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SR625_Jackson Low Drag Trawl Sea Trials – Trial 1 MFV Harvest Hope

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Jackson Low Drag Trawl Sea Trials
Trial 1 MFV Harvest Hope

Summary:

Sea trials were carried out in April 2009 to compare the drag of a large single hard ground trawl constructed of traditional knotted polyethylene (PE) twines with a new trawl constructed entirely in knotless Ultra Cross Dyneema to the same design.
The trawl was built by Jackson Trawls of Peterhead and tested onboard MFV Harvest Hope PD120.

Initially the trawl doors, ground gear, sweep lengths and flotation remained exactly the same when changing from the old trawl to the new one.
The trawl doors were then changed to ones with a reduced surface area.

There was a significant reduction in the drag of the trawl. This reduction however was not transferred through to a similar reduction in warp tension.
The drag could be further reduced by reducing the size of the dyneema trawl to cover the same area of ground as the original PE trawl

The dyneema net appears to be taking up a different shape in the water compared to a similar PE trawl towed at the same speed. Modelling of both trawls for testing in the flume tank could help to clarify this anomaly.

It would appear that the hydrodynamic characteristics of the trawl doors changes as the drag of the trawl behind them decreases.

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1. Introduction

From 2004 until 2008 the price of fuel for the UK fishing fleet has risen from 18 pence per litre to 56 pence per litre in 2008. Skippers and trawler operators are therefore desperate for any way to reduce fuel consumption in their vessels.

When towing and steaming, there are small changes such as reducing speed which can lower fuel consumption but generally if towing speed is reduced this will result in reduced catches and hence reduced earnings. With the introduction of days at sea and kilo watt days the skipper also has to take into account the loss of actual fishing time if he decreases his speed when steaming to the grounds.

To maintain catch levels but reduce fuel costs, the skipper of a trawler can only realistically do one of the following:

- reduce the drag of the trawl gear
- use a more efficient propulsion system

Either of these two things gives the skipper the option of either towing at the same speed and saving fuel or, towing faster and consuming the same amount of fuel but potentially catching more fish.

There are a number of other changes which may have a marginal effect but reducing gear drag is the one which will probably have the most significant effect in the short term.

In calm weather the vast majority of fuel is consumed to overcome the drag of the trawl gear and only a very small proportion to propel the vessel (perhaps 10-20%). This means that gear drag is the main element which needs to be reduced to save fuel.

Drag of gear can be reduced by making the trawl smaller, reducing the opening (wing end spread and headline height), reducing the twine surface area of netting, reducing the ground contact friction or using lower drag trawl doors and components. Twine surface area can be reduced either by using larger mesh sizes and/or reduced twine diameters.

If the same design of trawl is used but constructed with smaller diameter twines the drag of the trawl will reduce when compared with the original trawl with larger diameter twines. When the drag of a trawl is decreased there will usually be changes in the door spread, wing end spread and headline height. One or all of these parameters will usually increase, decreasing the benefits of the drag reduction and reducing the possible fuel savings. To maximise the benefits from the use of smaller diameter twines and large mesh, it is necessary to make other alterations to the gear to optimise the catching potential and fuel savings.

Jackson Trawls of Peterhead, in collaboration with NET Systems USA (manufacturers of netting) and the skippers of 3 fishing vessels from North

East Scotland, MFV Harvest Hope, MFV Amity and MFV Apollo put together a project to trial Ultra Cross Knotless Dyneema netting. This was to be trialled on the 3 different fishing vessels using different methods of trawling. The Harvest Hope using single trawl to target demersal fish, the Amity uses twin rig trawls to target *Nephrops* in North Sea grounds and the Apollo uses modern double bagged trawls in a twin rig configuration to target *Nephrops* for freezing onboard.

The netting to be used is Ultra Cross knotless netting made with dyneema twine. This is a highly advanced form of knotless netting that delivers superior strength and performance over conventional netting. This netting should reduce the drag of the trawl on 2 separate dimensions. Firstly the trawl can be constructed in twine of much as 50% less diameter. Secondly by using knotless netting the drag will be further reduced. Taking into account that the drag of a trawl is directly related to the twine surface area of its netting this should reduce the over-all drag of the gear considerably. Given that a trawl is part of a dynamic system, if the drag of the trawl is decreased other parts of the trawl gear will change shape to accommodate this. This could mean alterations may be needed to the floatation, the weight of groundgear, the trawl door size or change of towing speed to get the gear fishing to its optimum using the low drag trawls.

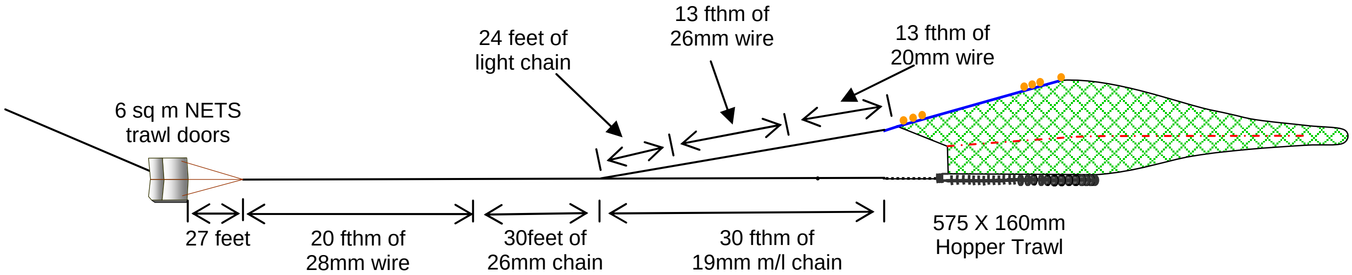
2. Trials equipment and procedure

The trawl to be tested is a traditional hard ground trawl rigged on a heavy hopper ground gear rig as used by several vessels in NE Scotland.

2.1. Trawl Gear

The trawl used was the vessels own Jackson Trawl design with the following specification:

Headline length	178 ft
Fishing line length	153 ft
Ground gear	216 ft
Fishing Circle	575 x 160 mm meshes
Floats	86 x 12" deepwater type (centre hole)
Doors	6 sq m NETS / 5 sq m NETS
Back strops	27 ft
Sweeps	25 fathom
Bridles	30 fathom



Standard Harvest Hope Hopper Trawl

The experimental trawl was made to exactly the same dimensions and mesh counts using the knotless dyneema netting resulting in a reduced twine surface area.

Twine diameter	Old nets	4.0 mm
	New nets	2.0 mm
Twine surface area	old nets	145 sq m
	New nets	94 sq m

This is the calculated figure, the actual twine surface area (TSA) of the experimental net will be considerably less because the calculation makes no allowance for the knot size or its orientation to the direction of towing. This is a 35% reduction in TSA in the knotless net trawl. The drag reduction is not expected to be in the same proportions as the number of floats, the size and weight of the ground gear is the same in both trawls. The difference in 'bulk' of netting in the dyneema net is quite considerable when seen on board the vessel

Bellies of both trawls on the pier.
Left - vessels original net in 4.0 mm polyethylene netting.
Right - trials net in 2.0 mm ultracross dyneema

2.2. Doors

Both sets of trawl doors used were NETS Hi-Lift Doors. These are a double foil design with a low aspect ratio made in USA by NET Systems.

Size in m sq	Recommended horsepower	Weight in air kg	Weight in water kg
5.0	600 - 900	1,286	1,115
6.0	1,100 – 1,500	1,545	1,340

Both were rigged with similar double back strops as supplied by the manufacturers. Both are fitted with scanmar housings in the upper plate for installing the vessels own scanmar distance sensors.

3. Vessel Specification

Name	Harvest Hope	
Year built	1999	
Length registered	33.75m	
Breadth registered	9.30m	
Tonnage	gross 629 tons	net 188 tons
Engine	MaK 8m20 rated at 1771hp (1320kw)	

MFV Harvest Hope

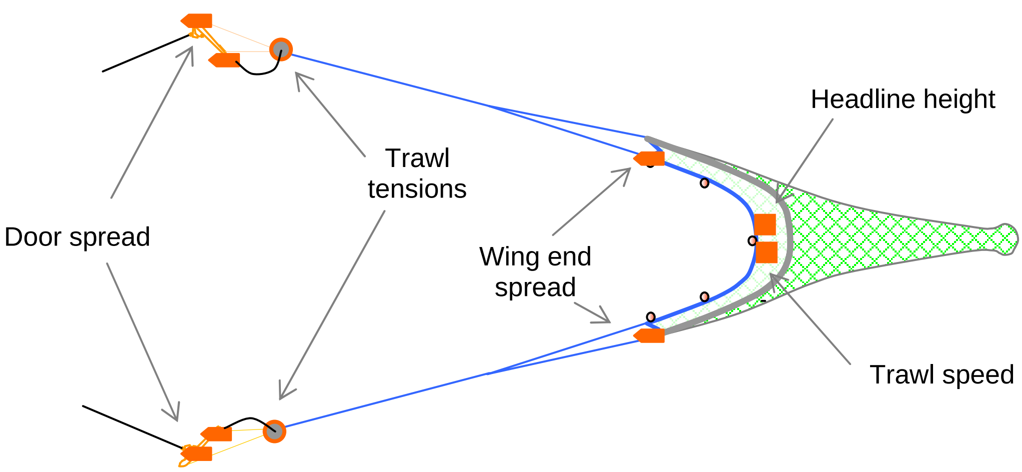
4. Instrumentation

The trawl geometry and loads were measured by the Seafish Scanmar suite of instruments. No logging software was used but the readout (Scanbas) was read every minute giving five readings to average for each parameter for each of the 5 minute legs.

The vessel is rigged with a Scantrol autotrawl system therefore it was not practical to use the Seafish deck mounted loadcells and data logger to record warp tensions. The warp tensions instead were read off the damped readings on the auto trawl system display in the same routine as the scanmar readings. The load of the trawl alone was measured by Scanmar underwater tension cells placed immediately behind each trawl door.
Net speed was measured at the trawl headline with Scanmar speed sensors (Net Speed) and supplemented by speed over the ground from a GPS receiver integrated with the Scanbas system and verified with the vessel's own GPS system (speed over ground) The ship speed through the water from a Vale port current meter towed from boom over the vessel's side (Vessel Speed).

Scanmar sensors used:

1. Door spread
2. Wing end Spread
3. Headline Height
4. Tension – Starboard Door back strop
5. Tension – Port Door back strop
6. Trawl Speed



Positions of Scanmar sensors on the Harvest Hope trawl

As these Scanmar sensors are temporary attachments to the trawl gear, there are occasions when the readings are missed through the transponder units not being in the correct orientation to the towed receiver unit. The orientation of the sensors can change as the net changes shape with the alterations to vessel speed, vessel course and direction and strength of tidal flow. With a limited number of transponder frequencies available, there are times when readings are missed through 2 or more sensors operating in conflicting frequencies. It is not always possible to collect readings from all sensors on every run. It is sometimes necessary to sacrifice sensor readings on certain parameters that do not change much in order to get reliable readings for the more important parameters. By performing numerous sets of readings, enough good data should be collected in each scenario to give a good average on all gear parameters.

Underwater 5 ton load cells fitted to the back strops of the trawl door. The black cable leads to the Scanmar sender unit attached further up the back strop

4.1. Test Procedure

The trials were carried out approximately 25 miles east of Peterhead in water between 60-65 fathom deep. Although not the vessels normal fishing grounds the proximity to Peterhead allowed quick return to port should any alterations such as smaller trawl doors be needed during the trials

The trials would take the form of a series of runs, each run comprising of a number of ‘legs’ with readings taken from the instrumentation throughout these legs. All the legs would be either both directly into the tidal flow and directly against the tide and avoid the times of slack water. Each leg would comprise of three to five speed settings.

On each leg, the skipper was asked to tow at what he considered his normal or standard speed/rpm setting taking into account usual fishing considerations, and 1 or 2 settings above and below this.

As this vessel operates the engine at constant revs to run the shaft generator and varies his towing speed by altering the pitch of the propeller it was decided to use only 3 variations of speed. One below normal pitch (65% pitch), the second being the normal towing pitch (75%) and 85% for the setting above towing speed. To get the maximum number of readings in both directions in this trial it was decided to tow for 4 hours against the tide, taking a series of runs through the rev range.

This routine was to be similar for the 4 variations of the gear –
1 – Vessels standard hopper trawl with 6 sq m NETS doors.
2 – Dyneema trawl with 6 sq m NETS doors
3 - Dyneema trawl with smaller doors (5 sq m NETS)
4 – Vessels standard trawl with smaller doors (5 sq m NETS)
Variations 1, 2 and 3 are the main comparisons, the fourth variation was more for the skippers benefit to see if they could tow the large net efficiently with the smaller doors.

The vessels standard gear was shot towing North against the tide and let to settle for 30 minutes. The reason for this is that trawl gear can often take up to 20 minutes to settle into its fishing position. The speed was the dropped to 65% pitch, the first speed setting, in preparation for starting the first leg.

Five minutes was allowed to let the gear settle, then a series of five readings over a five minutes period were then recorded from the instrumentation.

After the lowest speed setting was completed, the speed was increased to normal towing speed (75% pitch). After allowing at least 5 minutes to let the gear settle into the new speed another series of readings were taken. This was repeated for the highest pitch setting of 85%. This routine was repeated for each leg until enough readings were collected towing into the tide.

This was then repeated with the vessel towing with the tidal flow. No readings were taken in the period of the 30 minutes either side of the tide turning (slack water) to decrease the chance of erratic readings being collected.

