Assessment of pair fishing towards more efficient targeting of demersal fish species

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Assessment of pair fishing towards more efficient targeting of demersal fish species

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Key Findings

- 40% reduction in fuel use
- 29% increase in catches
- 32% increase in profitability
- Major scope for scale-up in the Irish whitefish sector

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Introduction

Energy efficiency is a key challenge facing the Irish fishing Industry. In the long term, the European Commission is seeking to align taxation with climate objectives under the European Green Deal which aims for net zero carbon emissions by 2050. This will likely lead to increased taxes on fossil fuels to encourage development and transition to use of more sustainable fuels, with marine engine and fuel infrastructure technologies endeavouring to keep pace.

The energy crisis is driving on such developments. Faced with a 150% increase in fuel prices between 2021 and 2022 (BIM, 2022) short-term measures are needed to maintain the commercially viability of current fishing operations. Gear technology has a role to play in this regard.

Most fishing for demersal species such as haddock, whiting and hake in Ireland is carried out by individual or 'solo' vessels using bottom-towed gears such as trawls or seines. Commonly used in other parts of the world, bottom-pair trawling or seining where two vessels tow the net was identified as a potentially more energy efficient fishing method.

This study aims to assess the practicalities, catching performance, energy and economic efficiency of pair trawling in a fishery targeting mixed-demersal fish species in the Celtic Sea.

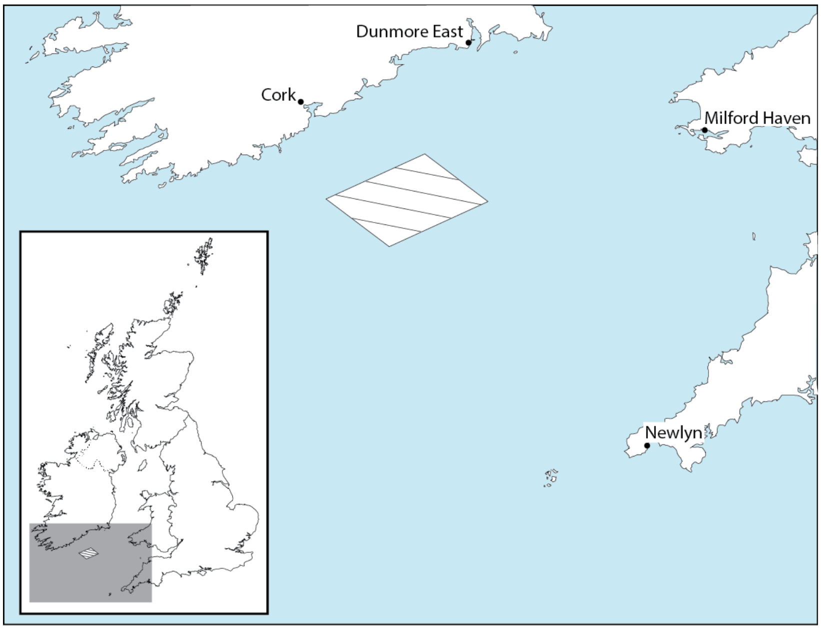

Figure 1. The trial location (hatched area)

Methods

<u>Fishing operations and gear</u>

The pair-trawl trial was conducted on board two 25 m trawlers targeting mixed-demersal fish species in the Irish sector of ICES Divisions 7g and 7j in the Celtic Sea in October 2022 (Figure 1). Due to rigging and logistical constraints, it was not possible to conduct alternate hauls using pair and solo trawling.

