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Assessment of artificial light on the headline towards improving energy efficiency in the Celtic Sea trawl fishery for demersal fish species

Fisheries Conservation Report

Key findings

51% increase in haddock catch weight with lights on the headline during nighttime.

64% increase in the value of haddock caught with lights during nighttime.

Simple, inexpensive option to boost catch and energy efficiency.

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Introduction

The drive towards net zero carbon emissions by 2050 is encouraging development and transition to use of more sustainable fuels and more energy efficient fishing methods. BIM and Irish fishing Industry gear-based research on improving energy efficiency has focused on Nephrops and whitefish trawl fisheries which generally use more fuel than other fisheries.

This works includes development of more hydrodynamic trawls (McHugh et al., 2022), reduced drag otter doors (McHugh et al., 2023), and enhanced catch detection using acoustic sensor technology in the Nephrops fishery (McHugh et al., 2019). In the whitefish fishery, efforts have focused on pairing up on trawl operations to reduce energy use and boost profitability (McHugh et al., 2022a) with further pair trials in the commercially important demersal seine-net fishery due to occur in the latter half of 2023.

Artificial lights are another potential method for improving catch and energy efficiency in terms of kg of produce per litre of fuel. Depending on the species and type of light used fish can display negative or positive phototaxis i.e., they move toward or away from the light. Studies have shown attraction of species like snow crab and mantis shrimp, and negative responses from turtles and fish such as eulachon (smelt) and yellow tail rockfish (Nguyen et al., 2017; Wang et al., 2013; Lomeli et al., 2020).

BIM previously assessed lights on raised-fishing line (RFL) trawl gear, a BIM/Irish Industry developed gear measure which successfully mitigates catches of low-quota cod in the Celtic Sea. Results showed a significant 62% reduction in cod but also some reductions in haddock, hake and whiting with fish likely moving away and dipping under lights mounted on the fishing line to escape (Oliver et al., 2021; Oliver et al., 2022). Potential negative effects on commercial viability made it difficult to recommend use of lights on the RFL but the study did raise some interesting questions around potential energy efficiency applications.

This trial aimed to take advantage of this negative phototaxis to try and improve catch rates of target species and operational efficiency.

Methods

Fishing operations and gear

The trial was conducted on board the MFV Virtuous (S80), a 23.4 m trawler targeting mixed demersal fish species in the Irish sector of ICES Division 7j in the Celtic Sea in March 2023 (Figure 1). The vessel fished a single-rig otter trawl (OTB) which they typically use to target haddock and hake. The ground gear consisted of 18 mm leaded footrope attached to the fishing line. The vessel deployed a 100 mm diamond (T0) mesh codend and 160 mm square mesh panel (SMP) in line with current regulations (Table 1).

Given the nature of the gear modification, the trial was designed as a catch comparison using the alternate haul method (Wileman et al., 1996). To minimise between-haul variability, test and control gears were deployed consecutively and to facilitate matching in subsequent analysis, each pair of hauls was conducted on the same ground (Browne et al., 2021). The trawl was deployed with artificial lights on the headline (test) (Figure 2) and without artificial lights on the headline (control). Hauls were evenly divided between day and night to account for diurnal variability which has been shown to occur in species such as haddock, in previous research (Krag et al., 2010).

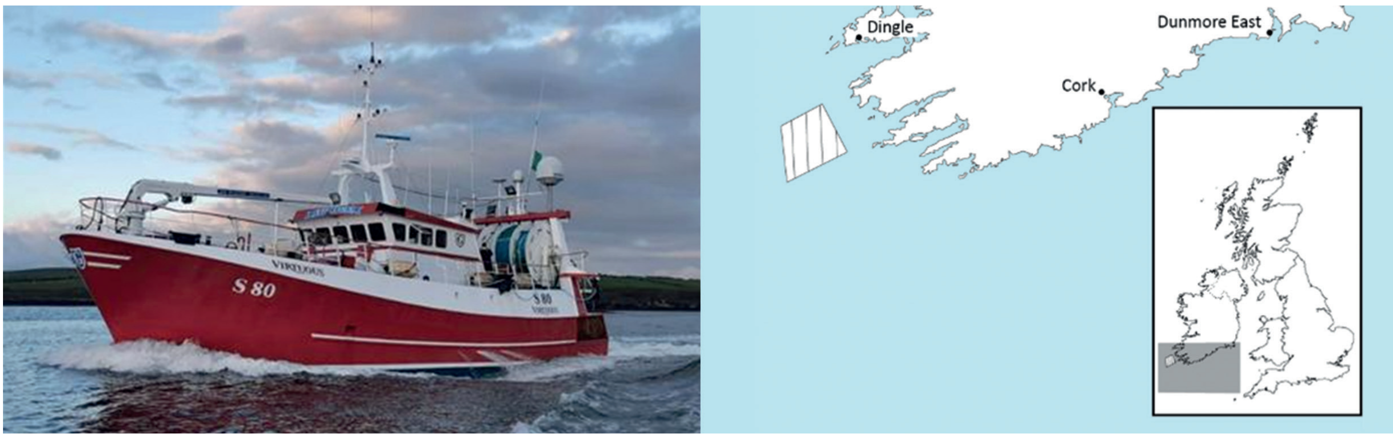

Figure 1: MFV Virtuous S80 (trial vessel) and trial location (hatched area).

Table 1. Gear characteristics

Gear type	Trawl
Warp length (average) (m)	457
Warp Diameter (mm)	18
Sweep length - singles (m)	218
Sweep length - doubles (m)	55
Door type	Thyboron type 11
Door weight (kg)	750
Trawl manufacturer	Swan Net Gundry
Trawl type	Single-rig
Trawl twine thickness (mm)	2.5
Fishing circle (meshes x mm)	1015 x 90
Number of floats on headline	48
Footline length (m)	57
Ground gear	18 mm leaded rope
Nominal codend mesh size (mm)	100
Measured codend mesh size (mm)	106
Codend twine thickness (mm)	6
Square mesh panel (mm)	160

Artificial Lights

14 Lindgren-Pitman® green (LPG) light emitting diodes (LEDs) were attached to the headline of the trawl with ~ 150 cm spacing between each light. Cable ties were used for easy attachment and detachment during the trial. This method could be improved for longer term deployments e.g., using soft shackles. All LPGs were taken off the headline between hauls (Figure 2). These LPGs have a depth rating of 850 meters, emit 0.5 – 2 lux and the battery lasts up to 350 hours. LPGs retail for $36 per light in the USA.
14 LPGs including batteries, shipping and taxes from the USA to Ireland cost approximately €600.

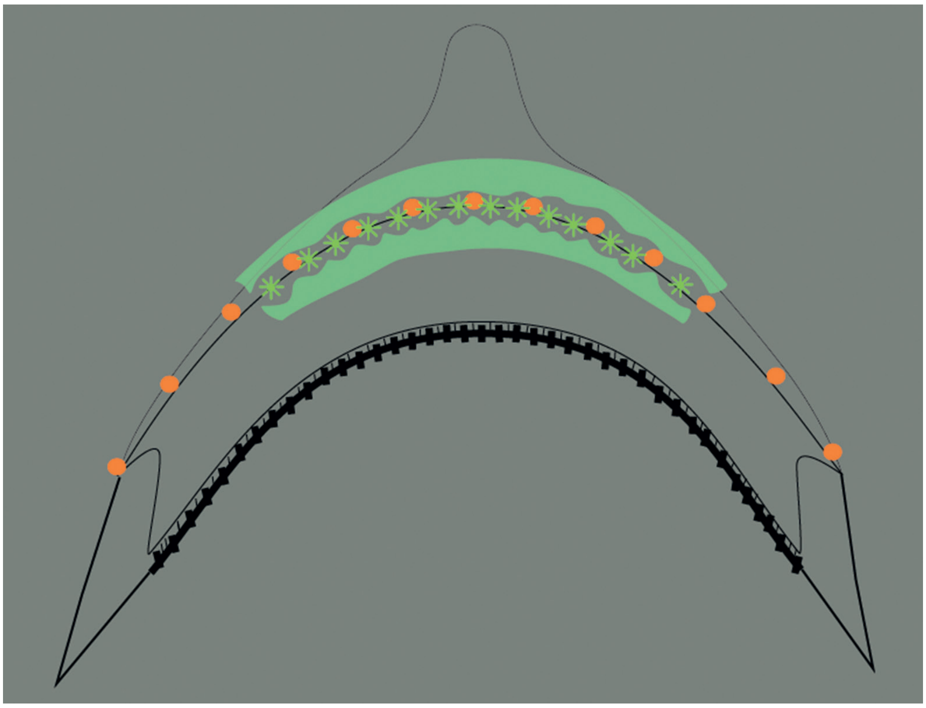

Figure 2: Trawl with 14 green artificial lights on the headline.

Sampling and analysis

Total catches from each haul were separated at species level and weighed. All commercial species were measured, with random representative sub-samples obtained when catch volume for specific species was high. Total lengths of commercial fish species were measured to the nearest cm below. Length-weight relationships (Silva et al., 2013) were applied to obtain estimated weights by length class for comparative purposes.

Non-commercial species such as boarfish, blue whiting, mackerel, horse mackerel, starry smooth hound were weighed but not measured. Environmental data such as cloud cover, sea state and wind speed were recorded for each haul.

Price data for different haddock size grades were obtained from sales notes provided by the vessel owner. These price data were incorporated with length weight data to provide commercial values for haddock in test and control gears.

Tow duration was 3 hours for all hauls excluding hauls 12 and 16 which were 4 and 2.17 hours, respectively. To account for this, hauls 12 and 16 were given a haul duration ratio in relation to a 3-hour haul (0.72 and 1.33). This was incorporated into the subsratio calculation by multiplying the subsample / weight by the haul duration ratio. As the raising factor is calculated by 1 / subsratio, this gives the longer haul a smaller raising factor and the shorter haul a larger raising factor to account for the difference in duration.

Proportional differences in catches were modeled using a binomial generalised additive model (GAM). Modeling used consecutively matched alternate test and control hauls in line with optimal experimental design for single-rig trawl catch comparison experiments (Browne et al., 2021). Modeling was limited to haddock due to insufficient catches of other species.

Resulting catch-comparison plots include pointwise confidence intervals on the predicted proportions. The null hypothesis of equal catch efficiency between hauls with and without lights was rejected for a given length-class, when the confidence limits for a given length-class did not overlap the reference value of 0.5 (50% catch probability).

Results

A total of 16 hauls consisting of 8 test and 8 control deployments were completed during the study. Mean haul duration, towing speed, and depth fished during the trial were 3 hrs, 3 knots and 139 m. The weather was variable during the trial with wind speeds ranging from 16 – 56 km^{-h} (mean 39 km^{-h}) and swell height ranged from 3 – 4 meters (mean 3.4 meters). Cloud cover was 100% or eight oktas for the duration of the trial.

Haddock was the dominant species corresponding to 90% by weight of all commercial species landed with 60% of haddock catches occurring at nighttime. Observed haddock catches were 51% greater with lights on the headline during night and 9% lower with lights on the headline during daytime (Table 2).

The length frequency distributions and catch curve for haddock at night generally displayed upward trends with increased catches of larger haddock in the test gear. Little difference was observed during the day. Confidence Intervals of the catch curves were relatively large likely due to elevated levels of between haul variability: although almost all proportions > 40 cm occurred above the 0.5 reference value, the confidence limits overlapped up to ~ 49 cm. Catches were significantly greater above this point (Figure 3).

Price data from the current study showed higher prices for larger grade haddock corresponding to a 64% increase in the value of haddock caught with lights during nighttime.

Table 2. Total catch weights and percentage differences

Species	Control (kg)		Test (kg)		Difference (%)	
	Day	Night	Day	Night	Day	Night
Haddock	1304	1451	1189	2193	-9	51
Non-commercial species*	818	214	533	226	-35	5
Monkfish	88	68	54	-39	-40	-41
Flatfish**	80	34	59	19	-26	-44
Hake	74	13	45	17	-39	31
Other fish***	70	16	23	8	-67	-50

Non-commercial species*: Boarfish, blue whiting, mackerel, horse mackerel, starry smooth hound. Flatfish**: Lemon sole, megrim, plaice, black sole. Other fish***: Whiting, white pollock, John dory, skates and rays.

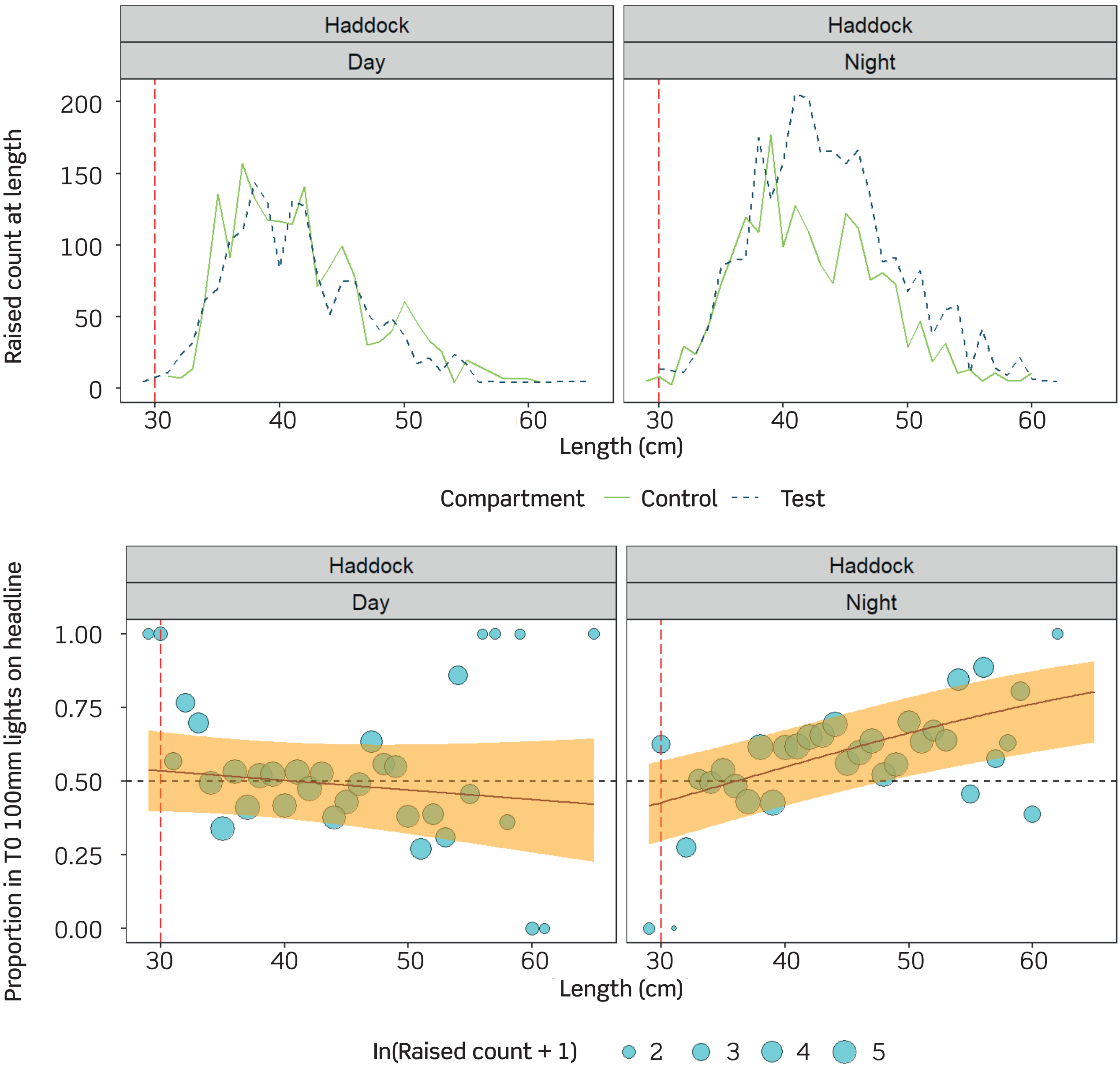

Figure 3: Length frequency distributions (LFD) (top) and catch curves (bottom) for haddock.

Top: Navy hatched line represents the test gear and green solid line represents the control gear in the LFD plot.
Bottom: Overall modelled proportions of haddock catch at length in the test gear are outlined in the catch curves by day and night. Points represent the empirical raised proportions over all hauls with point sizes proportional to the raised counts. Model fit and 95% confidence intervals (yellow band) come from the GAM. Vertical lines represent the minimum conservation reference size for haddock (≥ 30 cm).

Discussion

Variable diurnal effects of lights on haddock during day and nighttime could be caused by the absence of day light penetration potentially linked with differences in haddock depth preferences during nighttime. The greater quantities of larger haddock retained with lights at nighttime could be linked with swimming speed and the ability of larger, faster fish to escape over or duck under the headline. Main and Sangster (1981) observed that larger haddock swam in front of towed gear at 1.5 ms^{-1} for up to 150 seconds before dropping into the net, whilst smaller haddock swam in front of towed gear for periods of only 30 to 60 seconds.

Whatever the reasons behind these differences, adding green lights to the trawl headline is a simple inexpensive option to improve efficiency in this fishery with the lights effectively paying for themselves in around one nighttime haul.

Fish behaviour in response to light has been shown to vary at different times of year and in different locations so there is no guarantee that this will work all the time. However, the low cost and ease with which lights can be attached or detached from fishing gear mean they can easily be tested and deployed or kept on board depending on their effects.

Insufficient data were available to determine if the lights had a significant effect on species other than haddock. Observed hake catches were 28% greater with lights on the headline at nighttime. Further Industry-led testing of the lights during normal fishing operations could help elucidate the effects of lights on species like haddock and hake in trawl and also potentially seine-net or gillnet fisheries which target these species.

Aside from improved energy efficiency, study results suggest that deploying lights on the headline could help incentivise use of RFL gear which helps mitigate catches of low quota species like Celtic Sea cod and plaice, and vulnerable skates and rays. Oliver et al. (2022) observed a 13% reduction in haddock with lights on the RFL likely due to haddock dipping under the fishing line in response to the lights. Increased haddock catches due to lights on the headline might offset or even exceed losses due to lights on the RFL. Of course, lights in different locations could affect light levels and fish behaviour in different ways around the trawl mouth and further testing would be needed to assess the effects.

The cost of using artificial light was relatively low in the current trial, with the lights paying for themselves in around one nighttime haul. The LPGs are a one-time purchase and come with batteries. The recommended energizer ultimate lithium (AA) batteries last for ~ 350 hours and should last for ~ 44 nights before they need to be replaced at a cost of ~ €110. Other available underwater green LED light models might also deliver positive results.

Acknowledgements

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