Raw Results of first six runs

17th April 09		Start	Duration	Depth	Prop	SPEED					Spreads		TENSIONS						
Leg 1		Time	in	in	pitch	hip speed			Net		Door		Warp			Net			
Run			minutes	fthms	%	peed Log		OG	speed	X tide			Port	Port +	Stbd	Port	Port +	Stbd	
No.						m/s	kts	kts	kts	kts	fthms	mtrs	t	Stb	t	t	Stb	t	
1	1	1.45	5	61.0	66	1.78	3.46	3.10	3.60		43.00	78.64	5.10	10.80	5.70	3.70	7.40	3.70	into tide
	2			61.0	66	1.80	3.50	3.20	3.50		43.00	78.64	5.40	10.80	5.40	2.80	5.60	2.80	into tide
	3			61.0	66	1.77	3.44	3.20	3.10		44.00	80.47	5.50	11.00	5.50	2.95	5.90	2.95	into tide
	4			61.0	66	1.78	3.46	3.20	3.00	0.20	44.00	80.47	5.20	10.40	5.20	2.90	5.80	2.90	into tide
	5			61.0	66	1.87	3.64	3.20	3.00	0.20	43.00	78.64	5.40	10.80	5.40	2.73	5.46	2.73	into tide
	Averages					1.80	3.50	3.18	3.24		43.40	79.37	5.32	10.76	5.44	3.02	6.03	3.02	into tide
2	1	1.55	5	61.0	75	1.95	3.79	3.50			45.00	82.30	5.80	11.70	5.90	3.19	6.38	3.19	into tide
	2			60.5	75	1.99	3.87	3.60			45.00	82.30	5.80	11.50	5.70	3.20	6.40	3.20	into tide
	3			61.0	75	1.84	3.58	3.50			45.00	82.30	6.00	12.00	6.00	3.20	6.40	3.20	into tide
	4			61.0	75	2.01	3.91	3.30			46.00	84.12	6.20	12.40	6.20	3.20	6.40	3.20	into tide
	5			61.0	75	2.09	4.06	3.50			45.00	82.30	5.40	10.80	5.40	3.20	6.40	3.20	into tide
	Averages					1.98	3.84	3.48			45.20	82.66	5.84	11.68	5.84	3.20	6.40	3.20	into tide
3	1	2.00	5	61.0	80	2.02	3.93	3.60			45.00	82.30	6.60	13.20	6.60	3.30	6.60	3.30	into tide
	2			60.5	80	2.01	3.91	3.60			45.00	82.30	6.10	12.20	6.10	3.40	6.80	3.40	into tide
	3			61.0	80	2.12	4.12	3.60			45.00	82.30	6.50	13.00	6.50	3.40	6.80	3.40	into tide
	4			61.0	80	2.10	4.08	3.60			46.00	84.12	6.50	13.00	6.50	3.50	7.00	3.50	into tide
	5			**61.0**	80	**2.14**	4.16	**3.60**			**45.00**	82.30	**6.50**	13.10	**6.60**	**3.50**	7.00	**3.50**	into tide
	Averages					2.08	4.04	3.60	0.00	0.00	46.00	84.12	6.44	12.90	6.46	3.42	6.84	3.42	into tide
4	1	2.25	5	57.0	80	2.14	4.16	3.70			46.00	84.12	6.70	13.40	6.70	3.40	6.80	3.40	into tide
	2			57.0	80	2.09	4.06	3.80			46.00	84.12	6.70	13.40	6.70	3.30	6.60	3.30	into tide
	3			56.0	80	2.05	3.99	3.80			46.00	84.12	6.50	13.00	6.50	3.60	7.20	3.60	into tide
	4			56.0	80	2.09	4.06	3.90			46.00	84.12	6.50	13.00	6.50	3.40	6.80	3.40	into tide
	5			**55.0**	80	**2.09**	4.06	**3.70**			**47.00**	85.95	**6.50**	13.00	**6.50**	**3.50**	7.00	**3.50**	into tide
	Averages			56.20		2.07	4.07	3.78	0.00	0.00	46.20	84.49	6.58	13.16	6.58	3.44	6.88	3.44	into tide
5	1	2.45	5	56.0	75	1.90	3.69	3.50			45.00	82.30	5.80	11.60	5.80	3.40	6.80	3.40	into tide
	2			55.0	75	2.00	3.89	3.70			46.00	84.12	5.90	11.80	5.90	3.30	6.60	3.30	into tide
	3			55.0	75	1.96	3.81	3.70			45.00	82.30	5.70	11.40	5.70	3.20	6.40	3.20	into tide
	4			54.0	75	1.90	3.69	3.50			45.00	82.30	6.00	12.00	6.00	3.20	6.40	3.20	into tide
	5			**53.0**	75	**2.00**	3.89	**3.40**			**44.00**	80.47	**5.60**	11.20	**5.60**	**3.10**	6.20	**3.10**	into tide
	Averages			54.60		1.95	3.79	3.56	0.00	0.00	45.00	82.30	5.80	11.60	5.80	3.24	6.48	3.24	into tide
6	1	3.00	5	53.0	65	1.77	3.44	3.00	3.20		41.00	74.98	5.10	10.30	5.20	2.79	5.58	2.79	into tide
	2			53.0	65	1.80	3.50	3.00	3.00		39.00	71.32	5.20	10.10	4.90	2.78	5.56	2.78	into tide
	3			52.0	65	1.78	3.46	3.00	3.40		41.00	74.98	5.20	10.40	5.20	2.80	5.60	2.80	into tide
	4			52.0	65	1.79	3.48	3.00	3.60		40.00	73.15	4.90	9.80	4.90	2.90	5.80	2.90	into tide
	5			**52.0**	65	**1.80**	3.50	**2.80**	**3.60**		**41.00**	74.98	**4.90**	9.90	**5.00**	**2.76**	5.52	**2.76**	into tide
	Averages			52.40		1.79	3.48	2.96	3.36	0.00	40.40	73.88	5.06	10.10	5.04	2.81	5.61	2.81	into tide

5. Results and Discussion

The intention was to get at least one block of four runs for each of the trawls (old and new) covering both directions of tidal flow and trying to avoid the periods of slack water. This meant that there were periods when results could not be taken but ensured that better quality results were obtained over all.

Slack water (when the tide is turning) can be a time of confusing readings, as the exact time of the tide (according to tide tables)may not be accurate for the vessels position. The time can be different at the surface to that on the seabed, thereby having a different effect on the vessel to that on the gear.

As the scanmar net sensors and hydrophone receiver are only temporary fitments to the vessel and gear it can sometimes be difficult to get continuous reliable readings. As the transponder units are clipped onto the wing ends and back strops of the doors there are times when they do not give good signals to the towed hydrophone. Several of the Seafish sensors had conflicting frequencies with the vessels own door and headline sensors therefore there had to be some swapping of sensors each haul to get enough good readings. For these reasons there are gaps in some of the recordings of raw data. It is hoped that by undertaking numerous ‘runs’ the effects any anomalies can be minimised. The headline height readings for both trawls during the sea trials were a bit erratic. The headline height figures stated are a combination from readings taken during the trials and readings taken by the skipper on both trawls in the 3 fishing trips following the sea trials.

The vessels own gear was shot in 60 fathom depth giving the figures below for each speed setting. Each reading has been averaged out to negate any tidal effects on the gear.

5.1. Variation 1 - Vessels standard trawl spread by 6 square metre trawl doors

Prop pitch %	Speed thr water kts	speed OG kts	Net speed kts	door spread mtrs	wing end spread mtrs	height mtres	Tensions total in warps	total in trawl	Sweep angle (calc)	Mouth area (WES x HH) sq m	**Fuel** usage litres / hour
65	3.6	3.3	3.3	76.6	24.4	6.1	10.9	5.3	12.9	140.4	
75	4.0	3.8		82.6	23.3	5.9	12.1	6.2	13.9	130.3	220.0
80	4.3	4.0	4.0	83.5	*23.3*	5.8	12.9	6.4	14.0	129.3	

All these parameters are similar to those recorded by the skipper during the vessels normal fishing operations. The vessel usually tows at 70% – 75% pitch on the propeller only dropping to 65% when towing with a strong tide and increasing to 85% in bad weather or towing against strong tides. These are all measurements that the skipper has found, through experience, to enable the gear to fish to its optimum efficiency. They all concur with recommended parameters for this type of fishing. The net opening (wing end spread) is in the region of 44% of the nets headline length, the recommended would be somewhere in the region of 40% to 55%. The door spread, wing end spread and total sweep length correlate to give a calculated sweep angle of 13-14 degrees, the recommended for this gear would be between 13-15 degrees.

These averages were recorded over a series of 5 full runs, each of 3 legs, all either directly into the tide or directly before the tide.

Using the same 6sq metre trawl doors, the trawl was now changed to an identical trawl but constructed in knotless dyneema netting. Again a series of runs both into and against the tide were done and the recorded readings averaged out to the readings below.