Instead, we qualitatively compared data obtained during pair trawling with the following data sources from solo operations:

- Operational data such as fuel use and engine load were obtained from subsequent solo trips by the trial vessels in November 2022 in ICES division 6a
- Gear performance data on wing-end and door spread from a previous solo trip on board one of the trial vessels in the same general area as the pair fishing trial
- Catch data from a similarly sized solo vessel operating in the same area at the same time

Table 1. Gear characteristics

	Pair	Solo
Vessels	Two	One
Trawl doors	No	Yes
Headline length (m)	51	51
Ground gear	Hopper discs	Hopper discs
Warp diameter (mm)	22	22
Sweep/bridle Length: singles (m)	669	105
doubles (m)	55	55
Diamond cod end nominal mesh size (mm)	120	120
Nominal twine thickness (mm)	4 (double)	4 (double)

The main difference between pair and solo trawling is the absence of otter doors and much greater sweep lengths in pair trawling. Irish solo trawlers targeting demersal fish typically use a single-rig trawl with ≥ 700 kg trawl doors and ≥ 110 m sweeps. Comprising a mixture of combination (wire rope) and wire diameters, the sweeps used during pair trawling were ~ 4.5 times greater in length than the normal 'solo' sweep arrangement. The same single-rig trawls and 120 mm mesh codends were used in both pair and solo operations on board the trial vessels (Figure 2, Table 1).

The pair vessels used 38 mm combination rope which replaces use of a clump weight near the double bridles which was formerly used by pair trawlers to weigh down the sweeps. Up to 640 m of wire warp was deployed depending on the depth fished. Pair vessels operated a maximum of 550 m apart with the lead vessel, which deployed and retrieved the net, always operating to the port side of the other vessel. Typically, pair and solo vessels use a towing warp to depth ratio of between 3 and 5 to 1. Greater ratios are often used to ensure that the gear is heavy on the ground, but compromises are required depending on the depth and amount of warp available on the vessel.

Swept area provides a measure of the area fished by towed gears and is generally correlated with catches (Jones et al., 2021). Hence, estimation of this parameter contributes greatly towards assessment of efficiency of different gears.

To estimate swept area we first needed to calculate the maximum distance between sweeps or 'sweep divergence'. Sweep divergence for the solo trawl is simply the door spread.

The solo vessel swept area (km^2) was calculated as:

Vessel speed (ms^{-1}) × haul duration (sec) × door spread (km) ÷ 1000

Sweep divergence in pair vessels occurs where the sweeps join to the towing warps and we needed to derive the sweep angle to get this value (Seafish, 2010):

Vessel distance was initially used to obtain the sweep angle under the assumption that the warps continued at the same angle as the sweeps - angle A in Figure 3 - to the vessel. This angle was applied to the sweep length to estimate the sweep divergence. The following trigonometry function was used to calculate the sweep angle based on a right-angle triangle:

Sin (length of opposite)/ length of hypotenuse

where hypotenuse = sweep and warp length, opposite = (vessel distance - wing spread)/2

A second function was then applied to calculate the sweep divergence:

Sweep divergence = (((Sin(sweep angle)) × sweep length) × 2) + wingspread

The pair trawl swept area (km^2) was subsequently calculated as:

Vessel speed (ms^{-1}) × haul duration (sec) × sweep divergence (km) ÷ 1000

Operational data including fuel use (L/hr), engine load, vessel distance, and door spreads were collected by skippers up to six times per haul during pair and solo trawling. We deployed Marport wing end and headline sensors during pair trawling to obtain additional information on gear performance.

