivity of panels at this new position as little data has been collected of their performance in the tapered section. Another key objective was to assess if SMP's are more selective on low-powered vessels compared to high-powered vessels.

Two commercial charter trials were carried out in April and August 2008. The first trials were for 15 days on the high-powered vessel and the second for 12 days on a low-powered vessel. The first trials were reported in *Kynoch et al.* (2008a). This report considers the data from both trials.

VESSELS AND FISHING GROUNDS

The *Nephrops* twin trawl Zenith (BF106), the high-powered (500kW) vessel, was chartered for the first trials, which were carried out (14-28 April, 2008) on North Sea commercial *Nephrops* grounds at the NE Holes, Bressay ground, Skate Hole and the Moray Firth. The Bountiful (BF79), the low-powered (298kW) vessel, was chartered (4-16 August, 2008) for the second trials, which targeted commercial *Nephrops* grounds approximately 35niles east of Fraserburgh close to the Buzzard platform and in the Moray Firth.

FISHING GEAR

The Zenith used her own commercial twin MKII Faithlie prawn disc trawls, each with a 492 x 80mm mesh fishing circle. The Zenith usually fishes with these trawls from April through the summer months. Overall ground gear length was 61m and consisted of 200mm diameter discs in the centre, reducing to 150mm at the wings. The trawls were fished with a three-warp towing system with a 900kg roller clump centre weight and spread using 600kg Perfect spherical otterboards. The wire rig consisted of 128m combination sweep, 36.6m of 50mm rubber sweep and 9.1m double bridles (top – combination & lower – rubber leg) giving an overall sweepline length of 173.7m.

The Bountiful used her own commercial twin Pisces prawn disc trawls, each with a 520 x 80mm mesh fishing circle. Overall ground gear length was 39.6m and consisted of 200mm diameter discs in the centre, reducing to 150mm at the wings. The trawls were fished with a three-warp system with a 650kg chain centre clump weight and spread using 600kg Dunbar Vee otterboards. The wire rig consisted of 73.2m combination sweep, 36.6m of 50mm rubber sweep and 2.7m double bridles (top – combination & lower – rubber leg) giving an overall sweepline length of 112.5m.

Although the trawls on Zenith are larger than those on Bountiful, the design of the two gears is similar. Both gears are low headline trawls and the last 50 meshes of the tapered sections incorporate similar shallow cutting rates, giving a small decrease in width (of 1 mesh per side) for every 5 meshes in length. To accommodate the shallower taper, the main body of these trawls are longer (about 50 meshes) than traditional *Nephrops* trawls, which traditionally incorporate a belly section length of 200 meshes. Due to this extra length in the tapered section, the length of the straight extension is usually shortened to allow the net to fit onto the net drum. Therefore for this design of trawl the SMP is incorporated into the end of the tapered section so that its rear row of mesh bars is still 15m from the codline, the maximum distance permitted under current legislation. Rigging the SMP into the taper and not the leading edge of the straight extension provides a position that is not susceptible to twisting and keeps the panel on the top sheet.

EXPERIMENTAL TEST CASES

During the Zenith trials three different 3m long SMP configurations were tested which provided sufficient data for subsequent analysis, all with an 80mm (nominal) diamond mesh codend. The 110mm (nominal) mesh size panel was tested in two positions; tapered section

and straight extension but the 120mm (nominal) panel was only tested in the tapered section (Figure 1). All panels were made from 6mm diameter knotless Ultra-cross netting and positioned at 15-18m from the codline. The 80mm codend was constructed from 4mm (nominal) single compact twine and had 108 open meshes around its circumference. The codend was fitted with a 160mm (nominal) diamond mesh lifting bag constructed from 5mm double PE twine with 54 open meshes round the circumference and 2.5m long. The codend was supplied off the shelf by a local net maker for vessels targeting North Sea offshore *Nephrops* grounds. During the last 3 hauls the codend was fished without any SMP to collect data on the selectivity performance of this type of codend by itself. For convenience, these test cases are labelled as 'Z 110 T', 'Z 120 T', 'Z 110 E' and 'no panel' respectively.

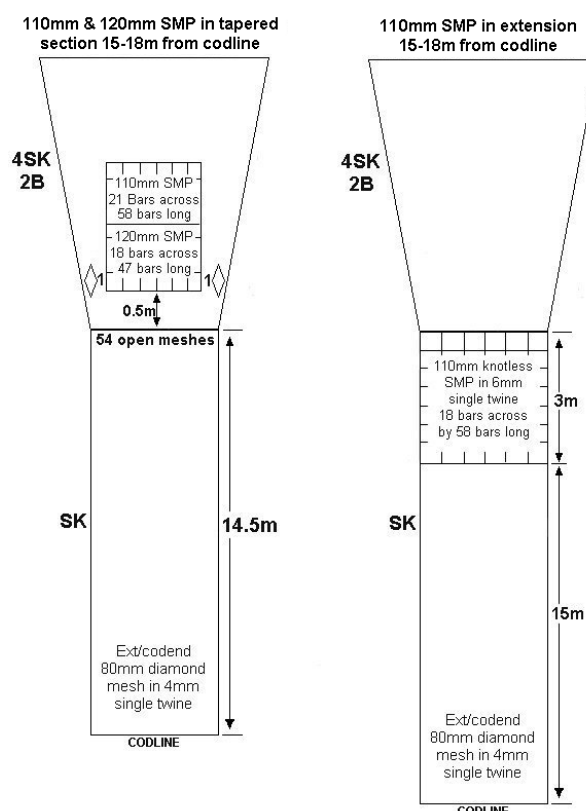


Figure 1: SMP test cases used during Zenith trials.

During the trials on Bountiful the same 110mm and 120mm SMPs were tested at two different positions; at the end of the tapered section and at the start of the straight extension. The panels were rigged into the tapered section at the same position used by the skipper for his own panels when commercial fishing. The rear edge of each SMP was 2.5 meshes ahead of the taper/extension join and 3 diamond mesh in from each selvedge. When rigged into the straight extension the leading edge of each panel was attached to the last mesh of the tapered section (Figure 2). During both cruises the joining ratios (diamond to square mesh) for the 110mm and 120mm SMPs were approximately 3:1 and 4:1 respectively. For convenience these test cases are labelled as 'B 110 T', 'B 120 T', 'B 110 E' and 'B 120 E' respectively. All the SMP were fished with the same 80mm diamond mesh codend as used during the Zenith trials. For hauls 16, 17 and 18 both nets were fished with 40mm codends to check whether the two trawls were fishing equally. This test case is labelled 'small mesh'.

FISHING TRIALS PROCEDURE

During the Zenith trials the tow duration for most hauls was between 3 and 4 hours and towing speed over the ground varied from 2.4 to 2.7 knots, the vessels normal range when fishing commercially for *Nephrops*. On Bountiful haul duration ranged from 2.3 to 3 hours and towing speed varied from 1.9 to 2.6 knots, again the vessels normal commercial range but overall slightly slower than Zenith. Net geometry was monitored on both cruises using a Notus net monitoring system. Weather conditions were similar throughout both trials, relatively calm with wind strength ranging from force 2 to 5.

