Assessment of the impacts of the Landing Obligation on Irish Vessels

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Key findings:

- **Cod and haddock were the principal choke species for both the *Nephrops* and mixed demersal whitefish vessels.**
- **The *Nephrops* vessel was able to reduce cod catches and mitigate the economic impact of the landing obligation, and a range of technical measures are available to further assist *Nephrops* vessels in this regard.**
- **Similar to the results of the 2014 study, the mixed demersal whitefish vessel failed to minimise the economic impact of the landing obligation through tactical measures.**
- **The technical measures tried during the trials did not reduce catches of haddock sufficiently to avoid choking in the whiting fishery.**
- **No increase in the number of days fished occurred under quota uplift or de minimis scenarios.**
- **Reducing the quota imbalance between whitefish species such as haddock and whiting will likely be required if the mixed demersal whitefish fisheries are to remain commercially viable.**
- **Persistent choking of the demersal whitefish fishery may lead to an influx of vessels to the *Nephrops* fishery when the LO is fully implemented.**
- **An alternative fishery based quota management system which optimises quota allocations on the basis of the main species upon which vessels are reliant, would help lessen choke issues.**

1. Introduction

The 2013 reform of the EU Common Fisheries Policy came into force in January 2014 and included a Landing Obligation (LO) whereby the discarding of quota species is prohibited. Article 15 of EU regulation 1380/2013 outlines how the new LO policy will be introduced gradually, starting with pelagic fisheries in 2015 and extending to demersal fisheries in 2016, with the objective that all fisheries will be included by 2019. The LO will require catches of quota managed species to be landed except in cases where high post catch survival can be demonstrated. Furthermore a limited amount, or 'de minimis', level of discarding will continue if improvements in selectivity are considered to be very difficult or if a need arises to avoid disproportionate costs of handling unwanted catches. Up until now the management of EU fisheries has been restricted to regulation of landings, whereas under the LO these fisheries will now be managed by catch regulation. The switch from landings to catch regulation represents a major change for the management of EU fisheries and has major implications for the fleets that depend on them. The LO will introduce a number of challenges to the Irish fleet particularly in the demersal mixed fisheries fleet segment. Key challenges will include requirements to land undersize quota species, cessation of fishing activity once the quota for the first individual TAC species is exhausted (choking) and costs associated with handling and disposal of catches which cannot be sold for human consumption.

Previous work undertaken by BIM and the Marine Institute has highlighted specific choke issues with regards to haddock in the Celtic Sea (Cosgrove, 2015). From January 2016, *Nephrops* (VII), haddock (VIIa/VIa) and whiting (VIIb-k) will be the first demersal species to be brought into the landings obligation in 2016. Following discussion with the Discard Implementation Group (DIG) it was considered appropriate to undertake further studies to assess the potential impact of the LO to help inform national issues prior to the commencement of the LO in demersal fisheries in January 2016 and full scale introduction in 2019.

Previous work on the impacts of the LO has been restricted to studies which model impacts using aggregated fisheries data, or which focus broadly on a range of potential issues such as enforcement, and on board handling and markets for fish which cannot be sold for human consumption (e.g. Poseidon, 2013; Catchpole *et al.*, 2014; Condie *et al.*, 2014). Building on previous work carried out in 2014, this study combined field testing of the impacts of choking on two demersal trawl fisheries, with economic analysis of related outcomes. Furthermore, the utility of technical and tactical changes in fishing practices as well as increased catch allowances in offsetting such impacts was assessed.

This study also forms part of Ireland's contribution to an EU project "Strategies for the gradual elimination of discards in European fisheries – Discardless". This is a four year project involving many European countries, several of which are doing similar trials e.g. France, UK, and Denmark. The Discardless project includes research on how to change gear or fishing tactics to mitigate discards and the impact of the LO, how to handle and market any remaining unwanted catch that has to be landed under the LO, the ecological and economic impact of the LO and policy advice on any future developments in the LO.

2. Methods

Two vessels were chartered to undertake the trial predominantly in the Celtic Sea but were also permitted to move to other areas to reflect normal fishing practices: Vessel 1, a 23 m quad-rig trawler targeting *Nephrops*; Vessel 2, a 23 m single-rig demersal trawler targeting mixed whitefish species. Throughout the study vessels fished their standard monthly quota allocation as normal but were required to retain and land all catches of demersal species specified in Article 15.1.C(ii) of EU regulation 1380/2013, namely cod, haddock, whiting, saithe, Norway lobster, hake, common sole and plaice. Fishing was permitted to continue until the quota for the target stock(s) had been taken or where any by-catch quota allocations had been exhausted (provided a quota allocation for the target stock(s) remained). Catches of all other TAC species were fully documented during the trials, but discarding of undersize and over quota catches was permitted. This provided full information on the catch retained and facilitated detailed economic assessment of documented fishing activities under different scenarios.

The study was split into two phases: Phase 1, commenced in July 2015, where the vessel was expected to operate as per normal, but under LO conditions; Phase 2, commenced in August 2015, again operating under LO conditions, but the individual skippers were presented with the results of the first phase of the trial and were challenged to reduce levels of unwanted catch as much as practically possible by choosing from a range of existing mitigation tools and/or by adjusting their fishing behaviour and tactics.

Vessel 1 employed the use of a 300 mm square mesh panel (SMP) on all four trawls of the quad-rig for 40 of the 43 hauls conducted in August as a technical measure to reduce unwanted catches. Vessel 2 concentrated on the use of behavioural and tactical changes during Phase 2. The skipper of Vessel 2 proposed to avoid fishing at night when there is a greater haddock to whiting fishing ratio and to fish in deeper waters (~110m) where by the skippers knowledge suggested there is a greater whiting to haddock ratio as opposed to the shallower waters (~70-90m) where haddock are more likely to be situated. Vessel 2 used a combination of 100mm square mesh panels and 120mm square mesh panels.

For both phases of the study, vessels fished using their own monthly quota allocation and any additional landings (over quota/fish <MCRS) were counted against an additional scientific quota. Regular updates on the amount of scientific quota available were provided to vessels. Where insufficient scientific quota was available to cover over quota landings, documented discarding was permitted if required. Any fish caught in excess of the vessels monthly allocation was sold by the vessel and discounted against the total charter cost. This approach prevented targeting of over quota fish, was considered to be closest to normal fishing operations and resulted in optimal simulation of the actual impacts of the LO.

2.1 Analysis

Catch data were collected from the two vessels during both phases of the study by on-board scientific observers. Following each haul the weight of the overall bulk catch was recorded. The catch was then sorted by species, size grade and condition e.g. large gutted and broken down into the weight of landings (marketable landings that are normally kept for sale), obligation landings (quota species that will come under the LO i.e. under MCRS or over quota allocation) and true discards (non-quota species that will continue to be discarded under the LO). Representative length frequency samples were also obtained at haul level for all fish species whenever possible. As part of the LO, minimum landing sizes have been replaced with 'minimum conservation reference size' (MCRS) to take account of the obligation to land all catches regardless of size. Catches of ≥ and < MCRS quota species which exceeded the monthly quota allocation for a given month were defined as 'choke' species. Cumulative catches of key species were assessed over time to identify at which point during monthly fishing operations 'choking' occurred and a vessel would, under the LO, be required to cease fishing operations, return to port and land their catches.

The ratio of non-target to target species for each individual haul was calculated to allow for the identification of hauls that were most likely to contribute to each vessel becoming choked. Ratios were binned into three categories:

1. low ratios, whereby continued fishing effort would not result in over-quota catches of non-target species;
2. medium ratios, whereby continued fishing effort would result in over-quota catches of non-target species by up to five times current quotas and;
3. high ratios, whereby continued fishing effort would result in over-quota catches of non-target species by greater than five times current quotas.

This information was plotted spatially based on haul position and temporally based on haul start times to determine where and when non-target species were more or less likely to be caught in relation to target species.

Length frequency data on the main fish species caught during the trial were examined to assess whether technical or tactical changes adopted in Phase 2 of the study affected the size distribution of catches. For three of the trips carried out by Vessel 2, discards were not measured. These trips were removed for the length frequency analysis. All remaining data were raised to trip level and standardised by effort (number of hauls) across vessel and month to permit effective comparisons of length frequency distributions (LFD) and catches of ