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AN ENGINEERING PERFORMANCE OF 2 SINGLE TRAWLS USED BY THE SCOTTISH UNDER 10M FLEET TARGETING *NEPHROPS* IN ICES SUB AREA IV

Iain Penny

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Fisheries Research Services
Marine Laboratory
375 Victoria Road
Aberdeen AB11 9DB

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INTRODUCTION

Since early 1997 a number of high-powered trawlers, commonly known as “super under tens” have entered the under ten-metre *Nephrops* fleet. This addition has had a potentially significant effect on the effort exerted by this sector of the fleet. The average total engine power of a vessel within the under ten metre fleet has increased by 19% in the years from 1993 to 2003. This new style of vessel is designed to tow multiple trawls, have larger engine capacities and in some cases incorporate a “Kort” nozzle. Due to the restriction in length these designs incorporate a wider beam and deeper draught to aid stability. They are, in a sense, miniature distant water trawlers and are present in many ports around Scotland. These designs were originally conceived to access the non-sector *Nephrops* quota allocation, which historically had no upper catch limits and was considered by some to be “less bureaucratic” than that of a producer’s organisation. However, since 2000 upper catch limits have been introduced in part as a consequence of the increased effort exerted by these new vessels.

Since 1993 the total number of vessels in the under ten-metre fleet has steadily increased from 1562 to 1632 by 2003. These figures include the *Nephrops* creel fleet and trawl fleets. The creel fleet numbered 1421 vessels in 1993 and 1406 vessels in 2003, reaching a peak of 1527 in 1994. In comparison to the relatively stable numbers in the creel fleet the *Nephrops* trawl fleet has increased steadily from 1993 when it contained 47 vessels to its peak of 102 vessels in 2003. Between 1999 and 2003, *Nephrops* was by far the most important species landed into the U.K., contributing £52 million (20589 tonnes) by 2003. The general trends within the Scottish *Nephrops* trawl fleet at the end of the 1990’s was one of an offshore twin rig fleet and an inshore single and to a lesser extent twin trawl fleet. However, during periods of bad weather the offshore fleet did move to inshore grounds. As whitefish quotas rapidly reduced there was also a migration by the older less powerful whitefish vessels into the *Nephrops* fishery. This may have caused an increase in the effort exerted on inshore and offshore *Nephrops* grounds. Due to movement within the *Nephrops* fleet the under 10-metre class of *Nephrops* trawler initially appeared an attractive proposition to skippers. Considering the influx of former whitefish vessels onto *Nephrops* grounds, some skippers both whitefish and existing *Nephrops* men, elected to leave their Producer’s organisations and build “super under tens”. The rationale was to access the less bureaucratic non-sector quota and work inshore areas, migrating around the coast therefore maximising their fishing capabilities at different times of the year.

This report presents data comparing the single *Nephrops* trawl gear used by an older design of under ten metre vessels with that of the newer “super under ten” design. Comparisons are made between the swept areas, gear drags, trawl drags, spread parameters and mechanical efficiencies of the gears. Engineering trials were carried out on traditional Firth of Forth *Nephrops* grounds at the start of 2003. The two vessels used were MFV Osprey III (BF500), an example of this newer “super under ten” metre trawler and MFV Pegasus (KY442), an 11 year old (1991/2) vessel with a forward wheelhouse, that had only been

based in Scotland for a short period of time. Pegasus is a design typical of older Scottish inshore *Nephrops* trawlers.

Vessels and Fishing Gear

MFV Osprey III (BF500) is a steel-hulled vessel that incorporates Macduff shipyard's deepened double chine hull design with a draught of 3.2m and incorporating a bulbous bow. Launched in 2001, Osprey has an overall length of 9.98m and a beam of 4.8m. It is powered by a 3406TA Caterpillar engine that develops 239kW (320hp). It is worth noting that Osprey was designed with a "Kort" nozzle, which can provide increased static pull for the same main engine power and equivalent propeller size. The fishing gear used for the trials was the vessel's own Stuart prawn "Discer" trawl. The trawl has a fishing circle of 600 meshes x 80mm and headline and footrope lengths of 64.9m and 72.6m respectively. The trawl was fished using a sweepline length of 77.7m and spread using 1.89m^2 "Dunbar Hi-Flite" doors.

MFV Pegasus (KY442) is a steel hulled vessel built in 1991/2 with an overall length of 9.99m and beam of 4.6m. Depth of draft was 14% less that Osprey's at 2.8m. A Cummins engine provided the power of 192kW (257hp). Pegasus was able to offer two nets for testing, a *Nephrops* "Scraper" trawl and a *Nephrops* "Discer" trawl, used for harder ground, an evolution of the clean trawls with rubber discs and in some cases shorter wings. The "Scraper" trawl has a headline and fishing line length of 19.8m and 25.2m respectively. The "Discer" trawl, a more suitable comparison with the gear towed by Osprey, has a headline and fishing line length of 29.6m and 30m respectively. It should be noted that there is a marked difference in the size of the trawls towed by the two vessels. The Pegasus "Discer" net has a much shorter headline and fishing line, 45% and 41% respectively of that of Ospreys. This difference between the trawls is not as pronounced when focusing on the number of meshes present in the fishing circle, 560 meshes of 80mm, evaluating to some 93% of Osprey's fishing circle. The "Scraper" and "Discer" trawls were fished with sweepline lengths of 39.4m and 38.8m respectively. Both sets of trawls were fished using 1.74m^2 "Dunbar Vee" doors. It should be noted that these doors are larger than would be expected for these single trawls; however, the vessel also uses these doors to spread its twin rig trawl gear by adjusting the hydrodynamic efficiency of the doors.

Instrumentation

The resultant trawl speeds were taken from the net-log flow meter. Mean values of wing spread, door spread, sweep angle and tensions were calculated by averaging each reading once the gear had settled.

Loads on each trawl were measured using the Marine Laboratory's shear pin tension meters. These were shackled into three positions on each trawl (at the tow ends, ahead of the doors and aft of the deck towing bar, exact positions are shown in *figs.16-18*). These tension meters are self-recording and are accurate to better than 1% of full scale (*Urquhart, 1981*). The information is stored on 16 bit solid-state memories. These readings were downloaded to a laptop computer and stored for further analysis at the end of each day.

Wing-end and door spreads were measured using Scanmar sensors. An attempt was made to evaluate the headline height of the gear but this proved to be out-with the effective range (under 2m) for the Scanmar sensors. The operational range of the Scanmar HT-60 height sensor used is quoted as being 1.5m to 60m. A delay mechanism (time gate) is incorporated into the sensor circuitry to ensure that the sensor will not accept a return signal until after the transducer has stopped vibrating from the transmit pulse. At the short ranges encountered the return signal arrived back at the sensor within the gated period and was therefore excluded.

The Marine Laboratory's own Net-log flow meter was attached to the underside of the top sheet of the trawl in the centre of the square to record the speed through the water. This system counts the number of revolutions in a ten second period and then writes this to a memory. The net log was mounted on gimbals and measures the resultant velocity of the trawl relative to the local water flow. The data was downloaded to a laptop computer at the conclusion of each day for later analysis.

A Garmin GPS75 unit was used for positional and groundspeed outputs. Water depth, weather conditions, vessel speed, propeller pitch and engine revolutions were recorded manually.

METHODS AND PROCEDURES

The first cruise onboard MFV Osprey III was undertaken at the end of January 2003 and was conducted within the sheltered waters of the Firth of Forth. Three fully instrumented hauls were carried out using Osprey's prawn scraper trawl. All of the tows were conducted in water depths of 34-45m; warp length of 135m was used for all the valid tows.

Trials onboard MFV Pegasus were undertaken the following week in the same area. Pegasus's "Discer" trawl was tested first and three fully instrumented hauls were carried out. The water depth varied between 32m and 43m and a warp length of 135m was used again.

MFV Pegasus's "Scraper" trawl was then tested similarly, with 3 fully instrumented hauls being carried out. The water depths varied between 32m and 59m. The increase in depth range was due to poor weather conditions, which resulted in a change of fishing grounds for one day, but the warp length used, remained at 135m.

The daily procedure for all three cruises remained the same throughout, with instrumentation being fitted to the gears each morning followed by two, 2-hour tows. Four blocks of 15 minutes duration at systematically varied speeds were carried out and then repeated on a reciprocal course as per ICES recommendation (1981). All tows included had full sets of reciprocal blocks completed.

RESULTS

The gear performance data for each haul can be seen in Tables 1-9. All gear parameters have been plotted against resultant trawl speed and appear in Figures 1-14.

The net drag and total gear drags were derived from the load cell mean values resolved horizontally and vertically in the direction of travel.

Sweep angle is calculated assuming that back strops and sweeps are straight.
The spreads, tensions, swept area and power of the three gears were assumed to be a linear function of towing speed over the data range with the following form: -

$$g = s * b + a$$

Where ***g = gear variable***
s = commercial towing speed
a and b = regression parameter

Values for a and b were calculated for each gear variable using linear regression using the combined data for each gear.

Power (kW) was calculated once total net drag had been resolved horizontally and vertically using the formula: -

$$Power = \frac{dvK}{1000}$$

Where ***d = total gear drag (kgf)***
v = velocity (knots)
K= velocity conversion constant

The calculated performance parameters are shown in Table 10.

CONCLUSIONS

The three gears that have been investigated show some quite significant differences. The Osprey's trawl is as expected, by far, the biggest with the highest drag and spread parameters of the three. It is also worth noting that Osprey also has the lowest sweep angle (8^0) of the three trawls which can be explained as a consequence of the longer sweeps that are employed. To accommodate the skipper's desire for flexibility, the longer sweeps were attractive allowing varying water depths to be fished. This sweep configuration should prevent over spreading of the trawl in deeper water.

When the Osprey's "Discer" trawl is compared directly with that of the Pegasus it is clear that the power required to tow Osprey's trawl is higher (18.2kW compared to 14.8kW respectively). Osprey has a larger door spread than that of Pegasus with the total swept area per hour between the doors being 36% greater.

The increased capacity, both in towing and handling fishing gear, has allowed Osprey to increase the swept areas markedly over that of Pegasus. The nature of a *Nephrops* trawl dictates that the best performance indicator for comparison is trawl swept area as there is little or no herding effect from the sweeps, making the area within the wing ends critical.

Osprey's trawl swept area per hour is 45% greater than that of Pegasus's at a cost in terms of gear power of 22% more than that of Pegasus. Therefore in terms of effort Osprey is justifying the increased drag and power usage brought about by the larger fishing gear by sweeping a much larger area than that of Pegasus and potentially increasing catching capacity (Table 10). .

Pegasus's "Scraper" trawl proved to be too light for the Dunbar doors that were used to spread it in conjunction with the sweeps used. This is a compromise between the two nets and the desire to twin rig, allowing the different sets of gear to be switched over without the added time incurred to fine-tune the set up. As can be seen in Figures 17 and 18 the actual wire rig and doors do not change at any time. This trawl has significantly less drag (719kgf at 2.3 knots) than Pegasus's "Discer" trawl. This is highlighted further on seeing the wing-end spread and door spread for this trawl exceed that of the Discer net at 2.3 knots. This all leads to a sweep angle that is understandably high at 12.3°. The lack of drag in this trawl then in turn affects the calculated area versus drag figures and the trawl area per gear kW figure, making them unnaturally high. In reality it is probable that this trawl may have been light in its bosom with the possibility of lifting occurring.

ACKNOWLEDGEMENTS

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TABLE 1

MFV Osprey III BF 500

Haul 3	Trawl Swept Area (m^2/hour)	67075	Total Swept Area (m^2/hour)		164506		
Block Number	Resultant Trawl Speed (kts)	Ground Speed (kts)	Door Spread (m)	Wing-end Spread (m)	Sweep Angle (degrees)	Trawl Drag (kgf)	Total Gear Drag (kgf)
1	2.3	2.6	37.8	15.3	8.46	994	1555
2	2.5	2.8	37.1	15.1	8.30	1152	1774
3	2.0	2.3	36.9	15.3	8.13	871	1405
4	2.3	2.5	35.7	14.7	7.92	1027	1607
5	2.5	2.5	35.3	14.3	7.91	1116	1718
6	2.9	2.9	34.5	13.6	7.85	1427	2107
7	2.2	2.1	35.4	14.7	7.80	888	1403
8	2.5	2.5	32.8	13.5	7.26	1140	1693

Table 2

Haul 4	Trawl Swept Area (m^2/hour)	66637	Total Swept Area (m^2/hour)		164045		
Block Number	Resultant Trawl Speed (kts)	Ground Speed (kts)	Door Spread (m)	Wing-end Spread (m)	Sweep Angle (degrees)	Trawl Drag (kgf)	Total Gear Drag (kgf)
1	2.7	2.5	36.5	14.7	8.21	1106	1741
2	3.1	3.0	36.8	14.8	8.27	1420	2178
3	2.3	2.2	36.7	15.1	8.13	905	1488
4	2.6	2.5	36.3	14.6	8.16	1139	1810
5	2.4	2.5	35.0	14.6	7.67	1022	1615
6	2.8	2.8	34.6	14.0	7.79	1281	1948
7	2.3	2.2	35.2	14.3	7.87	915	1471
8	2.6	2.5	33.8	13.6	7.61	1110	1702

TABLE 3

MFV Osprey III BF 500

Haul 5	Trawl Swept Area (m^2/hour)	67116	Total Swept Area (m^2/hour)		164506		
Block Number	Resultant Trawl Speed (kts)	Ground Speed (kts)	Door Spread (m)	Wing-end Spread (m)	Sweep Angle (degrees)	Trawl Drag (kgf)	Total Gear Drag (kgf)
1	2.2	2.5	37.2	15.2	8.31	933	1538
2	2.5	2.9	36.8	14.9	8.24	1161	1850
3	2.0	2.2	37.2	15.5	8.17	762	1309
4	2.1	2.5	35.8	14.8	7.92	899	1495
5	2.7	2.5	36.0	14.4	8.12	1177	1859
6	3.1	2.8	33.9	14.0	7.50	1682	2467
7	2.6	2.2	35.3	14.3	7.92	1039	1641
8	2.8	2.5	33.3	13.5	7.46	1257	1878

TABLE 4

MFV Pegasus KY 442 “Discer” Trawl

Haul 1	Trawl Swept Area (m^2/hour)	38575	Total Swept Area (m^2/hour)		110131		
Block Number	Resultant Trawl Speed (kts)	Ground Speed (kts)	Door Spread (m)	Wing-end Spread (m)	Sweep Angle (degrees)	Trawl Drag (kgf)	Total Gear Drag (kgf)
1	2.7	2.5	25.4	8.9	12.37	1012	1399
2	3.2	2.9	24.1	8.5	11.67	1178	1599
3	2.4	2.2	25.1	8.8	12.23	851	1222
4	2.7	2.5	24.5	8.6	11.93	967	1367
5	2.0	2.5	24.7	8.5	12.14	786	1141
6	2.7	3.0	24.3	8.2	12.10	918	1330
7	1.8	2.2	21.7	7.7	10.51	692	1008
8	2.2	2.5	21.5	7.7	10.36	900	1251

TABLE 5

Haul 2	Trawl Swept Area (m^2/hour)	36599	Total Swept Area (m^2/hour)		101041		
Block Number	Resultant Trawl Speed (kts)	Ground Speed (kts)	Door Spread (m)	Wing-end Spread (m)	Sweep Angle (degrees)	Trawl Drag (kgf)	Total Gear Drag (kgf)
1	2.1	2.4	21.8	8.0	10.32	888	1221
2	2.8	2.9	21.4	7.6	10.38	1202	1592
3	1.9	2.1	22.2	7.8	10.84	833	1156
4	2.3	2.5	22.2	7.8	10.80	901	1258
5	2.0	2.4	23.9	8.3	11.66	705	1046
6	2.4	2.9	24.5	8.4	12.03	871	1252
7	1.9	2.3	20.8	8.3	9.45	714	1017
8	1.7	2.4	20.0	7.8	9.19	838	1154