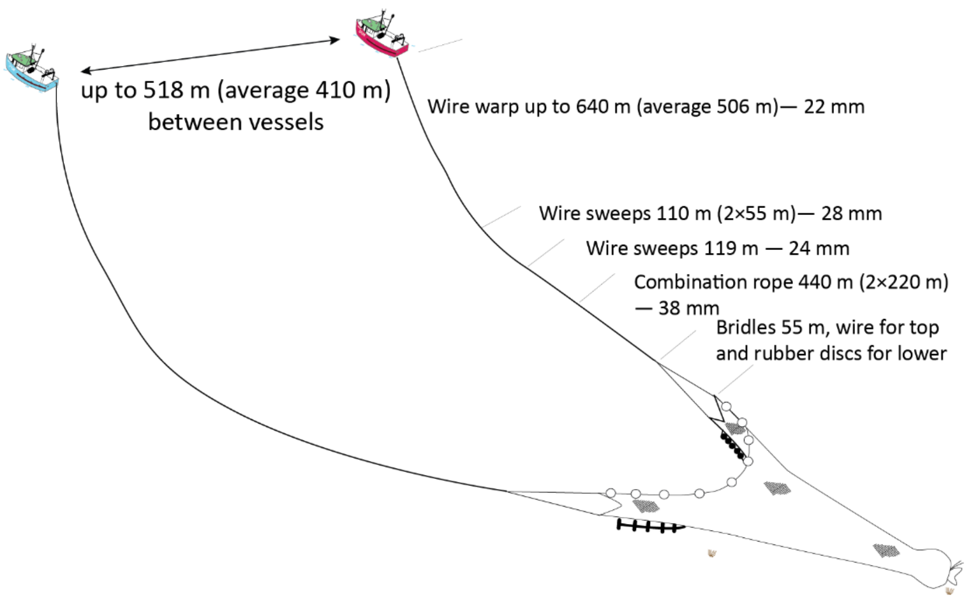

Figure 2. Pair trawl configuration used in the trial

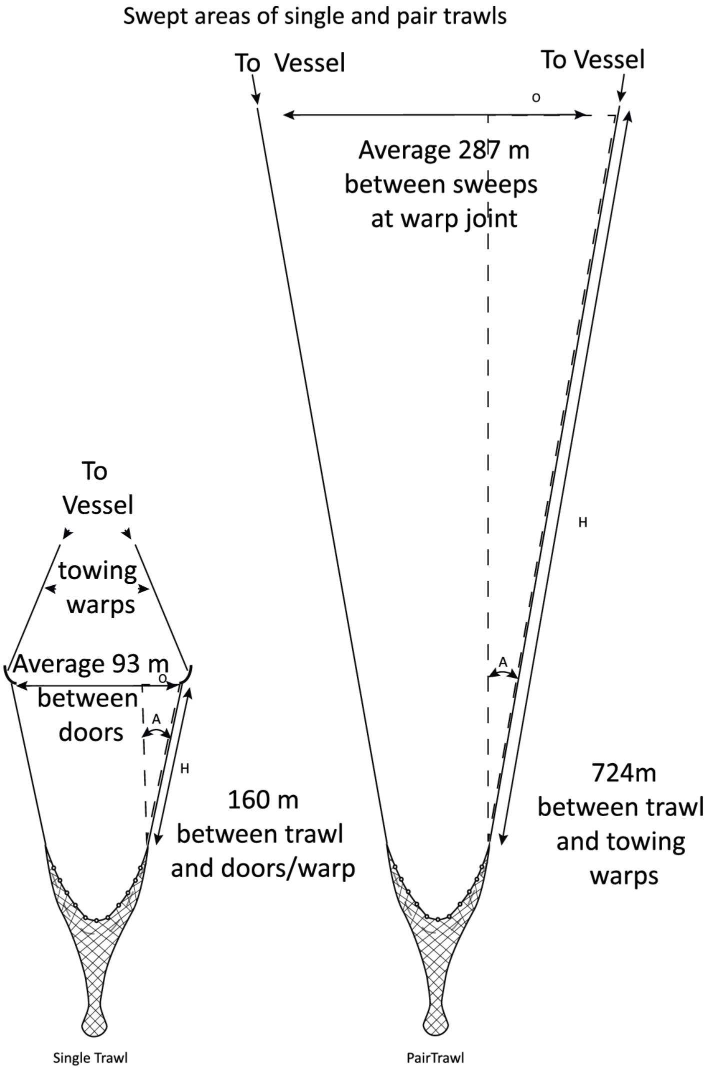

Figure 3. Graphical representation of swept areas in solo and pair trawl configurations. O (opposite); H (hypotenuse); A (sweep angle)

Catch sampling

The vessels took it in turn to shoot and haul their nets during the trial. Three random representative samples of fish were taken from the conveyor belt around the start, middle, and end of catch sorting. All random samples were weighed, and sampled fish were separated to species level, measured to the nearest cm below and raised to estimated bulk weights for each haul to provide length frequency distributions. Length weight relationships (Silva et al., 2013) were used to derive total catch weights by species and catches in relation to minimum conservation reference size (MCRS).

Four hauls (two day and two night) which were similar in haul duration and relatively close in space and time were compared to assess potential diurnal differences in catch rates.