5.2. Variation 2 - Experimental trawl made of knotless Dyneema spread by 6 square metre trawl doors

Prop pitch %	speed thr water kts	speed OG kts	Net speed kts	door spread mtrs	wing end spread mtrs	height mtrs	Tensions: total in warps tons	Tensions: total in trawl tons	Sweep angle (calc) deg	Mouth area (WES x HH) sq mtrs	**Fuel** usage litres / hour
65	3.9	3.4	3.0	82.4	30.1	6.6	10.8	4.4	13.9	200.0	180
75	4.3	4.0	3.5	84.6	28.2	6.6	12.3	5.1	14.2	185.4	218
80	4.7	4.1	3.8	86.6	28.0	6.8	13.0	5.8	14.6	189.3	242

Comparison of Dyneema net with 6 sq metre doors to the standard PE net with 6 sq metre doors

The speed through the water and speed over the ground both increased slightly but the speed of the net through the water altered very little. In line with this the warp tension (autotrawl) has changed very little between the 2 nets. However there are large changes in the trawl tensions (down by 9% - 16%), the wing end spread, increase of 20% - 23%, headline height increased by 9% - 16% and the door spread increased by only 4% - 8%.

This resulted in an increase in the mouth area of the trawl (headline height times the wing end spread) of between 34% - 40%.

The door spread increased by between 3 to 5 metres but the wing end spread increased by 5 or 6 metres. The sweep angle changed slightly (0.5 degree approx) but still remained within recommended limits. Due to the wing end spread increasing the relationship between it and the headline length did increase to just over 51%. This is probably the maximum spread that a skipper would want with this net to fish efficiently. At this spread the skipper would have to be aware of the possibility of the net starting to lose seabed contact.

Therefore for no increase in overall warp tension the trawl doors are covering a slightly greater area and the net itself is covering a much wider area of seabed with a higher headline. At the higher towing speed, with the lighter net (dyneema) there was some evidence that the net and doors were tending to lift off the seabed

The tension in the warps changed very little but the actual drag of the trawl decreased by between 9 and 16% depending at what power setting the vessel was towing with. For the tension in the warps to remain similar there must have been some change in the characteristics of the trawl doors. It may be, due to the decrease in tension behind the trawl doors, that the angle of attack of the doors has increased resulting in more drag from the trawl door.

Four full runs of 3 legs each were done successfully with this rig. Two runs at 80% pitch and 1 at 70% pitch were discounted as it was felt that the trawl and trawl doors had lost contact with the seabed therefore the readings from the various instruments would be unreliable.
The trawl doors were now changed for ones of the same design but 17% less surface area. This is a big change of door size. It is more normal for a skipper to change door size by around 8 – 10% in one step.

5.3. Variation 3 - Experimental trawl made of knotless Dyneema spread by 5 square metre trawl doors

Prop pitch %	speed thr water kts	speed OG kts	Net speed kts	door spread mtrs	wing end spread mtrs	height mtres	Tensions total in warps	Tensions total in trawl	Sweep angle (calc)	Mouth area (WES x HH) sq m	**Fuel** usage litres / hour
65			3.4	86.2	*32.0*	7.3	10.6		14.5	225.0	175.0
75			3.9	87.0	29.7	6.3	12.3		14.6	196.9	216.0
80			4.1	89.3	30.0	6.8	12.8		15.0	204.3	

Comparison of Dyneema net using 6sqm doors and 5 sq m doors
In the same routine of runs, both with the tide and against the tide, at the same propeller pitch settings there was a slight increase in the speed of the net through the water (8% – 11%) when compared to the same net with the larger trawl doors. There was a further increase in door spread and wing end spread this was not what was expected. It can only be presumed that the 5sq m trawl doors were rigged slightly differently to be more hydro-dynamically efficient. The headline height remained similar. There was a further slight decrease in warp tension, on average (between 0% and 2.6%) There was a similar decrease in fuel consumption but the fuel meter installed on the vessel did not provide the accuracy required to give a confident readings in the relatively short time span of the sea trials.

It would appear that the smaller trawl doors can spread the dyneema net in an efficient and practical way.

Comparison of Dyneema net with 5 sq metre doors to the standard PE net with 6 sq metre doors
There was again a very slight decrease in warp tension and a very slight increase in speed, 0.1 of a knot. There are no recorded net tensions in this setup as no readings were recorded from the sensors fitted behind the trawl doors. This was due to conflicting transmitting frequency with the vessels own trawl-eye unit. As the gear (nets, sweeps etc) behind the doors has not changed it can be assumed that the net tensions are similar when using dyneema net with the 5 sq metre doors to what was recorded using the dyneema net with 6 sq m doors
There was on average an 8% increase in door spread. There was a larger increase at the slower speed setting when the drag of the trawl was less.
The big differences were in the measurements of wing end spread and headline height. The wing end spread increasing from 23-24 metres to 30-32 metres using the smaller doors. Using recordings taken by the skipper in the 4 commercial fishing trips following the engineering sea trials the headline height increased by between 0.5 metre and 1 metre, an increase of between 10 and 20 percent. Due to the increases in head line height and wing end spread the mouth opening has increased greatly. At 65% pitch it increased by 56%, at 70% pitch a 40% increase and 52% increase at the 80% pitch setting. As both the door spread and the wing end spread

have increased by a similar amount, 6 – 10 metres each, the sweep angle of the gear has remained similar to that of the original net and doors. Only a 1-1.5 degree increase, with a maximum of 15 degrees, which is still within recommended limits for this type of gear.

The increase in mouth opening demonstrates a greater catching potential, in theory the trawl could be decreased in size to create a similar mouth opening to the original PE trawl. If this was done the drag of the trawl would be further decreased enabling the vessel to use even smaller trawl doors to cover the same area of seabed as the original trawl or tow the gear at a greater speed through the water.

Considering the door spread in relation to the wing end spread and headline height, it would appear that the dyneema trawl is taking up a different shape in the water compared to the PE trawl. This is due to the reduced drag of the belly and bag sections of the trawl that this is allowing the mouth and wings of the trawl to open more.

5.4. Variation 4 - Vessels standard trawl spread by 5 square metre trawl door

Prop pitch %	speed thr water kts	speed OG kts	Net speed kts	door spread mtrs	wing end spread mtrs	height mtres	Tensions total in warps	total in trawl	Sweep angle (calc)	Mouth area (WES x HH) sq m	**Fuel** usage litres / hour
65		3.31	0.00	78.41	26.96	6.75	10.24	0.00	13.2	181.9	181.00
75		3.94	0.00	75.95	24.62	6.33	11.43	0.00	12.8	155.8	212.00
80		4.07	0.00	77.29	24.89	6.57	11.74	0.00	13.0	163.6	232.00

Comparison of Standard PE net with 5 sq metre doors to the standard PE net with 6 sq metre doors

This variation was more for the skippers benefit than for the project results**.**

What it did show was that during the instrumented trials, there was very little difference in the parameters of the trawl when the size of the trawl doors was decreased by 17%. Although the net changed very little in this situation, this may not be the case under normal commercial fishing conditions.

At a similar speed through the water there was an 8% decrease in door spread at the vessels normal towing settings. There was however an increase of more than 1 metre in wing end spread on all the settings. There was a decrease in the warp tensions by between 5% and 9%, this should result in a decrease in fuel consumption of as similar percentage.

From these results it would appear that the smaller trawl doors were rigged slightly differently to the larger ones, making them a bit more efficient in this situation. This could change in different weather conditions, different type of sea bed and different depths with more warp out.

In this configuration the gear appeared to come off the bottom at the 80% pitch settings, 15 fathom more warp had to be slacked out to get the gear on the seabed.

6. Conclusions

1. The dyneema trawl has considerable less drag than the PE trawl when towed at the same speed. (9% - 17%)

2. The Dyneema trawl has a much greater mouth opening, with reduced drag than the PE trawl, when towed at similar speed

3. There is only a small reduction in warp tension (towing load) when towing the dyneema trawl. The angle of attack of the doors must have altered due to the reduced net tension behind them resulting in increased drag from the doors themselves.

4. The dyneema trawl is taking up a different shape in the water compared to the PE trawl. This is probably due to the different drag characteristics of the netting in relation to other parts of the trawl gear that are unaltered. (trawl doors, floats, groundgear, sweeps etc)

5. Due to the greatly increased mouth opening at all propeller pitch settings with the dyneema trawl (40% - 56%) the physical size of the trawl could be reduced to give the same fishing potential as that of the vessels standard trawl.

7. Recommendations

1. The trials results should be correlated with skipper's experience in using the trawl and trawl doors in a commercial fishing scenario to give an overall opinion on the trawl

2. It would be beneficial to get a scale model made of the trawl in low drag twine to observe the differences in shape of the trawl in various situations. From this it may be possible to alter the design of the trawl to further benefit from the use of low drag twines.

3. It would be beneficial to involve the trawl door manufacturers to get some advice on alterations to the rigging of the trawl doors to allow for the decreased drag behind the doors.

4. The performance of the dyneema netting should be monitored in the commercial fishing situation to determine its suitability compared to PE netting for use in this type of trawl in Scottish waters. This should include comments on chafe and abrasion of the netting, any difficulties in repairing the trawl after damage, any unusual meshing of fish, any loss of commercial species and any change in discards—both amount and species.

5. The angle of attack of the trawl doors should be monitored in future drag reduction trials.

8. FULL RESULTS - Raw recorded data

	Run No.	Depth in fthms	Prop pitch %	speed through water kts	speed over ground kts	Net speed kts	door spread mtrs	wing end spread mtrs	headline hieght mtres	Tensions total in warps	Tensions total in trawl	Tide with / into	**Fuel** usage litres / hour
Standard net 6sq m doors	1	61	65	3.5	3.2	3.2	79.4			10.8	6.0	into tide	
	2	61	75	3.8	3.5		82.7			11.7	6.4	into tide	
	3	61	80	4.0	3.6		84.1			12.9	6.8	into tide	
	4	56	80	4.1	3.8		84.5			13.2	6.9	into tide	
	5	55	75	3.8	3.6		82.3			11.6	6.5	into tide	
	6	52	65	3.5	3.0	3.4	73.9			10.1	5.6	into tide	
	7	63	65	3.6	3.5	3.6		25.2		11.8	5.6	into tide	
	8	63	75	4.1	3.7	4.3	84.7	24.1		12.6	6.8	into tide	
	9	63	80	4.5	4.0	4.5		0.0		13.6	7.5	into tide	
	10	63	80	4.6	3.9	3.9		0.0		13.4	7.3	into tide	
	11	63	75	4.2	3.7	3.9	77.2	23.3		12.6	6.6	into tide	
	12	63	65	3.7	3.3	3.8		25.5		11.3	5.5	with tide	
	13	63	65	3.5	3.5	2.7		21.7		10.5	4.3	with tide	
	14	63	75	4.0	4.0		83.6	22.9		12.1	5.7	with tide	
	15	63	80	4.2	4.2	3.7	82.7	0.0		12.5	5.6	with tide	

	Run No.	Depth in fthms	Prop pitch %	speed through water kts	speed over ground kts	Net speed kts	door spread mtrs	wing end spread mtrs	headline hieght mtres	Tensions total in warps	Tensions total in trawl	Tide with / into	**Fuel** usage litres / hour
Standard net 5sq m doors	40		65		3.0		77.5	26.7	7.0	10.7		into tide	178
	41		75		3.6		76.8	24.7	6.4	11.5		into tide	212
	42		80		3.7		78.6	24.9	7.2	12.5		into tide	232
	43	63	80		3.6		79.2	25.4	6.0	11.2		into tide	233
	44	62	65		3.6		79.4	26.7	6.4	9.9		with tide	180
	44	62	65		3.6		79.3	27.8	6.6	9.7		with tide	183
	45		75		4.2		75.1	24.6	6.3	11.4		with tide	213
	46	63	80		4.5		73.8	24.3	6.8	11.9		with tide	232
	47	63	80		4.4		77.6	24.9	6.2	11.3		with tide	

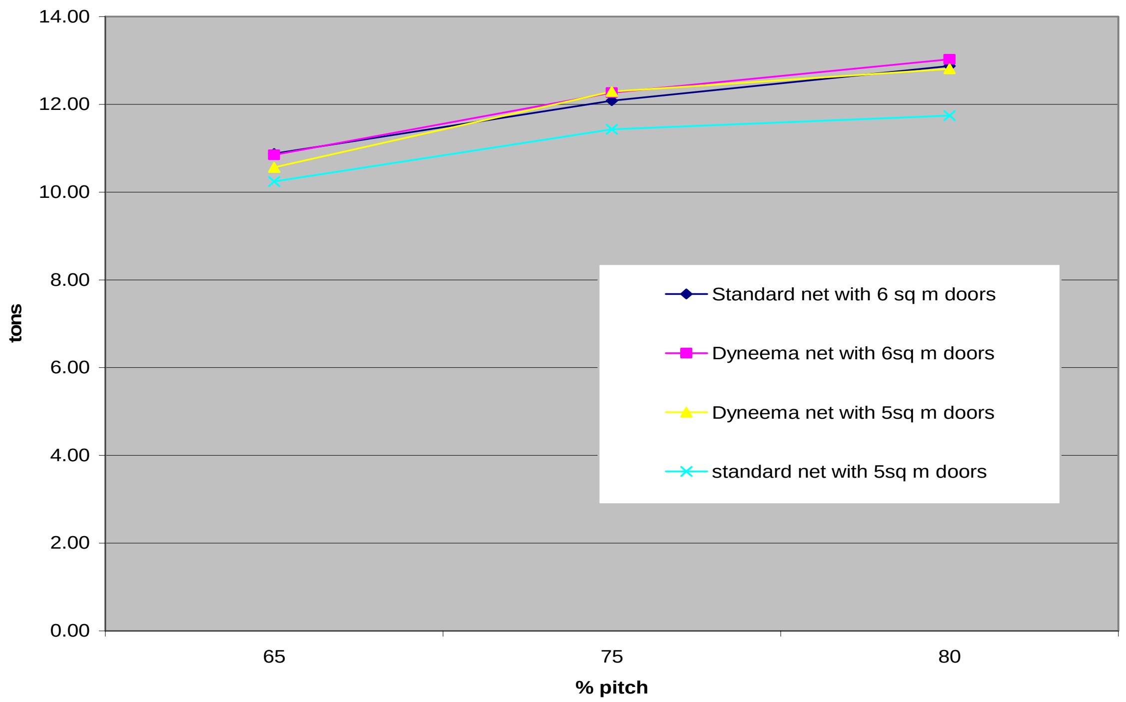
	Run No.	Depth in fthms	Prop pitch %	speed through water kts	speed over ground kts	Net speed kts	door spread mtrs	wing end spread mtrs	headline hieght mtres	Tensions total in warps	Tensions total in trawl	Tide with / into	**Fuel** usage litres / hour
Dyneema net 6sq m doors	16	63	65	4.1	3.3	3.3	87.8	29.8	6.8	10.8	4.3	into tide	
	17	63	75	4.7	3.9	3.7	86.8	28.0	6.8	12.4	5.4	into tide	
	18	63	80	5.1	4.0	3.8	90.9	28.0	6.8	12.9	5.2	into tide	
	19	63	80	4.8	3.9	3.9	87.6	28.0	6.8	13.0	5.2	into tide	
	20	63	75	4.6	3.6	3.5	82.7	28.0	6.8	12.2	4.6	into tide	
	21	63	65	4.0	3.1	3.1	82.9	30.4	6.5	11.0	4.2	into tide	
	22	63	65	3.4	3.2	2.8	79.6	30.4	6.5	10.5	3.8	with tide	181
	23	63	75	3.8	3.8	3.5	84.5	28.3	6.4	12.3	5.2	with tide	217
	24	63	80	4.3	4.2	3.7	83.9	28.0	6.8	13.1	5.6	with tide	242
	25		65	0.0	3.8		0.0	30.4	6.5		5.4	with tide	
			75	4.3	4.3	gear coming off bottom	0.0	28.3	6.4		0.0	with tide	214
			80	4.6	4.5		0.0	28.0	6.8		7.1	with tide	
			65	3.9	3.8		0.0	29.8	6.8	11.1	5.5	with tide	180
			60	0.0	3.3		0.0	30.5	7.1	10.4	4.6	with tide	165
			60	3.4	3.4		0.0	30.2	7.5	10.3	4.6	with tide	168