TABLE 6

MFV Pegasus KY 442 “Discer” Trawl

Haul 3	Trawl Swept Area (m^2/hour)	36300	Total Swept Area (m^2/hour)		102758		
Block Number	Resultant Trawl Speed (kts)	Ground Speed (kts)	Door Spread (m)	Wing-end Spread (m)	Sweep Angle (degrees)	Trawl Drag (kgf)	Total Gear Drag (kgf)
1	2.6	2.4	25.3	8.7	12.42	945	1333
2	3.1	2.8	22.9	7.9	11.25	1190	1514
3	2.4	2.2	23.2	8.0	11.34	918	1284
4	2.8	2.6	23.2	8.0	11.41	1059	1476
5	2.0	2.4	22.0	7.9	10.61	788	1129
6	2.7	2.9	21.8	7.5	10.69	1109	1508
7	1.8	2.2	19.9	7.6	9.24	781	1097
8	2.2	2.6	20.0	7.3	9.58	988	1332

TABLE 7

MFV Pegasus KY 442 “Scraper” Trawl

Haul 5	Trawl Swept Area (m^2/hour)	42230	Total Swept Area (m^2/hour)		137894		
Block Number	Resultant Trawl Speed (kts)	Ground Speed (kts)	Door Spread (m)	Wing-end Spread (m)	Sweep Angle (degrees)	Trawl Drag (kgf)	Total Gear Drag (kgf)
1	2.2	2.4	31.2	9.8	12.88	412	715
2	2.9	3.0	27.7	8.3	11.63	552	848
3	1.9	2.1	31.1	9.9	12.68	342	616
4	2.9	2.6	27.2	8.1	11.46	532	871
5	3.2	3.0	26.2	7.9	11.01	637	988
6	2.3	2.2	29.2	9.3	11.97	433	712
7	2.4	2.5	30.2	9.2	12.63	456	771
8	2.9	2.9	27.2	8.1	11.43	571	929

TABLE 8

Haul 7	Trawl Swept Area (m^2/hour)	38296	Total Swept Area (m^2/hour)		129845		
Block Number	Resultant Trawl Speed (kts)	Ground Speed (kts)	Door Spread (m)	Wing-end Spread (m)	Sweep Angle (degrees)	Trawl Drag (kgf)	Total Gear Drag (kgf)
1	2.7	2.4	31.1	8.7	13.45	532	771
2	3.2	2.8	27.8	7.8	12.05	633	881
3	2.6	2.1	29.4	8.4	12.67	473	632
4	2.9	2.5	26.0	7.4	11.19	561	788
5	2.1	2.5	27.8	8.5	11.69	418	697
6	2.5	2.9	28.7	8.4	12.20	513	508
7	1.8	2.1	27.7	9.1	11.24	364	586
8	2.2	2.5	28.7	8.7	12.11	430	710

TABLE 9

MFV Pegasus KY 442 “Scraper” Trawl

Haul 8	Trawl Swept Area (m^2/hour)	40178	Total Swept Area (m^2/hour)		140659		
Block Number	Resultant Trawl Speed (kts)	Ground Speed (kts)	Door Spread (m)	Wing-end Spread (m)	Sweep Angle (degrees)	Trawl Drag (kgf)	Total Gear Drag (kgf)
1	2.3	2.6	31.1	8.9	13.35	456	738
2	2.8	2.9	30.9	8.5	13.51	574	903
3	2.0	2.2	29.9	9.0	12.60	409	687
4	2.4	2.5	30.0	8.5	12.89	485	795
5	2.5	2.6	28.6	8.2	12.26	503	831
6	3.0	3.1	28.4	7.8	12.40	635	997
7	2.2	2.3	28.6	8.2	12.27	412	695
8	2.4	2.5	29.7	8.5	12.75	483	788

TABLE 10

Gear and efficiency parameters of each Trawl calculated for typical towing speeds

	Towing Speed (knots)	**Sweep Angle** (degrees)	**Wing-end Spread** (m)	**Door Spread** (m)	**Trawl Drag** (kgf)	**Total Gear Drag** (kgf)	**Trawl Swept Area** (m^2/hour)	**Total Gear Swept Area** (m^2/hour**)**	**Gear** (kW)	**Trawl Swept Area per Kg Drag** (m^2/kgf**)**	**Total Gear Swept Area per kg Drag** (m^2/kgf)	**Net Area swept per gear kW** (m^2/kW)
Osprey "Discer" Trawl	**2.3**	**8.0**	**14.8**	**36.0**	**976**	**1557**	**66943**	**164352**	18.1	**68.6**	**105.5**	3704
Pegasus "Discer" Trawl	**2.3**	**10.9**	**8.1**	**22.6**	**902**	**1259**	**37158**	**104644**	14.6	**41.2**	**83.1**	2542
Pegasus "Scraper" Trawl	**2.3**	**12.3**	**8.8**	**29.3**	**449**	**719**	**40235**	**136133**	8.3	**89.6**	**189.5**	4824