Economics

An economic questionnaire was used to collect cost per trip information from both pair-trawl vessels in the following categories:

- Capital costs - repayments
- Fixed Costs – fuel during steaming, ship maintenance, duties, levies, port fees, insurance
- Variable Costs – fuel during fishing, food, ice, transport of landings, net mending, crew telephone and broadband

The vessels also provided sales notes which contained gross income for the pair-trawl trip. A 24 m individual or 'solo' bottom trawl vessel was also operating in the same general geographic area during the trip and close contact was maintained between pair and solo-trawl operations to compare landings. The solo vessel provided information on the total number of hauls and boxes of fish they landed during the trip.

Using the above information and operational data collected by the trial vessel skippers during pair and solo fishing trips, an economic comparison of pair and solo trawling was carried out under a number of assumptions:

- The pair vessels travelled from Donegal to the Celtic Sea to do the trial and then returned to port incurring a round trip in excess of 1000 km which cost ~ €6000 for fuel per vessel. Normally these vessels conduct a trip towards the end of one month and at the start of the following month to avail of quotas in both months. To provide a more realistic economic assessment, we assumed that the vessels conducted two trips instead of one, retained the same cost of fuel use during steaming, and doubled all other costs and revenues.

- The pair vessels completed 10 observed valid hauls while the solo vessel operating in the same time and place did 9 so landings were standardised to 10 hauls and doubled to cover two trips.

- The economic value of each box of fish landed by the solo trawler was assumed to equate to the economic value of each box landed by the pair-trawl vessels.

- Transport of landings costs for the solo vessel were based on the transport costs for a pair vessel, standardised to the quantity of fish landed by the solo vessel.

- Mean economic values of the pair trawlers were compared with the solo trawler to provide an effective comparison.

- Crew wages were based on (gross profit less total costs)/2 for each of the pair vessels. The solo vessel did not turn a profit so their wages were standardised by catch values for comparative purposes:

  Solo vessel wages = (pair vessel wages)*(solo vessel catch value/pair vessel catch value)

- Profit rate was estimated as net profit/catch value.

Results

A total of 10 valid hauls were carried out over four consecutive fishing days on board the pair trawl vessels. Mean haul duration, vessel speed, and depth fished during the trial were 4 hrs 45 min, 3.2 kt and 84 m respectively. Wind speed ranged from light air to near gale or 9 – 50 km^{-h}.

The main commercial fish species caught were haddock, hake, plaice, lemon sole, whiting and cod, representing 86% of the total catch by weight (Table 2). Catches below minimum conservation reference size (MCRS) were generally low at ≤ 2% for haddock and whiting and 0% for hake and cod. Undersize plaice catches were marginally greater at 8% (Table 3; Figure 4).

Relatively little difference occurred in catches during night-time. Catches of haddock, the main species landed, were reduced by 20% during hours of darkness. Hake catches were also reduced at night-time by 53% but overall catches of this species were relatively low (Figure 5).

Table 2. Total combined catch weights for the pair trawlers

Species	Weight (kg)
Haddock	11,601
Hake	2,969
Spurdog	1,290
Skates and rays*	471
Plaice	375
Lemon sole	303
Lesser spotted dogfish	295
Whiting	289
Cod	186
Other fish species**	149
Megrim	147
Monkfish	79
Other flatfish species***	79
Ling	61

* Spotted ray, thornback ray, blonde ray, and flapper skate
** Scad, boar fish, mackerel, pouting, gurnard, john dory, and herring
*** Dab, witch, and brill

Table 3. Catch weights in relation to minimum conservation reference size (MCRS)

Species	Weight (kg)	≥ MCRS (%)	< MCRS (%)
Haddock	11,601	98	2
Hake	2,969	100	0
Plaice	375	92	8
Whiting	289	99	1
Cod	186	100	0

Table 4. Diurnal catch weights for comparable hauls

Species	Day (kg)	Night (kg)	Difference (%)
Haddock	2,277	1,823	-20
Hake	525	248	-53
Plaice	79	79	0
Whiting	88	37	-58
Cod	65	82	26
Lemon sole	54	74	37