The same experimental protocol was followed during both cruises. During each haul, the starboard net fished the test configuration and the port net fished a 40 mm diamond mesh control codend to sample the total population on the grounds. As standard practice, the test net was always brought onboard first, minimising the risk of wash-out and hence fish escapes at the surface. The catch was then sorted into baskets by species component and then weighed to give total catch weight. For small catches all haddock, whiting and cod were measured (to the nearest centimetre below). For larger fish catches and the majority of *Nephrops* catches a random sub-sample was measured and then raised to the total weight caught. To minimise cross-tidal effects such as asymmetry of the twin trawl system, tows were conducted either directly against or with the tide. A full haul summary for each cruise is given in Tables 2 and 3.

The effects of square mesh panel mesh size and position on the selectivity of high and low powered *Nephrops* trawlers

TABLE 2

Haul summary for Zenith cruise

Haul number	Test gear	Haul duration (Hrs)	Area fished	Weather conditions	Water depth (m)	Warp shot (m)	Mean speed over ground (kts)
Z08/1	110 SMP @ 3.7m from end taper	3.0	Moray Firth	SE 2	101	274	2.5
Z08/2	110 SMP @ 3.7m from end taper	2.5	Moray Firth	SE 2	97	275	2.6
Z08/3	110 SMP @ 0.5m from end taper (Z110T)	3.0	Long Hole	NE 2	135	366	2.6
Z08/4	110 SMP @ 0.5m from end taper (Z110T)	4.0	Long Hole	NE 2	135	366	2.6
Z08/5	120 SMP @ 0.5m from end taper (Z110T)	4.0	Long Hole	NE 2	133	366	2.6
Z08/6	120 SMP @ 0.5m from end taper (Z120T)	4.0	Long Hole	NE 2	135	366	2.6
Z08/7	120 SMP @ 0.5m from end taper (Z120T)	4.0	Long Hole	NE 2	135	366	2.6
Z08/8	110 SMP @ 0.5m from end taper (Z110T)	3.0	Bressay	NE 3	120	320	2.4
Z08/9	110 SMP @ 0.5m from end taper (Z110T)	3.0	Bressay	NE 3	119	320	2.6
Z08/10	110 SMP @ 0.5m from end taper (Z110T)	3.0	Bressay	NE 4	119	320	2.6
Z08/11	120 SMP @ 0.5m from end taper (Z120T)	3.0	Bressay	NNE 4	121	320	2.5
Z08/12	120 SMP @ 0.5m from end taper (Z120T)	3.0	Bressay	NE 4	121	320	2.6
Z08/13	120 SMP @ 0.5m from end taper (Z120T)	3.0	Bressay	NE 4	122	320	2.5
Z08/15	120 SMP @ 0.5m from end taper (Z120T)	2.0	Bressay	NE 2	118	320	2.6
Z08/16	120 SMP @ 0.5m from end taper (Z120T)	3.0	Bressay	N 1	120	320	2.5
Z08/17	120 SMP @ 0.5m from end taper (Z120T)	3.0	Bressay	N 2	120	320	2.5
Z08/18	120 SMP @ 0.5m from end taper (Z120T)	3.0	Bressay	N 2	120	320	2.6
Z08/19	110 SMP @ 0.5m from end taper (Z110T)	3.0	Bressay	NE 2	123	320	2.5
Z08/20	110 SMP @ 0.5m from end taper (Z110T)	3.0	Bressay	N 2	123	320	2.7
Z08/21	110 SMP @ 0.5m from end taper (Z110T)	3.0	Bressay	NE 2	119	320	2.6
Z08/22	110 SMP in straight extension (Z110E)	3.0	Moray Firth	SE 4	100	274	2.4
Z08/23	110 SMP in straight extension (Z110E)	3.0	Skate Hole	SE 3	112	320	2.7
Z08/24	110 SMP in straight extension (Z110E)	3.0	Skate Hole	SE 3	112	320	2.5
Z08/25	110 SMP in straight extension (Z110E)	3.5	Skate Hole	SE 3	113	320	2.5
Z08/26	110 SMP in straight extension (Z110E)	3.0	H&I Hole	S 2	121	320	2.6
Z08/27	110 SMP in straight extension (Z110E)	3.0	H&I Hole	S 2	121	320	2.5
Z08/28	110 SMP in straight extension (Z110E)	3.0	H&I Hole	S 2	122	320	2.5
Z08/29	110 SMP in straight extension (Z110E)	3.0	H&I Hole	S 2	128	320	2.6
Z08/30	110 SMP in straight extension (Z110E)	3.0	H&I Hole	S 5	122	320	2.6
Z08/31	80mm codend no SMP (No panel)	2.0	H&I Hole	S 4	128	320	2.6
Z08/32	80mm codend no SMP (No panel)	2.0	H&I Hole	S 5	128	320	2.5
Z08/33	80mm codend no SMP (No panel)	1.5	Moray Firth	S 2	101	274	2.6

TABLE 3

Haul summary table for Bountiful cruise

Haul number	Test gear	Haul duration (Hrs)	Area fished	Weather conditions	Water depth (m)	Warp shot (m)	Mean speed over ground (kts)
B08/1	110 SMP end taper (B110T)	3.0	Buzzard	Calm	108	270	2.6
B08/2	110 SMP end taper (B110T)	3.0	Buzzard	Calm	108	270	2.6
B08/3	110 SMP end taper (B110T)	3.0	Buzzard	Calm	108	270	2.4
B08/4	110 SMP end taper (B110T)	3.0	Buzzard	N 1	108	290	2.5
B08/5	110 SMP end taper (B110T)	3.0	Buzzard	N 2	108	270	2.3
B08/6	110 SMP end taper (B110T)	3.0	Buzzard	N 2	110	270	1.9
B08/7	110 SMP end taper (B110T)	2.75	Buzzard	N 2	108	270	2.4
B08/8	120 SMP end taper (B120T)	3.0	Buzzard	N 2	104	270	2.3
B08/10	120 SMP end taper (B120T)	2.7	Buzzard	NNE 3	110	270	2.5
B08/11	120 SMP end taper (B120T)	3.0	Buzzard	NNE 4	106	270	2.0
B08/12	120 SMP end taper (B120T)	3.0	Buzzard	NW 4	106	270	2.5
B08/13	120 SMP end taper (B120T)	3.0	Buzzard	N 4	106	270	2.4
B08/14	120 SMP end taper (B120T)	3.0	Buzzard	NNE 3	106	270	2.5
B08/15	120 SMP end taper (B120T)	3.0	Buzzard	N 1	106	270	2.1
B08/16	40mm codends both trawls (Small mesh)	1.0	Moray Firth	W 1	121	315	2.5
B08/17	40mm codends both trawls (Small mesh)	1.0	Moray Firth	W 2	113	315	2.5
B08/18	40mm codends both trawls (Small mesh)	1.0	Moray Firth	W 1	137	315	2.5
B08/19	120 SMP end taper (B120T)	3.0	Buzzard	SSE 2	106	270	2.3
B08/20	120 SMP end taper (B120T)	3.0	Buzzard	SE 2	106	270	2.5
B08/21	120 SMP end taper (B120T)	3.0	Buzzard	E 3	108	270	2.5
B08/22	110 SMP in straight extension (B110E)	3.0	Buzzard	E 3	108	270	2.5
B08/23	110 SMP in straight extension (B110E)	3.0	Buzzard	NNW 4	108	270	2.2
B08/24	110 SMP in straight extension (B110E)	3.0	Buzzard	N 4-5	108	270	2.6
B08/25	110 SMP in straight extension (B110E)	3.0	Buzzard	N 3	101	270	1.9
B08/26	110 SMP in straight extension (B110E)	2.6	Buzzard	N 1	94	270	2.3
B08/27	110 SMP in straight extension (B110E)	2.5	Buzzard	N 1	101	270	2.4
B08/28	120 SMP in straight extension (B120E)	2.5	Buzzard	S 2	101	270	2.3
B08/29	120 SMP in straight extension (B120E)	2.5	Buzzard	S 2	101	270	2.3
B08/30	120 SMP in straight extension (B120E)	2.5	Buzzard	S 2	99	270	2.3
B08/31	120 SMP in straight extension (B120E)	2.5	Buzzard	S 1	99	270	2.6
B08/32	120 SMP in straight extension (B120E)	2.5	Moray Firth	SSE 2	128	315	2.2

RESULTS

During the Zenith cruise, 33 hauls were completed but haul 14 was discounted as the gear came fast on the seabed. Hauls 1 and 2 were also discounted as few haddock escaped and the rigging was subsequently altered (See *Kynoch et al.*, 2008). A total of 30 valid hauls were completed with the other test cases (Table 4).

During the Bountiful cruise, 32 hauls were completed but haul 9 was discounted due to the port trawl becoming fouled. A total of 28 hauls were completed with the 4 test cases (Table 4). The results up to haul 15 indicated that the starboard trawl with the test cases was consistently catching slightly more *Nephrops* than the port control trawl. Therefore, to assess the populations of *Nephrops* and fish entering both trawls three hauls (16, 17 & 18) were made with 40mm codends attached to both trawls. However, only *Nephrops* and haddock were caught in sufficient numbers for subsequent analysis.

TABLE 4

Number of valid hauls completed for each test case during both cruises

	Zenith	Bountiful
120mm in taper	10	9
110mm in taper	8	7
120mm in extension	N/A	5
110mm in extension	9	7
No panel on 80mm codend	3	N/A
40mm control codends only	N/A	3

On Zenith fish catches varied during the trials and in some areas the quantities of marketable haddock (>30cm) and whiting (>27cm) were limited. There were hake in many of the offshore areas but catches of cod were small except for the Bressay and Long Hole grounds. This may be partly a seasonal effect as April is a post-spawning period, especially for cod and haddock. Grounds were chosen on the basis that whitefish species were the main target and consequently *Nephrops* catches were low, with 22 of the 33 hauls containing less than 50kg of *Nephrops*. As a result the *Nephrops* catches during these trials were not at the level of normal commercial hauls. The largest catches were taken during haul 5 with more than 100kg in both test and control codends. However, there was no indication of wash-out occurring through the SMPs in any position. On the Bressay grounds, large quantities of Echinus SP. locally known as 'Burrs' were retained in the codends but this was not considered to have an important effect on SMP selectivity.

On Bountiful sufficient numbers of haddock were encountered during most hauls with catches in the control trawl ranging from 82kg to 261kg. Whiting catches were considerably smaller and ranged from 2.5kg to 87kg and not enough cod were caught throughout the trials for subsequent analysis. *Nephrops* catches were larger than those from the Zenith trials with 9 hauls containing >100kg of *Nephrops* retained in the 80mm test codend. As found on Zenith there was no indication of wash-out occurring in any of the SMP test cases.

A breakdown of weights for target species and total catches are given in tables 5 and 6. The total catch weights include non-target species such as Norway pout, poor cod, long rough dab, common dab, dogfish, herring, mackerel and anglerfish on Bountiful.

The effects of square mesh panel mesh size and position on the selectivity of high and low powered *Nephrops* trawlers

TABLE 5

Summary of the catch composition on Zenith for test and control codends

Haul number	Test case 80mm codend Catch (kg)							Control Catch 40mm codend (kg)						
	Haddock	Whiting	Cod	Monk	Hake	Nephrops	Total	Haddock	Whiting	Cod	Monk	Hake	Nephrops	Total
Z08/1	207.0	0.5	1.0	0.0	0.0	39.0	292.0	198.0	2.0	2.5	0.0	0.0	41.0	326.5
Z08/2	127.0	1.5	5.0	0.0	0.0	37.0	205.0	132.0	15.0	2.0	8.5	0.0	34.0	305.0
Z08/3	45.0	3.0	17.0	0.0	0.0	18.0	132.0	27.0	3.5	6.0	0.0	0.0	23.5	279.0
Z08/4	47.0	3.0	29.0	13.0	0.0	19.0	156.0	45.0	6.0	13.5	13.5	0.0	18.0	449.0
Z08/5	27.0	1.0	18.0	31.0	6.0	101.0	221.5	38.5	3.0	15.5	15.0	7.0	116.0	463.0
Z08/6	29.0	3.0	30.0	10.0	6.0	10.5	164.5	36.0	3.0	16.0	7.0	6.0	16.0	426.0
Z08/7	29.0	3.5	20.5	5.5	2.0	50.5	156.5	47.0	4.0	27.0	5.0	4.5	58.0	408.5
Z08/8	118.0	52.0	28.0	34.0	10.0	9.0	416.0	140.0	93.0	39.5	38.0	10.5	10.0	1023.0
Z08/9	79.0	56.0	15.0	16.0	7.0	3.0	444.0	98.0	63.0	13.0	18.0	8.0	2.5	898.0
Z08/10	81.0	27.0	23.0	27.0	9.0	4.0	386.0	96.5	42.0	7.0	33.0	9.5	4.0	590.5
Z08/11	37.0	45.0	14.0	35.0	3.5	24.0	273.5	90.0	131.0	7.0	31.0	12.0	37.0	578.0
Z08/12	55.0	72.0	13.0	32.0	11.0	13.5	391.5	93.5	147.0	3.5	47.0	14.0	14.0	806.0
Z08/13	30.0	31.0	6.5	6.0	8.0	14.0	212.5	37.0	73.0	11.0	31.0	13.5	15.0	546.5
Z08/15	37.0	18.0	3.0	8.0	1.5	5.5	251.0	63.0	16.0	15.0	32.0	2.0	4.0	414.0
Z08/16	48.0	25.0	25.0	43.0	16.0	10.0	313.0	48.0	26.0	6.0	30.0	8.0	8.0	410.0
Z08/17	46.0	26.0	0.5	37.0	10.0	6.0	410.0	61.0	28.0	13.0	46.0	13.0	5.0	516.0
Z08/18	41.0	35.0	15.0	52.0	5.5	55.0	337.5	56.5	99.0	15.0	27.0	9.0	61.0	850.0
Z08/19	65.0	41.0	23.0	28.0	11.0	17.0	356.0	56.0	42.0	22.0	29.0	11.0	22.0	679.0
Z08/20	49.0	24.0	33.0	41.0	7.0	8.0	267.0	70.0	43.0	23.0	40.0	6.0	8.0	565.0
Z08/21	65.0	58.0	11.0	24.0	6.0	22.0	413.0	67.0	68.0	2.0	34.0	6.0	31.0	782.0
Z08/22	113.0	0.5	0.5	1.5	2.0	22.0	170.5	190.0	20.0	1.0	1.5	1.0	27.0	352.5
Z08/23	40.0	13.0	0.3	9.0	8.0	18.0	155.3	56.0	26.5	0.5	5.5	5.0	26.5	303.5
Z08/24	49.0	10.5	0.5	15.0	2.5	8.5	153.0	67.0	22.0	3.0	5.0	5.5	9.5	367.5
Z08/25	48.0	20.0	1.5	10.5	4.5	15.0	254.0	62.0	44.0	1.0	10.0	6.0	22.5	545.5
Z08/26	85.0	13.0	1.0	7.0	5.5	47.0	287.0	133.0	29.0	2.0	4.5	16.0	57.0	809.5
Z08/27	61.5	14.0	0.5	7.5	12.0	75.5	300.0	90.5	28.5	6.0	7.5	13.0	87.0	660.5
Z08/28	95.0	17.0	1.5	7.5	19.0	60.0	298.5	138.0	42.5	2.0	20.0	19.0	57.5	923.0
Z08/29	68.0	22.0	2.0	12.0	8.0	54.0	279.0	102.0	36.5	1.0	5.0	10.5	59.0	676.0
Z08/30	99.0	13.0	0.0	15.0	7.0	63.0	290.0	136.0	22.0	2.5	4.0	10.0	77.0	619.0
Z08/31	60.0	27.0	3.5	9.5	3.0	35.0	203.0	47.0	29.0	3.5	12.0	9.5	37.0	313.0
Z08/32	50.0	21.0	1.5	8.0	4.5	28.0	182.5	58.0	22.0	0.5	2.5	3.5	32.0	242.5
Z08/33	45.0	3.5	0.0	1.5	0.5	3.0	84.5	59.0	9.5	0.0	0.0	0.0	5.0	129.5

TABLE 6

Summary of the catch composition on Bountiful for test and control codends

Haul number	Test case 80mm codend Catch (kg)					Control Catch 40mm codend (kg)				
	Haddock	Whiting	Cod	Nephrops	Total	Haddock	Whiting	Cod	Nephrops	Total
B08/1	112.0	22.0	2.0	36.0	257.0	177.0	30.0	1.0	41.0	439.0
B08/2	93.0	13.0	1.5	52.0	245.5	119.0	12.0	0.5	42.0	381.0
B08/3	131.0	11.0	3.5	49.5	301.0	261.0	37.0	1.5	44.0	652.5
B08/4	154.0	20.0	1.0	111.0	388.0	193.0	36.0	0.5	82.0	497.5
B08/5	137.0	18.0	5.0	32.0	286.5	188.0	28.0	0.5	28.0	455.0
B08/6	88.0	15.0	2.0	53.0	236.0	86.0	9.0	1.5	52.0	285.5
B08/7	174.0	20.0	1.5	216.0	545.5	155.0	22.0	3.0	177.0	537.0
B08/8	115.0	15.0	3.5	99.0	368.5	245.0	24.0	2.0	88.0	587.0
B08/10	116.0	15.0	4.0	52.0	266.0	190.0	26.0	3.0	40.0	433.0
B08/11	54.0	18.0	2.0	86.0	238.5	91.0	29.0	1.5	70.0	342.5
B08/12	100.0	26.0	2.0	157.0	384.0	146.0	41.0	1.5	137.0	506.5
B08/13	82.0	13.0	0.5	24.0	214.5	188.0	25.5	2.5	24.0	440.0
B08/14	81.0	15.0	3.0	13.0	206.0	138.0	26.0	2.0	14.0	347.5
B08/15	73.0	23.0	2.0	100.0	294.0	110.0	30.0	1.0	82.0	405.5
B08/16	182.0	9.0	1.0	31.0	324.0	160.0	10.0	1.5	33.0	311.5
B08/17	121.0	7.0	0.5	35.0	282.5	100.0	2.5	1.0	20.5	232.0
B08/18	206.0	1.5	1.0	37.0	346.0	224.5	3.0	1.5	28.0	374.5
B08/19	38.0	21.0	1.0	120.0	266.0	52.0	34.5	0.5	107.5	330.0
B08/20	58.0	22.0	3.0	23.0	187.5	69.0	25.0	2.0	16.5	268.0
B08/21	83.0	12.0	4.0	58.0	236.0	82.0	25.0	1.0	43.0	294.0
B08/22	60.0	11.5	1.0	194.0	346.0	85.0	31.0	1.0	167.0	436.0
B08/23	40.0	6.0	0.5	163.0	274.5	50.0	17.5	2.0	138.0	355.5
B08/24	40.0	8.0	0.75	44.0	164.75	59.0	15.0	1.0	36.0	259.0
B08/25	140.5	20.0	2.5	61.0	316.5	234.0	69.0	0.5	53.5	659.5
B08/26	154.0	30.0	1.0	95.5	388.5	259.0	87.0	1.5	84.0	675.5
B08/27	183.0	36.0	1.0	103.0	447.5	237.0	69.0	1.0	107.0	705.5
B08/28	80.0	13.5	1.0	73.0	250.5	191.0	70.0	1.0	55.5	635.5
B08/29	62.0	24.0	1.0	115.5	311.5	134.0	46.0	2.0	97.0	519.0
B08/30	27.0	12.0	1.5	75.0	178.0	82.0	54.0	1.5	70.0	418.5
B08/31	69.0	26.0	0.5	86.0	304.0	175.5	78.5	0.0	70.5	611.5
B08/32	66.0	4.0	1.5	30.0	172.0	112.0	14.0	1.0	29.0	301.0

Effect of Each Test Gear on Landing Weight and Discard Numbers

The catches in the test and control codends were analysed in two ways (see Appendix for details). First, the catch rates of the test gears relative to the control codend were estimated and compared. The relative catch rates (Figure 3) can be interpreted as the proportion of fish retained at each length, with a value of 1 indicating that all fish are retained and a value of 0 indicating that all fish are released. Second, the selection of the test gears were estimated and compared directly. The selection curves (Figure 4) were taken to be logistic and adequately captured the main features of the data. In principle, the dual selection processes of the panel and codend should generate a more complicated selection curve, but the data gave no evidence to sustain this. The first method of analysis makes fewer assumptions than the second, but can be less powerful and only estimates selection indirectly. The results for haddock and whiting are shown below and focus on the relative

catch rates / retention of the seven main test cases (B 120 E, B 110 E, B 120 T, B 110 T, Z 110 E, Z 120 T, and Z 110 T). Too few cod and hake were caught by the Bountiful for detailed analysis. Relative catch rates and retention curves for cod and hake from the Zenith trials are given in Kynoch *et al.* (2008).