MFV Osprey III BF 500

Figure 1: (shaded points indicate speed blocks ahead of the tide**)**

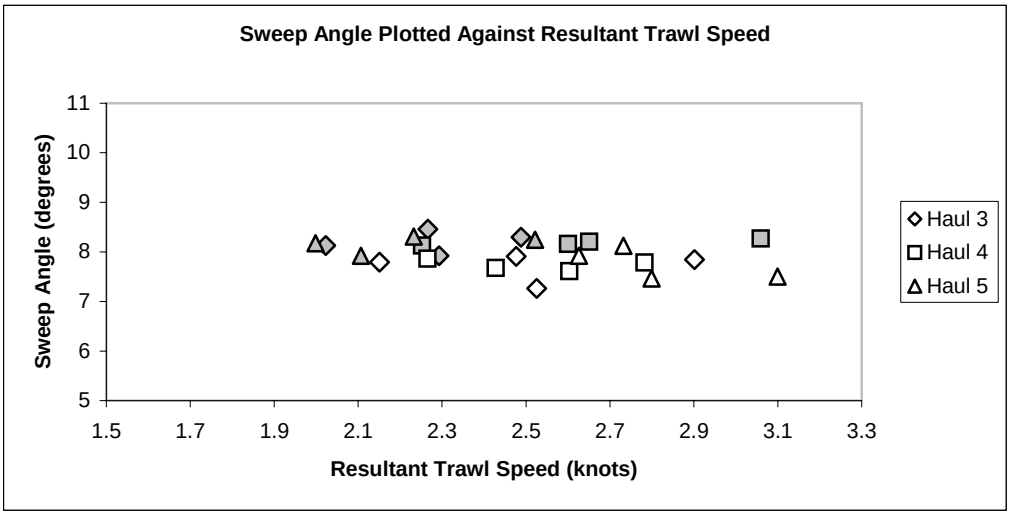


Figure 2:

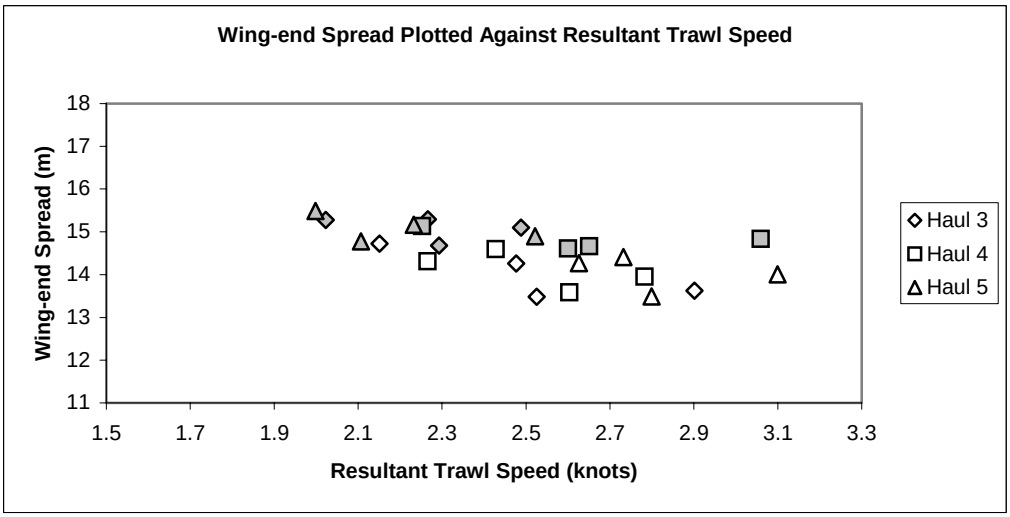
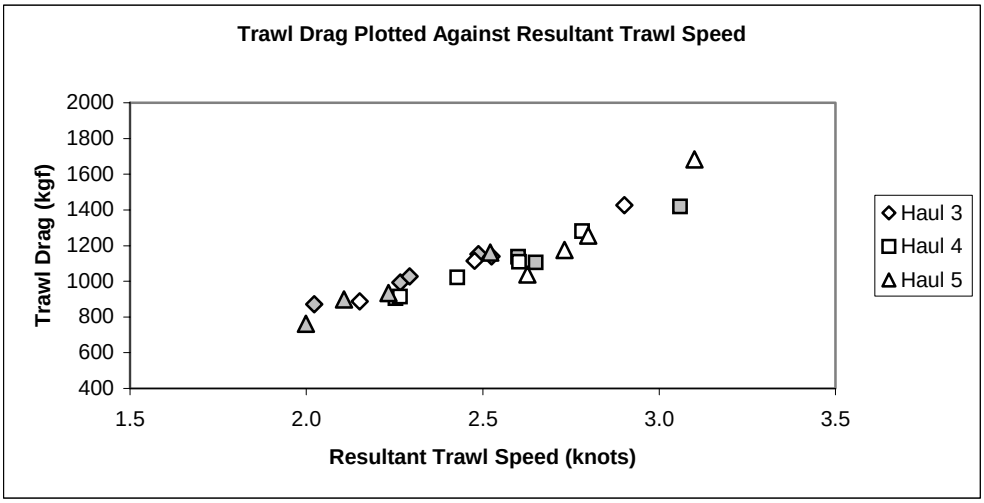


Figure 3:

MFV Osprey III BF 500

Figure 4: (shaded points indicate speed blocks ahead of the tide)



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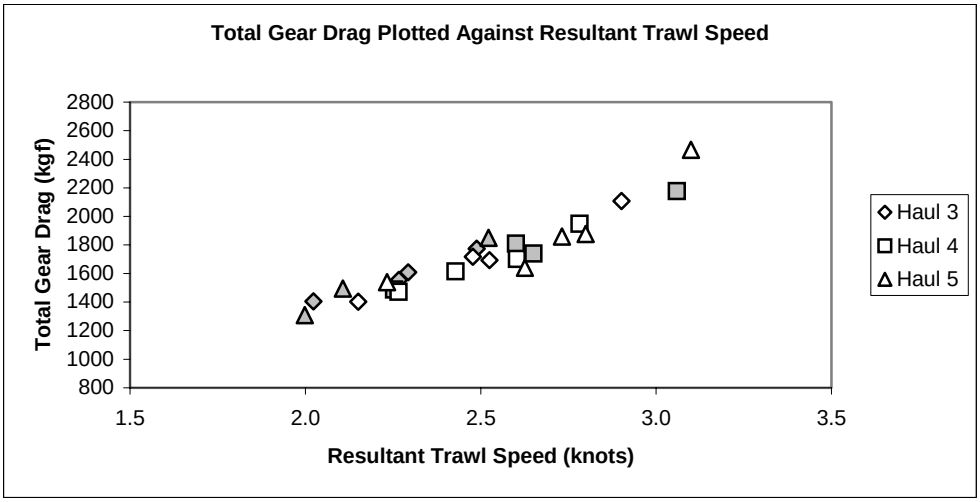
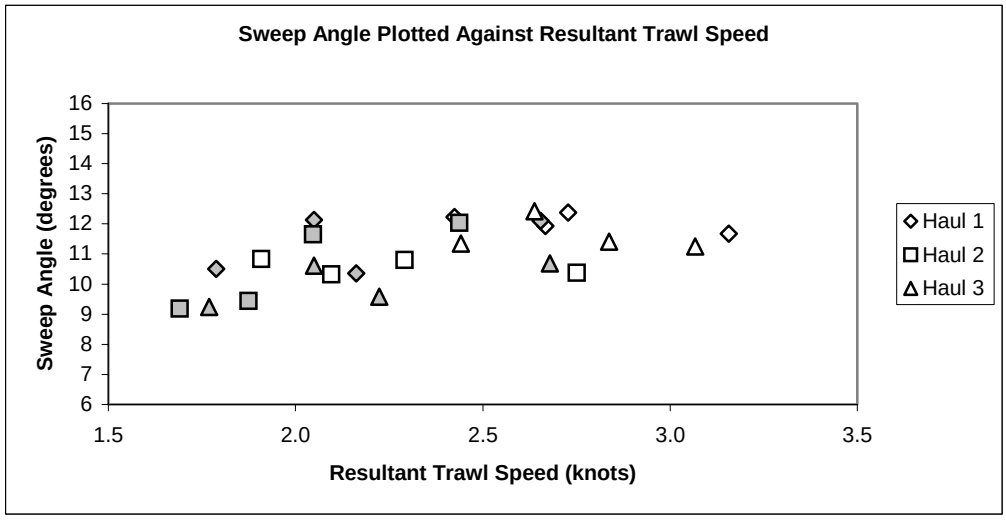


MFV Pegasus KY 442 “Discer” Trawl

Figure 6: (shaded points indicate speed blocks ahead of the tide)



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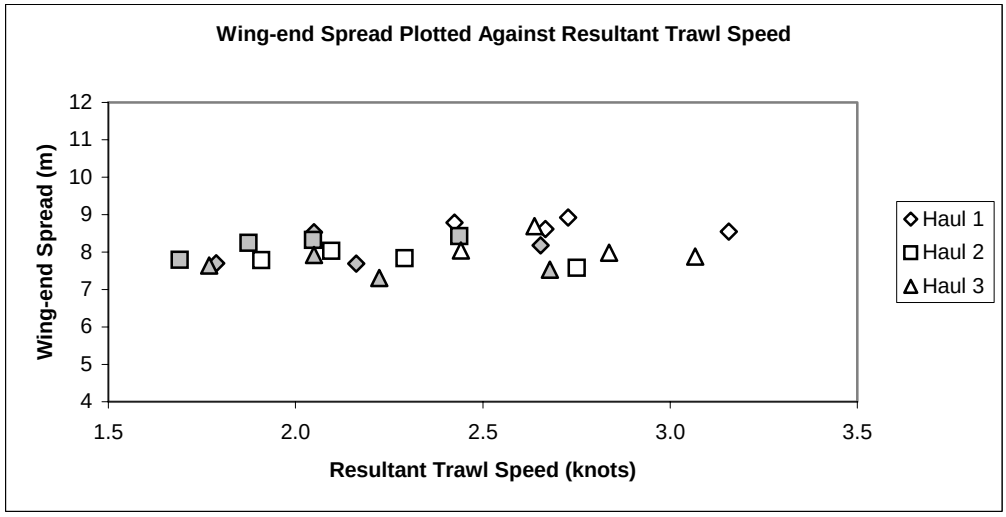


Figure 8:

MFV Pegasus KY 442 “Discer” Trawl

Figure 9: (shaded points indicate speed blocks ahead of the tide)

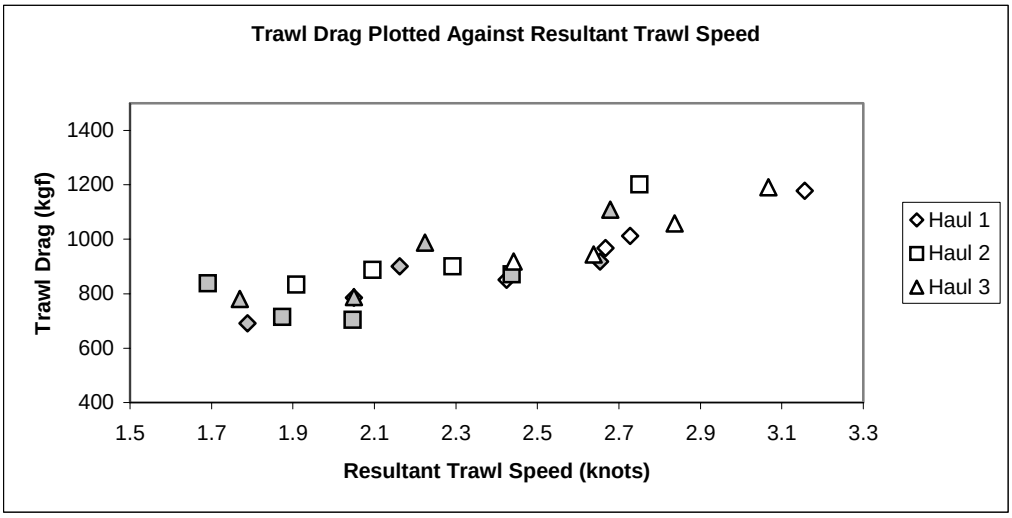
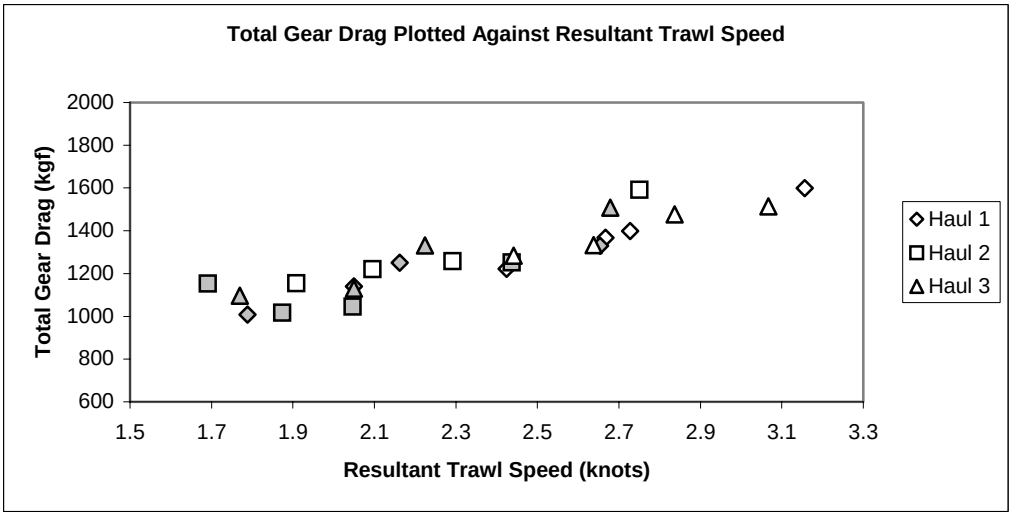


Figure 10:



MFV Pegasus KY 442 “Scraper” Trawl

Figure 11: (shaded points indicate speed blocks ahead of the tide)

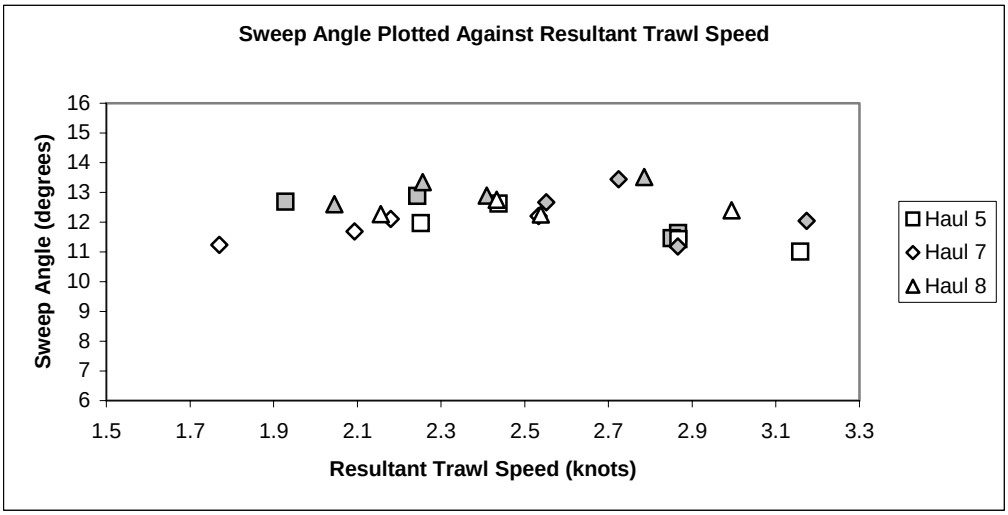
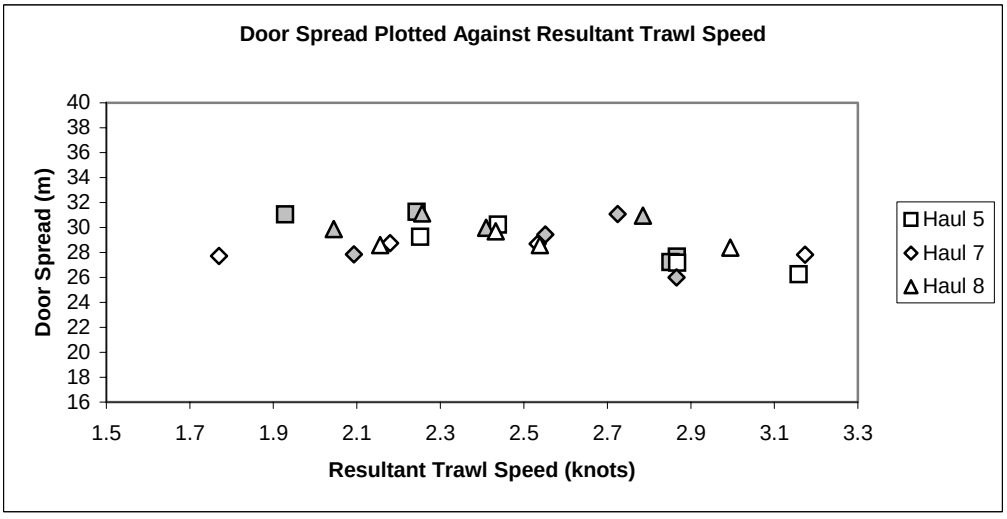