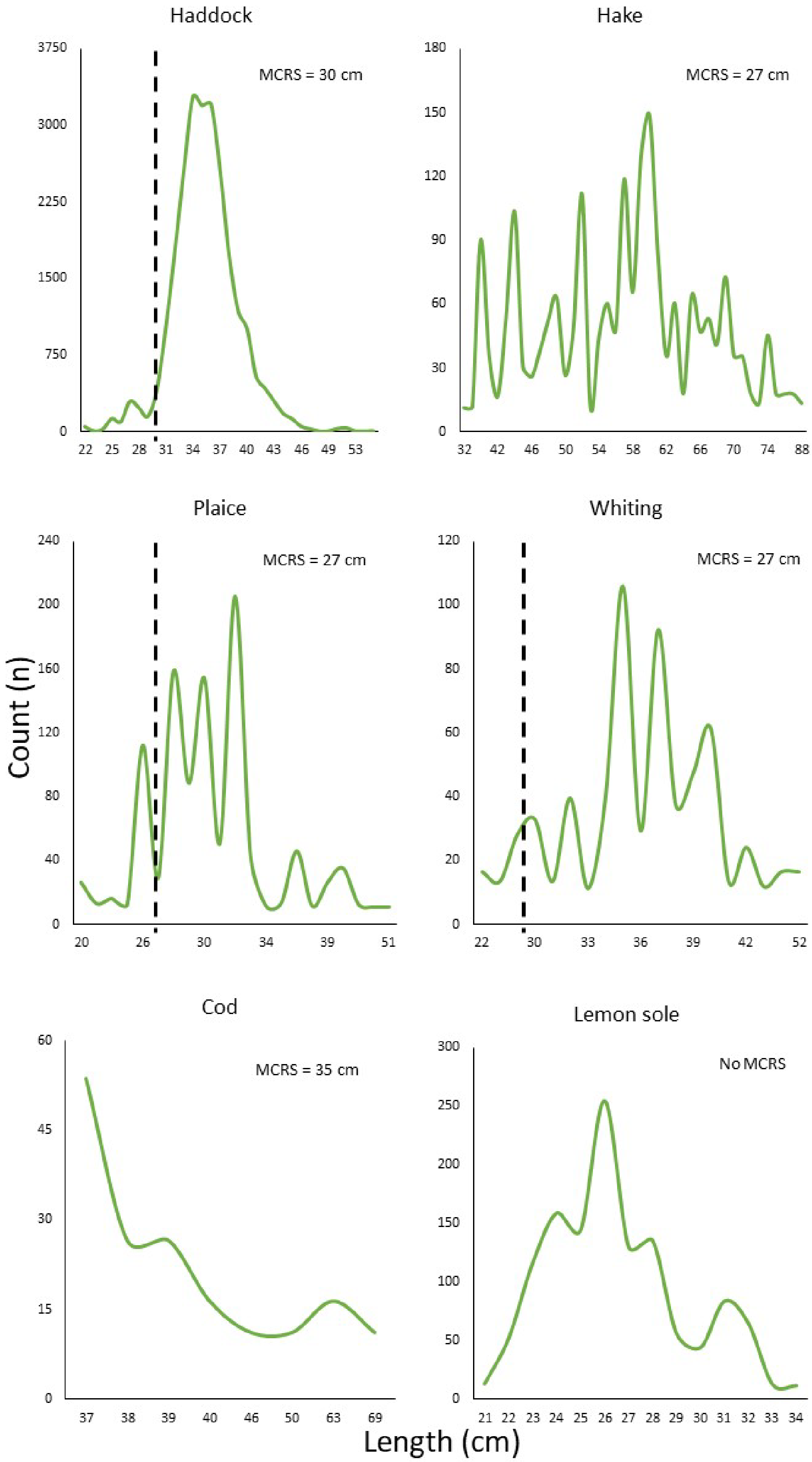

Figure 4. Raised length frequency distributions of key species (vertical dashed lines represent MCRS)