Nephrops

The control codend used by the Bountiful caught fewer *Nephrops* than expected, possibly due to this trawl being relatively new and the belly sheet not suffering any mesh shrinkage compared to the older test trawl, so no detailed analysis of the *Nephrops* data was attempted. However, on the Bountiful, all four test gears and the gear with the small mesh codend caught similar quantities of prawns (see Appendix). Relative catch rates and retention curves for *Nephrops* from the Zenith trials are given in Kynoch *et al.* (2008).

Haddock

There were no significant differences in selection between five of the test cases (B 110 T, B 100 E, B 120 T, Z 110 E and Z 120 T). These caught fewer haddock than the Z 110 T case and more haddock than the B 120 E case.

Whiting

All the gears had a common selection range. The l_{50} did not depend on vessel or panel mesh size but was an estimated 3.1 cm greater when the panel was in the extension compared to the taper.

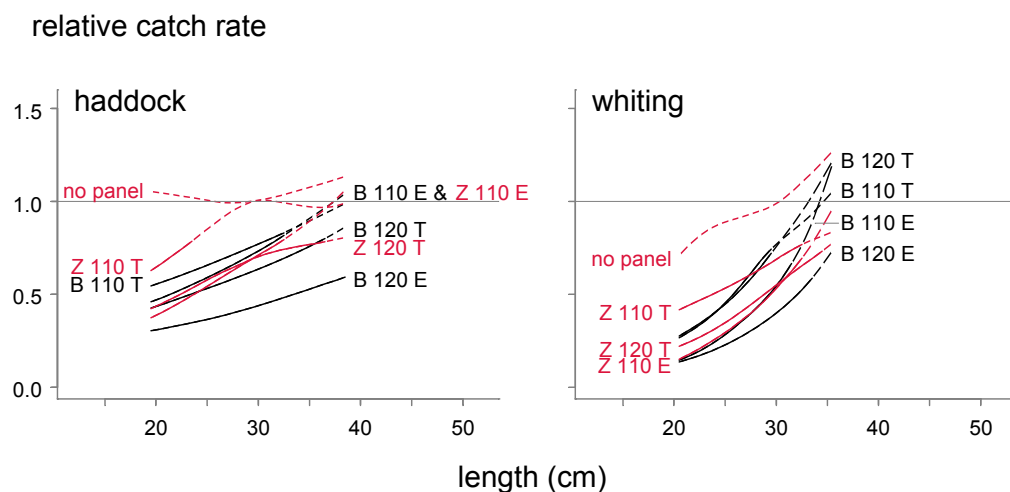


Figure 3: Estimated catch rates of each test case relative to the control codend. The lines are solid when the catch rate is significantly different from unity at the point-wise 5% significance level and dashed otherwise. The relative catch rate of the no panel case is also shown, but should be interpreted with caution as it is only based on three hauls.

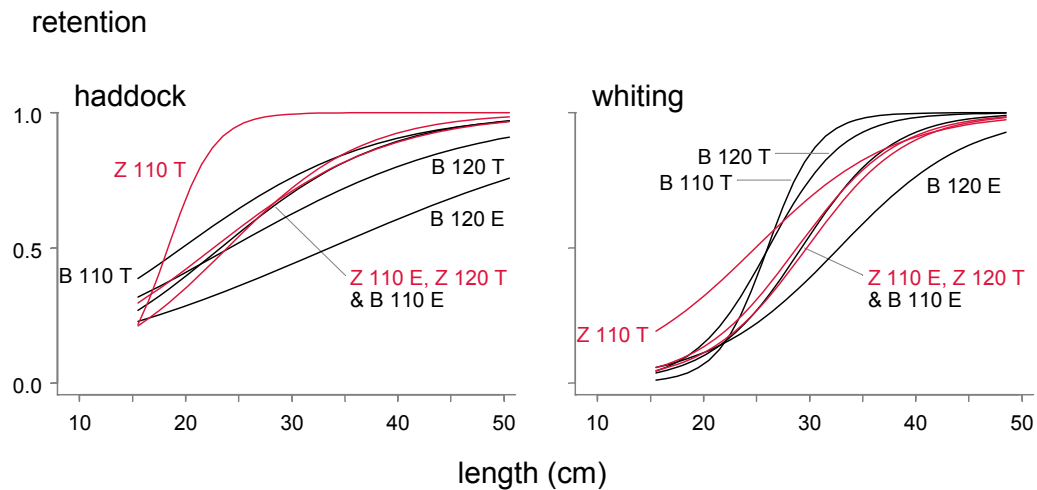


Figure 4: Estimated retention curves of each test case.

TABLE 6

Estimates and standard errors of the selection parameters α and β for each species and test case, with the corresponding l_{50} and selection range (SR). For numerical stability, α and β were estimated by centring fish lengths about 30.

		α		β		l_{50}		SR	
		est	se	est	se	est	se	est	se
haddock	B 120 E	-0.24	0.21	0.068	0.029	33.6	3.6	32.5	14.0
	B 110 E	0.86	0.33	0.128	0.035	23.3	2.0	17.1	4.7
	B 120 T	0.51	0.25	0.088	0.024	24.2	2.6	25.0	6.7
	B 110 T	1.15	0.41	0.111	0.036	19.6	2.8	19.7	6.4
	Z 110 E	0.95	0.30	0.157	0.029	23.9	1.4	14.0	2.6
	Z 120 T	0.90	0.34	0.122	0.029	22.6	2.1	18.1	4.3
	Z 110 T	5.29	1.13	0.454	0.097	18.3	0.7	4.8	1.0
whiting	B 120 E	-0.45	0.35	0.162	0.050	32.8	2.7	13.5	4.2
	B 110 E	0.18	0.33	0.237	0.050	29.2	1.3	9.3	1.9
	B 120 T	1.12	0.41	0.288	0.064	26.1	0.9	7.6	1.7
	B 110 T	1.71	0.60	0.432	0.116	26.0	0.8	5.1	1.4
	Z 110 E	0.06	0.29	0.213	0.041	29.7	1.3	10.3	2.0
	Z 120 T	0.25	0.30	0.212	0.044	28.8	1.3	10.4	2.1
	Z 110 T	0.78	0.40	0.153	0.055	24.9	2.0	14.3	5.1

TABLE 7

The estimated percentage of haddock and whiting retained by each test case at the minimum landing size and the mean Grade 3 length, with 95% confidence intervals in brackets. Haddock retention in a 120 mm diamond mesh cod-end is estimated from the model in Anon (2003).