	Run No.	Depth in fthms	Prop pitch %	speed through water kts	speed over ground kts	Net speed kts	door spread mtrs	wing end spread mtrs	headline hieght mtres	Tensions total in warps	Tensions total in trawl	Tide with / into	**Fuel** usage litres / hour
Dyneema net 5sq m doors	28	65	65			3.3	85.6		7.5	10.0		with tide	175
	29	75	75			3.9	86.0	29.7	6.5	12.0		with tide	217
	30	80	80			4.2	87.2	30.0	6.8	12.4		with tide	
	31	65	65			3.6	85.7	0.0	7.0	9.8		with tide	
	32	65	65			3.3	86.8		*6.8*	11.2		into tide	
	33	75	75			3.8	88.0		*6.8*	12.6		into tide	
	34	80	80			4.0	91.0		*6.8*	14.1		into tide	
	35	80	80			4.0	91.9		*6.8*	12.5		into tide	

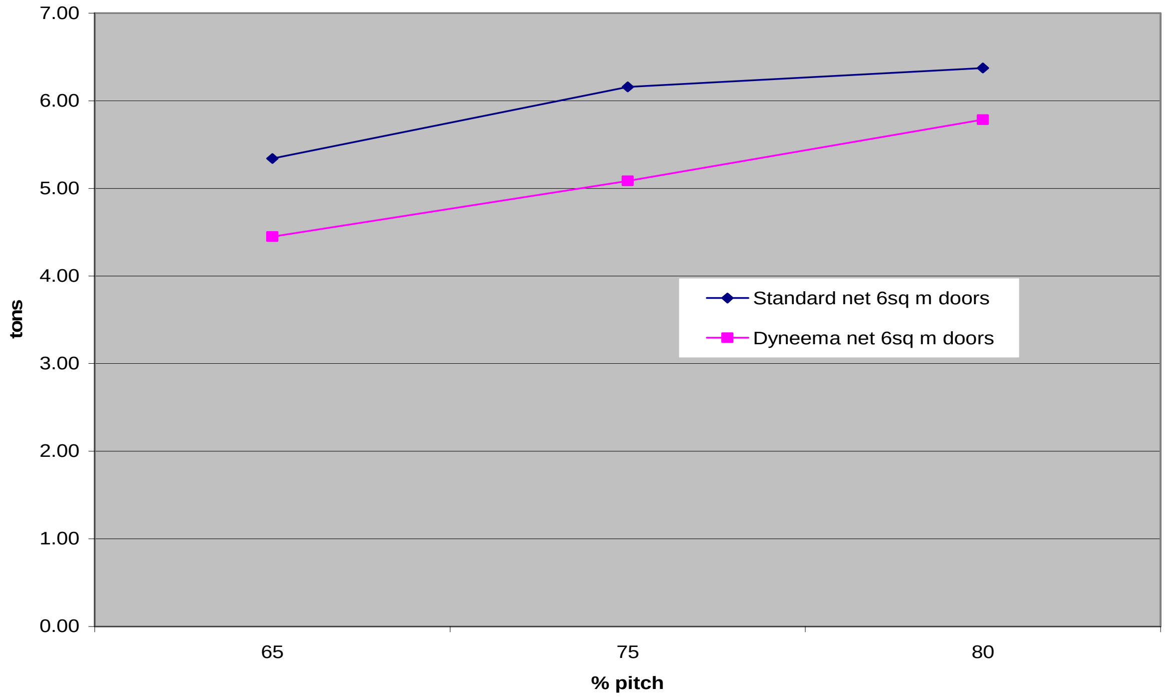
Averages for each propeller pitch setting in each of the configurations

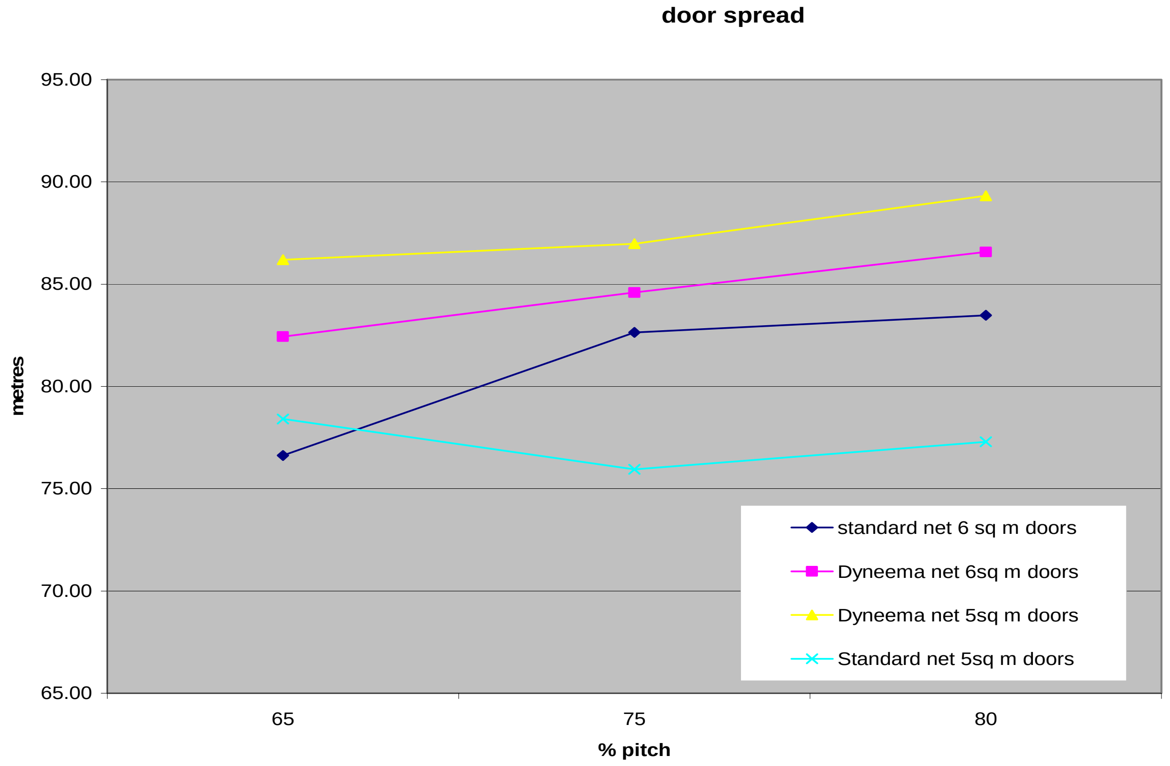
	Prop pitch	speed through water	speed over ground	Net speed	door spread	wing end spread	height	Tensions		Tide	Fuel usage litres per hour
								total in warps	total in trawl		
	%	kts	kts	kts	mtrs	mtrs	mtres	tons	tons		
Standard net 6sq m doors	65	3.51	3.21	3.39	76.63	25.22	5.50	10.88	5.75	into tide	
	75	3.99	3.62	4.07	81.70	23.66	5.30	12.11	6.58	into tide	
	80	4.29	3.81	4.22	84.31		5.30	13.27	7.12	into tide	
	65	3.59	3.38	3.27		23.60	6.00	10.88	4.93	with tide	
	75	4.02	3.96		83.58	22.86	5.90	12.06	5.74	with tide	
	80	4.25	4.20	3.72	82.66		5.80	12.48	5.63	with tide	
Dyneema net 6sq m doors	65	4.04	3.23	3.21	85.33	30.08	6.65	10.91	4.23	into tide	
	75	4.63	3.77	3.58	84.73	27.98	6.77	12.27	5.01	into tide	
	80	4.96	3.92	3.88	89.25	27.98	6.77	12.93	5.20	into tide	
	60	3.40	3.35			30.36	7.30	10.35	4.60	with tide	166.50
	65	3.68	3.50	2.84	79.55	30.08	6.65	10.79	4.67	with tide	180.50
	75	4.02	4.05	3.46	84.45	28.35	6.40	12.26	5.17	with tide	215.60
	80	4.44	4.34	3.70	83.91	27.98	6.77	13.12	6.37	with tide	242.40
Dyneema net 5sq m doors	65			3.44	85.62		7.26	9.89	0.00	with tide	175.00
	75			3.90	85.95	29.66	6.47	11.98		with tide	216.60
	80			4.18	87.23	29.96	6.84	12.36		with tide	
	65			3.30	86.76		6.80	11.24		into tide	
	75			3.82	88.00		6.80	12.60		into tide	
	80			4.00	91.42		6.80	13.26		into tide	
Standard net 5sq m doors	65		3.00		77.50	26.66	6.99	10.68		into tide	178.00
	75		3.64		76.81	24.65	6.40	11.48		into tide	212.40
	80		3.68		78.91	25.16	6.62	11.89		into tide	232.70
	65		3.62		79.32	27.25	6.51	9.80		with tide	181.30
	75		4.24		75.09	24.58	6.25	11.38		with tide	212.80
	80		4.45		75.68	24.62	6.53	11.59		with tide	232.00