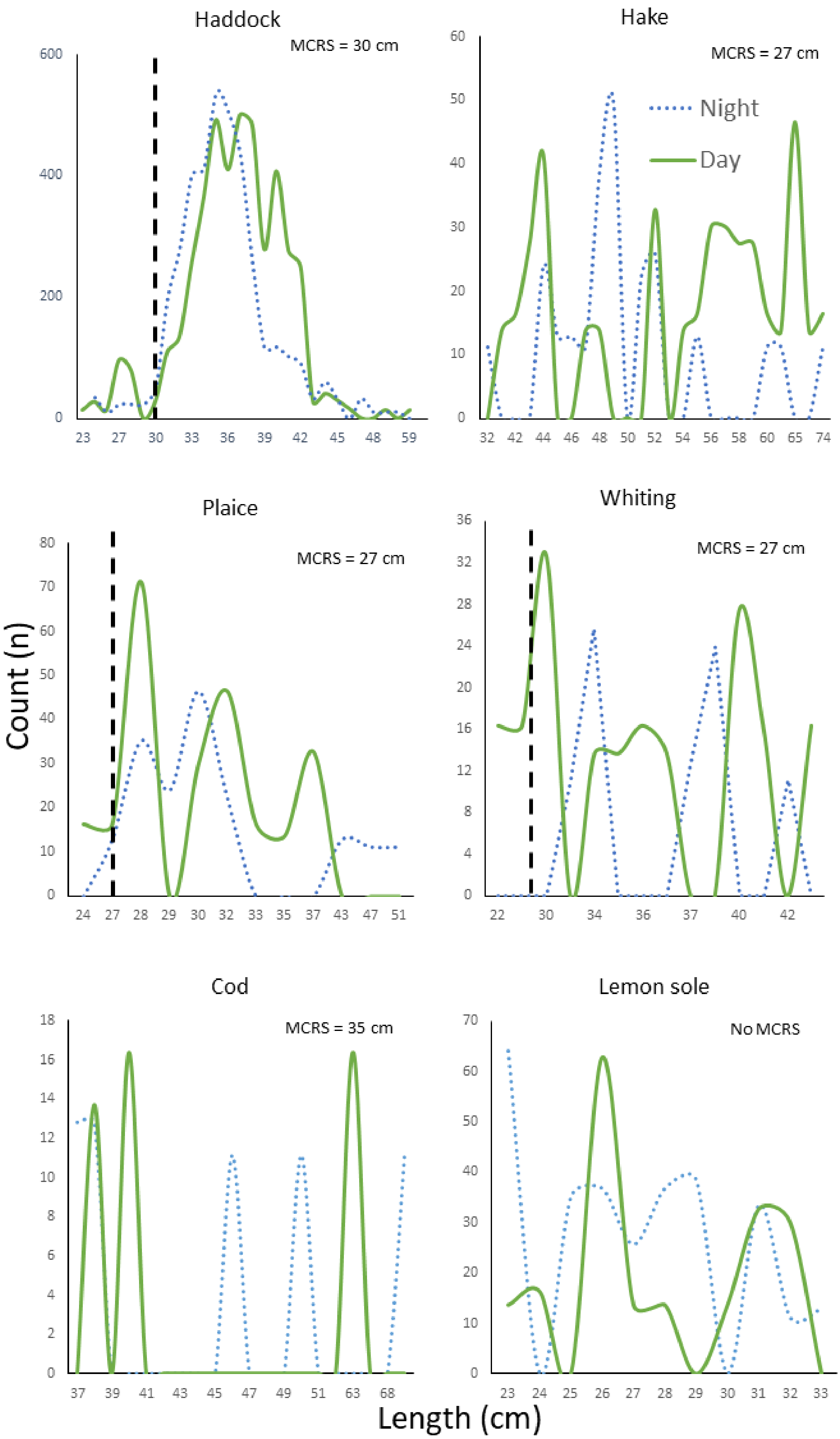

Figure 5. Raised day/ night length frequency distributions of key species (vertical dashed lines represent MCRS)

The operational data from the follow up trips comprised data from 9 days (3 from vessel A and 6 from vessel B) where vessel speed, door spread, and depth fished were 3 kt, 94 m and 166 m respectively.

Mean reductions in fuel of 40% and engine load of 37% (Table 5). This was supported by the econimic questionnaire completed by vessel skippers during the pair trawl trial which also provided an estimated 40% reduction in fuel use between pair and solo-trawl operations in the Celtic Sea. The mean sweep angle was 2^{o} or 17% lower in the pair trawl compared with the solo trawl (Table 5). Swept area of the pair trawlers was 3.2 times greater than the solo trawler (Table 5).

Table 5. Mean operational and gear performance data

Operational data	Solo vessel	Pair vessels	Difference (%)
Fuel (l/Hr, per vessel)	93	56	-40
Engine Load (%)	56	35	-38
Wing-end spread average (m)	29	29	0
Sweep angle (^{o})	12	10	-17
Trawl door/ sweep divergence** (m)	93	287	>100 (3.1×)
Estimated Swept area (km^2)	2.48	7.92	>100 (3.2×)

The economic analysis showed that fuel use during fishing was the greatest cost incurred by solo and pair vessels (Table 6). The pair vessels made an estimated profit of 12% while the solo vessel made a loss of 20%, a difference of 32% in profit rate over the course of two trips (Table 7).

Table 6. Vessel costs over two trips

Trip Cost description	Solo vessel (€)	Pair vessel (€)
Fuel during steaming	6000	6000
Ship maintenance	1700	1700
Duties and levies	500	500
Port fees	550	550
Insurance*	2730	2730
Repayments	9000	9000
Fuel during fishing	14560	10400
Food*	1200	1200
Ice (Total used on landings)	200	200
Net mending	200	200
Phone and crew transport	1000	1000
Transport of landings	2092	2700
Wages and Salaries total cost	4419	5702
Total cost	44151	41882

Table 7. Economics comparison over two trips

Profitability	Solo vessel	Pair vessel
Landings (boxes)	320	460
Hauls (N)	18	20
Landings (t)	11.2	16.0
Standardised landings (t)	12.4	16.0
Standardised catch value (€)	36877	47583
Total Cost (€)	44151	41882
Net Profit (€)	-7274	5702
Profit rate (%)	-20	12
Difference in profits (%)		32

Discussion

The pair-trawl trial was successful, and the method has major potential for uptake by other bottom trawl or seine vessels targeting demersal fish species. There is little difference in modern pair trawling and pair seining in terms of the rigging and fishing gear used. Variable speed during operations may, however, affect catch. The pair vessels in the current study fished at an average speed of 3.1 kts. Irish seiners typically travel at a speed of just over 1 kt during solo fishing operations (Oliver et al., 2022; McHugh et al., 2019). There may be scope for seiners to tow faster but they are unlikely to speed up to the same extent as more powerful trawlers. This may affect catch rates particularly during night-time when seiners typically refrain from fishing due to low catch rates. A similar gear trial on board a pair of seiners would help elucidate these issues.

The 40% reduction in fuel use on board each of the pair vessels compared with the solo vessel was likely due to the absence of trawl doors and reduced energy requirements for two boats towing one net. There is a paucity of research in this regard, but economic results are broadly in line with Moran Quintana and Wilkie (2022) who found that fuel cost as a proportion of income was 8% lower on Scottish pair compared with solo vessels in 2021. In the current study, this value was ~ 17% lower on the pair vessels with the difference between studies likely attributable to substantial increases in fuel costs between 2021 and 2022 (BIM, 2022).

Operational data for the solo vessels were collected in a different geographic area in much greater depths compared with the pair fishing operations. It is difficult to determine the relationship between depth, gear drag and fuel use. However, the main operational data of interest, fuel use and engine load were observed directly from wheelhouse instrumentation and recorded by the skippers in the different areas. The observed 40% difference in fuel use tallied with the economic questionnaire responses by the same skippers on the difference in fuel use between pair and solo trawl operations in the Celtic Sea. It also tallied with observations made by BIM scientists during a previous trip on one of the trial vessels in the trial area.

Fuel use accounts for around 90% of emissions in commercial fisheries so this method has major potential to improve carbon as well as fuel efficiency. Engine load was reduced by 37% suggesting additional potential benefits in terms of lower maintenance and improved engine resiliency.

The 29% increase in catch rates was likely due to the much longer sweep and bridle configurations (4.5 x) and associated increases in swept area (3.2 x) and fish herding by the pair vessels. While there is a positive relationship between increases in swept area and catches (e.g., Jones et al., 2021), this result should be treated with caution as it is based on catch rates from a different vessel operating at the same time and place which may have unaccounted differences in fishing power compared with the pair vessels.

It should be noted, however, that this was the first time the trial vessels conducted pair-bottom trawling together and it took some time to get acquainted with the new method. Further improvements in catch rates might be possible in future trips now that the vessels are operationally proficient in pair trawling. The sweep angle is important for a trawl's catching ability and is typically around 13^{o} (Eigaard et al., 2015). The mean sweep angle observed for the pair vessels was lower at 10^{o}. An ~70 m increase in sweep divergence would add 3^{o} to the angle. Increasing the observed vessel distance from the mean value of 410 m closer to the maximum of 550 m would assist in this regard.

The reductions in variable costs and increases in revenue provided an estimated 32% increase in profitability under the two-trip economic scenario. In addition to the increase in profitability, wages were 29% higher on board the pair vessels due to greater catches. Combined with reduced time on deck due to vessels taking turns to haul the net, this improves working conditions and should help with crew satisfaction and retention. The pair-trawl method also provided the crew with more time to handle catches potentially leading to improvements in fish quality and prices.

Haddock and to a lesser extent hake were the main commercial catch species. Over 97% of haddock, hake, cod and whiting were above minimum size. Some 8% of plaice were undersize but overall plaice catches were relatively low and well within the monthly quotas. Haddock catches were reduced by just 20% during night-time suggesting that this method is viable during hours of darkness for pair-trawlers with further assessment needed for seiners as outlined above.

Acknowledgements

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References

BIM 2022. Business of Seafood; A snapshot of Ireland's Seafood Sector, 2021. BIM Corporate report, April 2022. 72 pp

Eigaard, O.R., Bastardie, F., Breen, M., Dinesen, G. E., Hintzen, N.T., Laffargue, P., Mortensen, L.O., Nielsen, J.R., Nilsson, H.C., O Neill, F.G., Polet, H., Reid, D.G., Sala, A., Sköld, M., Smith, C., Sorensen, T.K., Tully, O., Zengin, M., and Rijnsdorp, A.D. 2015. Estimating seabed pressure from demersal trawls, seines, and dredges based on gear design and dimensions. – ICES Journal of Marine Science, doi: 10.1093/icesjms/fsv099.

Jones, A.W., Miller, T.J., Politis, P.J., Richardson, D.E., Mercer, A.M., Pol, M.V., and Roebuck, C.D. 2021. Experimental assessment of the effect of net wing spread on relative catch efficiency of four flatfishes by a four-seam bottom trawl. Fisheries Research, 244, 106106.

McHugh, M., Oliver, M., Browne, D., Minto, C. and Cosgrove, R. 2019. Benefits of 120 mm diamond and 100 mm T90 codends in the Celtic and Irish Seas, Irish Sea Fisheries Board (BIM), Fisheries Conservation Report, February 2019. 6 pp.

Moran Quintana, M., and Wilkie, O. 2022. Economics of the UK Fishing Fleet 2021. SEAFISH, Economics and Business Technical Report.

Oliver, M., O'Neill, R., McHugh, M., Browne, D., Murphy, S., Minto, C., and Cosgrove R. 2022. Assessment of cod survival in the Irish seine-net fishery using pop-up satellite archival tags, Irish Sea Fisheries Board (BIM), Fisheries Conservation Report, November 2022. 16 pp.

Seafish 2010. Bridle Angle and Wing End Spread Calculations. Seafish Factsheet. 6pp

Silva, J.F., Ellis, J.R., and Ayers, R.A. 2013. Length-weight relationships of marine fish collected from around the British Isles. Science Series Technical Report, Cefas Lowestoft, 150. 109 pp