Length (cm)	haddock		whiting	
	mls 30	Grade 3 mean 37.5	mls 27	Grade 3 mean 34
B 120 E	44 (34, 54)	57 (41, 71)	28 (18, 41)	55 (31, 77)
B 110 E	70 (55, 82)	86 (68, 95)	37 (26, 50)	76 (54, 89)
B 120 T	63 (50, 73)	76 (61, 87)	56 (42, 69)	91 (73, 97)
B 110 T	76 (58, 88)	88 (68, 96)	60 (42, 76)	97 (80, 100)
Z 110 E	72 (59, 83)	89 (76, 96)	36 (26, 47)	71 (52, 85)
Z 120 T	71 (55, 83)	86 (69, 94)	41 (30, 52)	75 (56, 88)
Z 110 T	100 (95, 100)	100 (99, 100)	58 (42, 72)	80 (57, 93)
120 mm diamond	15	73		

DISCUSSION

Performance with No Panel

Only 3 hauls were made on Zenith with an 80mm codend with no SMP. The relative catch rates (Figure 3) are not significantly different from unity for either haddock or whiting, suggesting that selection is poor or non-existent for fish ≥ 20 cm. The relative catch rates of these species is significantly lower than unity over some or all of the length range caught for all the gears using the 110 or 120mm SMPs demonstrating that the SMPs are the main cause of haddock and whiting selection in the gears tested in these trials.

Effect of Panel Mesh Size

Two SMP mesh sizes of 110 and 120mm were tested. The data do not indicate a significant difference between them, except in 2 cases. On Zenith the gear with the 110mm SMP in the taper (Z 110 T) released fewer haddock than the 120mm SMP (Z 120 T) and on Bountiful, the gear with the 110mm SMP in the extension (B 110 E) released fewer haddock than the 120mm SMP (B 120 E).

Effect of Panel Position

There are also differences between the performance of the panel when it is positioned in the taper rather than the straight extension. On Zenith the gear with the 110mm SMP in the taper (Z 110 T) released fewer haddock than in the extension (Z 110 E) and on Bountiful, the gear with the 120mm SMP in the taper (B 120 T) released fewer haddock than in the extension (B 120 E). Although more effective in the extension in these cases, considerable quantities of small haddock below mls are still retained – around 30 to 40% at 15cm. For whiting, the l_{50} was estimated to be 3.1cm larger when the SMP is in the extension rather than the taper. Around 10% of 15cm whiting are retained by the SMP in the extension.

Vessel Effect

The main analysis did not indicate any significant effect of the vessel on selective performance for any of the gears. Vessel motion has been suggested as a possible cause of differences in selection between large and small vessels - the greater movement of the smaller vessel possibly creating more pulsing of the codend. However, the weather was not

severe at any time during the trials (force 2-5) so that if this is the cause then we would not expect to see the effect during these trials.

Effect on *Nephrops* Catch

An important issue with the use of SMPs in *Nephrops* gears is whether there is any loss of prawns through the SMP. It was found midway through the Bountiful trials that the control net was not catching 100% of the *Nephrops* up to 36mm carapace length. It is therefore not possible to make any definitive statements about the selectivity of the nets for prawns. However, the net used with the 4 test codends and the same net with the small mesh codend attached all caught similar quantities of prawns, (see graphs of mean relative catch rates in the Appendix). This can be interpreted as evidence that all gears were retaining all *Nephrops*.

CONCLUSIONS

The main aims of these selectivity trials were to assess the differences in performance between SMPs placed in the straight extension or in the taper, between 110 and 120mm SMPs, and between gears towed by vessels of different horsepower.

- Compared to an 80mm codend with no SMP, all cases with a SMP improved the selection of haddock and whiting.
- Increasing the mesh size of the SMP from 110mm to 120mm was sometimes shown to improve the selection of haddock.
- Positioning a SMP in the straight extension of the net rather than the tapered section improved the selection of whiting and was sometimes shown to improve selection of haddock.
- Catches of haddock or whiting were not affected by the power of the vessel.

ACKNOWLEDGEMENTS

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APPENDIX

The catches from the test and control codends were analysed in two ways: using smoothers and generalised nonlinear mixed models.

The smoother based analysis (Fryer *et al.*, 2003) was in three stages:

1. a smoother was used to model the log catch rate of the test gear relative to the control gear for each haul;
2. the fitted smoothers were combined over hauls to estimate the mean log relative catch rate for each gear;
3. bootstrap hypothesis tests using the statistic T_{\max} were used to assess whether the mean log relative catch rates depended on mesh size, panel position, or vessel, and to compare the mean log relative catch rates to zero (or equivalently the mean relative catch rates to unity).