Figure 12:

Figure 13:



MFV Pegasus KY 442 “Scraper” Trawl

Figure 14: (shaded points indicate speed blocks ahead of the tide)

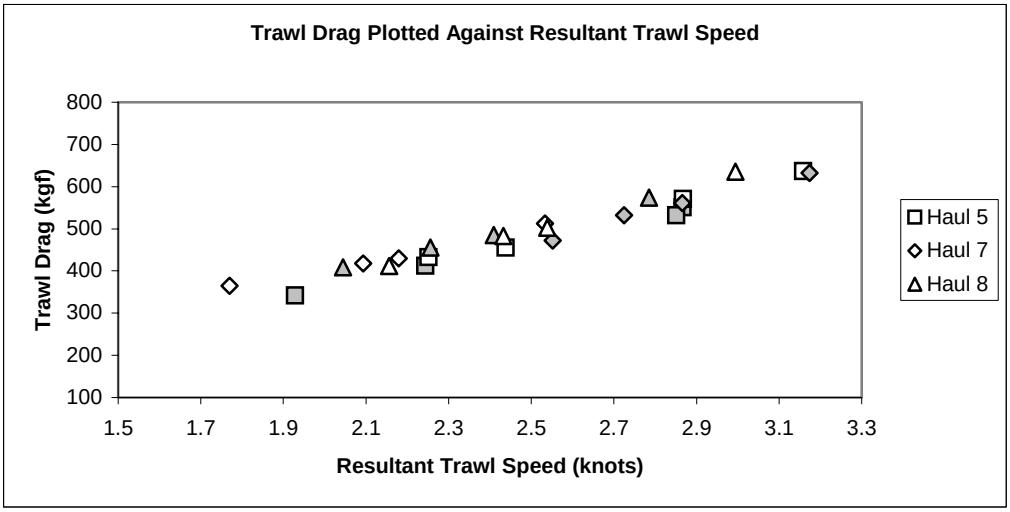
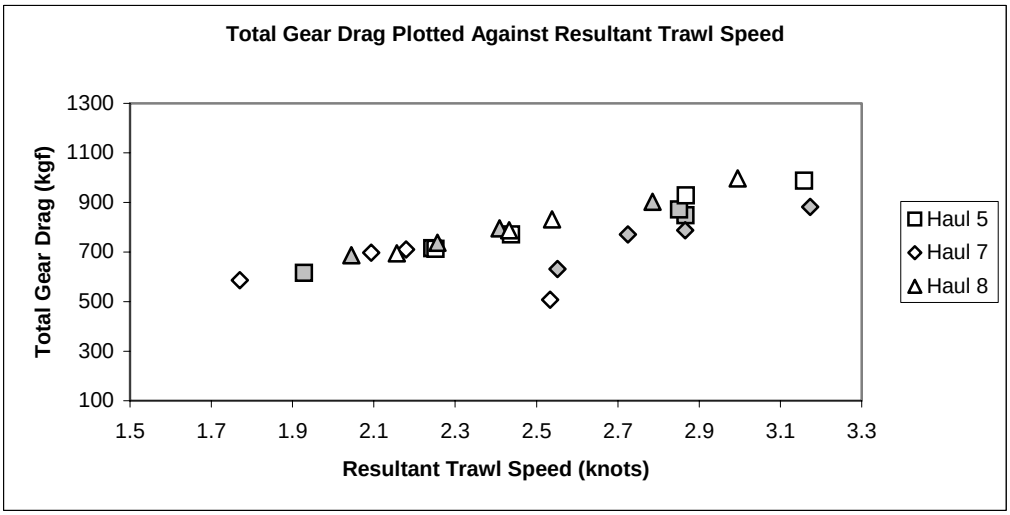
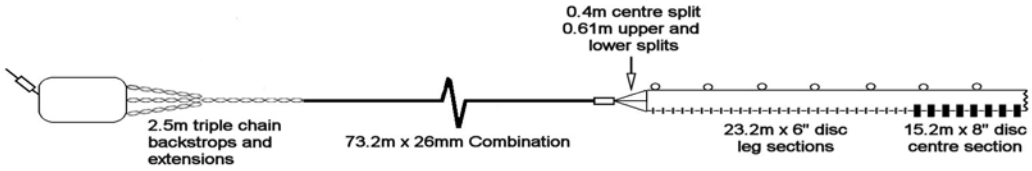


Figure 15:



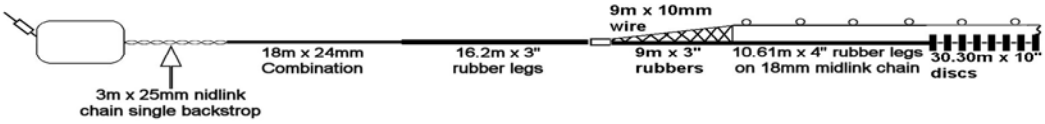
MFV Osprey III BF 500 Wire and Ground Rig

Figure 16:



MFV Pegasus KY 442 “Discer” Trawl Wire and Ground Rig

Figure 17:



MFV Pegasus KY 442 “Scraper” Trawl Wire and Ground Gear

Figure 18:

MFV Osprey III BF 500

MFV Pegasus KY 442