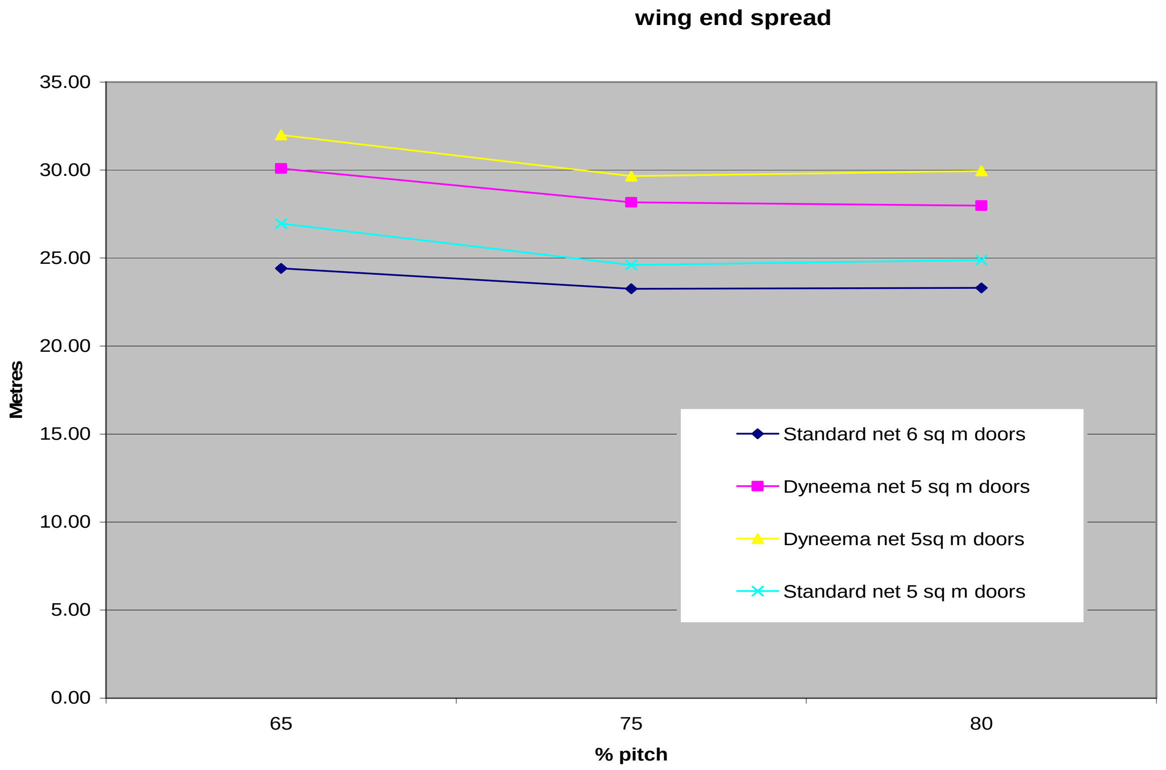
Warp tensions

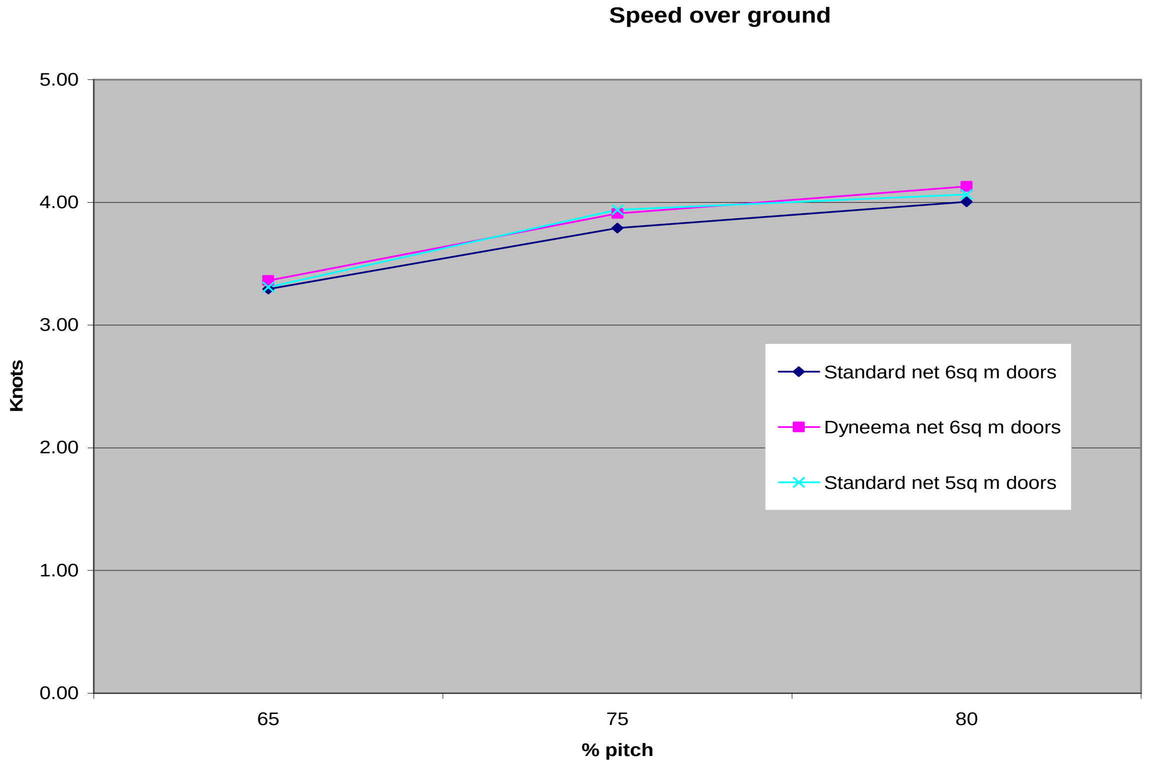


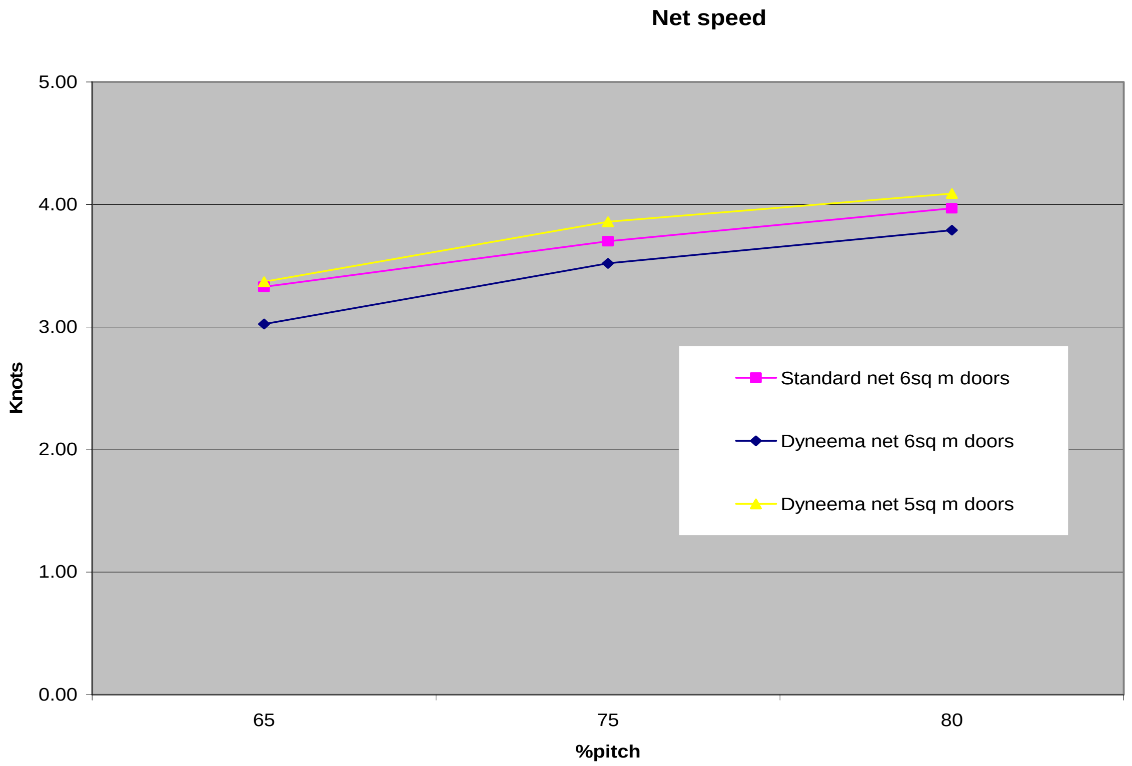
Net tensions with 6 sq m doors

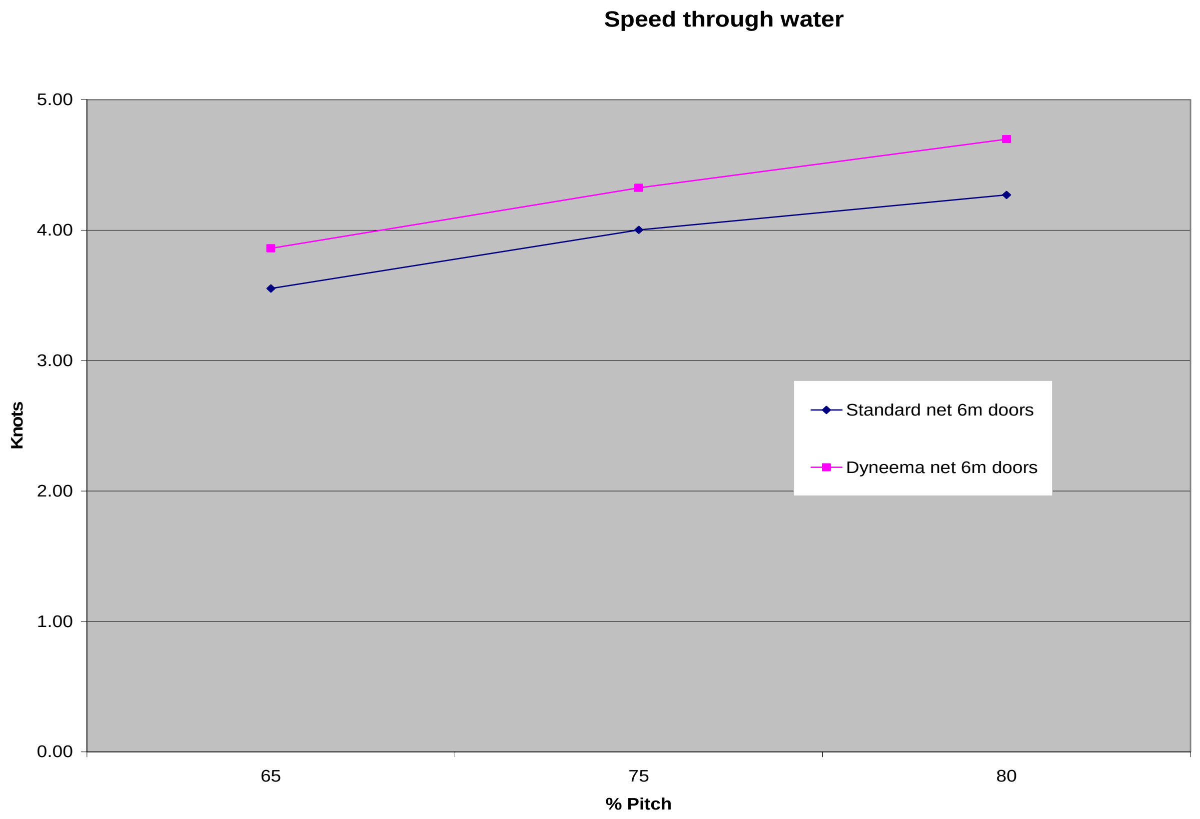



door spread
95.00
90.00
85.00
80.00
75.00
70.00
65.00
metres
65
75
80
% pitch
standard net 6 sq m doors
Dyneema net 6sq m doors
Dyneema net 5sq m doors
Standard net 5sq m doors


wing end spread
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Metres
65
75
80
% pitch
Standard net 6 sq m doors
Dyneema net 5 sq m doors
Dyneema net 5sq m doors
Standard net 5 sq m doors


Speed over ground
5.00
4.00
3.00
2.00
1.00
0.00
Knots
65
75
80
% pitch
Standard net 6sq m doors
Dyneema net 6sq m doors
Standard net 5sq m doors


Net speed
5.00
4.00
3.00
2.00
1.00
0.00
Knots
65
75
80
%pitch
Standard net 6sq m doors
Dyneema net 6sq m doors
Dyneema net 5sq m doors


Speed through water
Knots
5.00
4.00
3.00
2.00
1.00
0.00
65
75
80
% Pitch
Standard net 6m doors
Dyneema net 6m doors