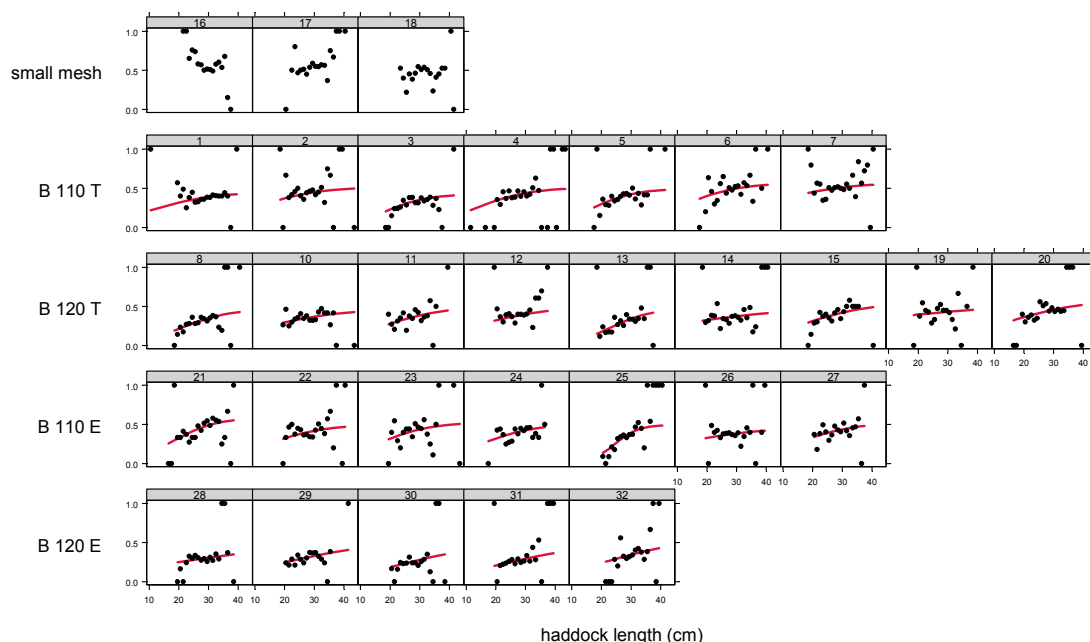
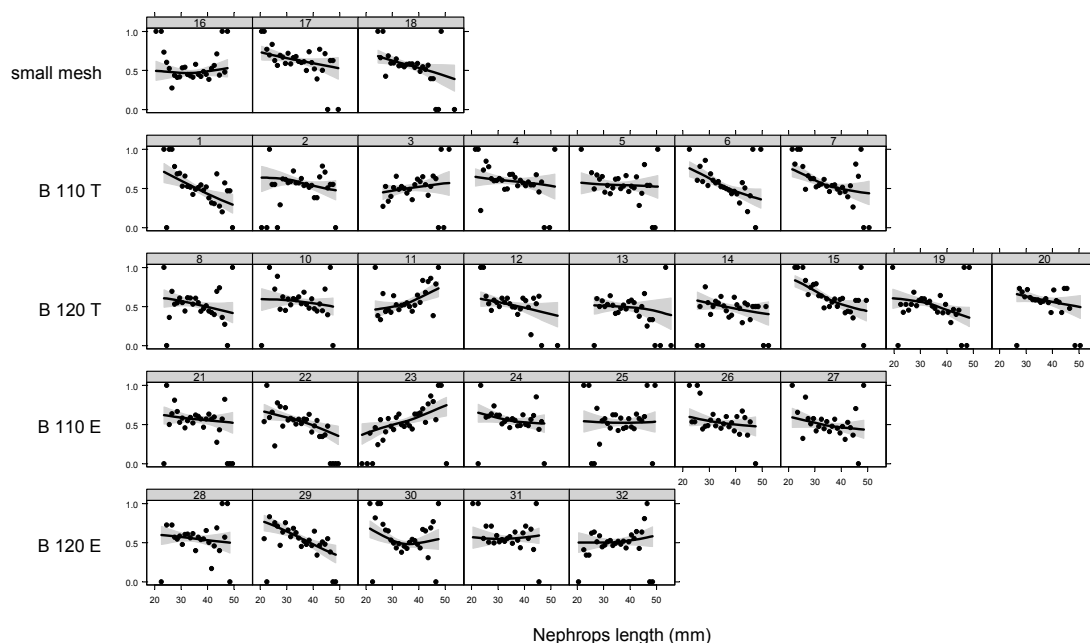
The smoother analysis was applied to *Nephrops*, haddock, whiting and cod, although the cod data were sparse and the smoothers were not combined over hauls. For *Nephrops*, the analysis revealed fundamental flaws in the Bountiful data (see below) and no attempt was made to compare the Bountiful and Zenith relative catch rates. For a more focussed analysis of the haddock and whiting data, only the relative catch rates / retention of the seven main test cases (B 120 E, B 110 E, B 120 T, B 110 T, Z 110 E, Z 120 T, and Z 110 T) were formally compared; i.e. the three hauls with the 'no panel' case (Zenith) or the 'small mesh' case (Bountiful) were ignored. Very few hake were caught in the Bountiful trials; hake results from the Zenith trials are reported in Kynoch *et al.* (2008).

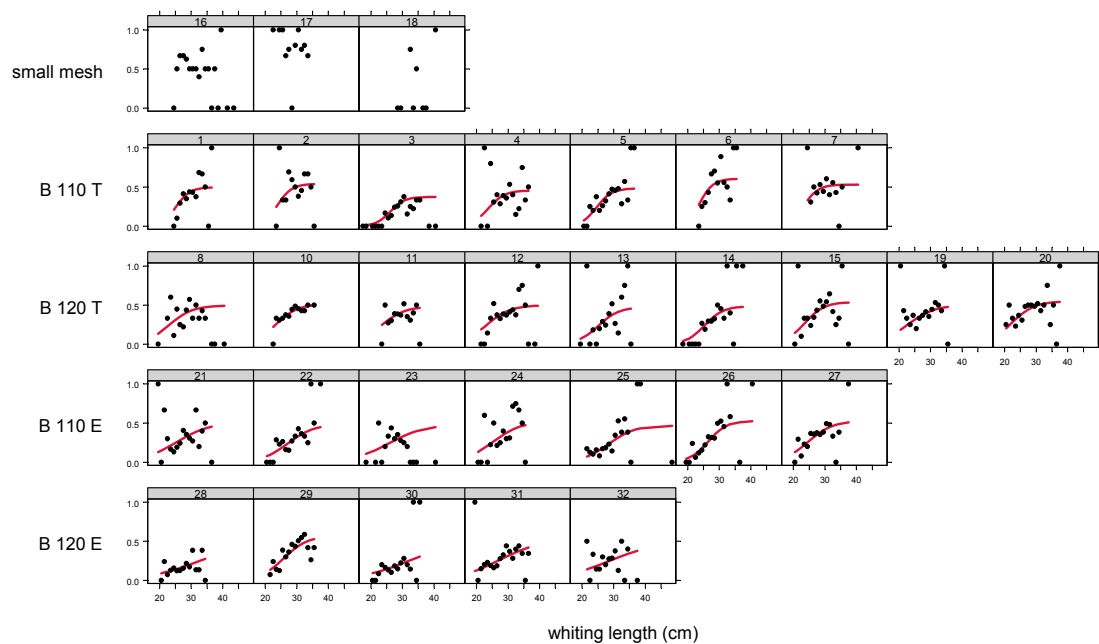
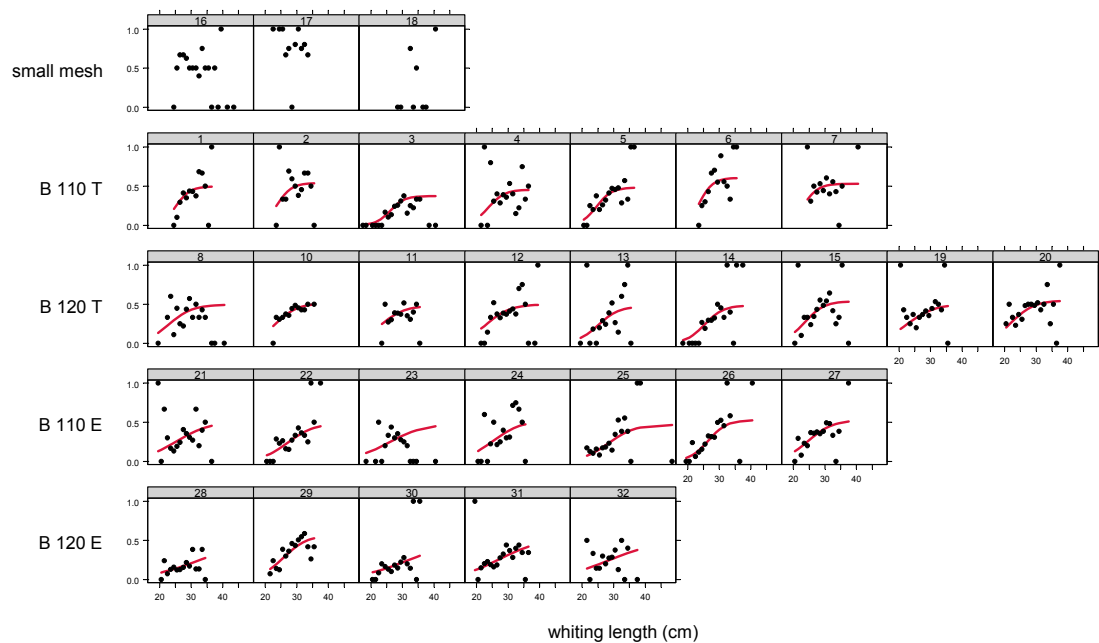
The generalised nonlinear mixed model is described in Kynoch *et al.* (2008). The mixed model was only applied to haddock and whiting and was restricted to the four main test gears. For haddock, the mean split parameter was estimated from the data, but was not significantly different from 0.5. For whiting, convergence could only be obtained by constraining the mean split parameter to be 0.5.

Both the smoother and mixed model analyses were on the logistic scale, but the results have been back-transformed for presentation.

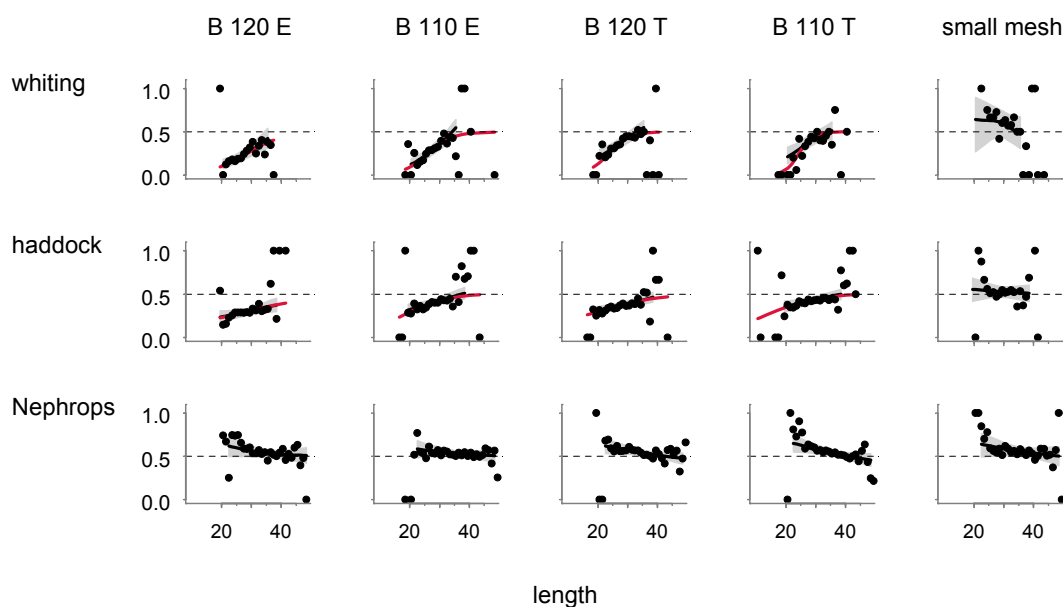
RESULTS

The proportions of fish retained in the test codend (of those retained in both codends) are shown below for each species and haul from the Bountiful trials. The black and red lines are the fitted values from the smoother analysis and the mixed model respectively. The grey shaded areas are pointwise 95% confidence bands on the fitted smoothers. The corresponding plots for the Zenith trials are in Kynoch *et al.* (2008).





The estimated mean relative catch rates for each species and gear from the Bountiful trials are shown below: the black lines are the fitted values from the smoother analysis (with pointwise 95% confidence bands indicated by the grey shaded areas) and the red lines are the fitted values from the mixed model. The corresponding plots from the Zenith trials are in Kynoch *et al.* (2008).



Nephrops: there were no significant differences in relative catch rate ($p = 0.94$) between the four main test cases tested on the Bountiful (B 120 E, B 110 E, B 120 T, B 110 T). However, the combined relative catch rate of the four cases was 160% for 23 mm *Nephrops* and significantly above unity for lengths up to 40 mm (5% pointwise significance level). Further, the relative catch rate of the small mesh case, both trawls fished with 40mm codends, was 175% for 23 mm *Nephrops* and significantly above unity for lengths up to 38 mm. The most likely explanation for these surprising results is possibly due to this trawl being relatively new and the belly sheet not suffering any mesh shrinkage compared to the older test trawl.

Haddock: there were significant differences in relative catch rates (smoother analysis: $p < 0.001$) and retention curves (mixed model: $p < 0.001$) between test cases. The smoother analysis found that vessel had no significant effect on relative catch rate ($p = 0.13$), but that the 110 mm panels retained more haddock than the 120 mm panels ($p < 0.001$) and that the panels in the taper retained more haddock than those in the extension ($p < 0.001$). However, these effects were driven by the data from the Z 110 T and B 120 E cases. Further analysis revealed that there were no significant differences in relative catch rates between the other five cases (B 110 T, B 110 E, B 120 T, Z 110 E and Z 120 T) and that these gears caught fewer haddock than the Z 110 T case ($p < 0.001$) and more haddock than the B 120 E case ($p < 0.001$). The mixed model found significant interactions between vessel and panel position ($p = 0.010$) and between vessel and mesh size ($p = 0.021$), both due to the Z 110 T and B 120 E cases. Again, there were no significant differences in retention between the other five cases ($p = 0.49$), which caught fewer haddock than the Z 110 T case ($p < 0.001$) and more haddock than the B 120 E gear ($p < 0.001$).

Whiting: there was only weak evidence of differences in relative catch rates (smoother analysis: $p = 0.075$) and retention curves (mixed model: $p = 0.043$) between test cases. The smoother analysis found that vessel and mesh size had no significant effect on relative catch rate ($p = 0.15$ and 0.16 respectively), but that panels in the taper retained more whiting than

those in the extension ($p < 0.001$). Although the Z 100 T and B 120 E gears were influential, the result persisted if these gears were omitted from the analysis ($p = 0.045$). The mixed model found no difference in the slope of the retention curves across gears ($p = 0.31$), but there were significant differences in intercept ($p = 0.014$); i.e. a common selection range but different l_{50} s. Further, the l_{50} did not depend on vessel or mesh size ($p = 0.76$ and 0.07 respectively), but was an estimated 3.1 cm (standard error 1.0; $p = 0.002$) greater when the panel was in the extension. Omitting the Z 100 T and B 120 E gears reduced the estimated difference in l_{50} to 2.1 cm (standard error 1.0; $p = 0.036$).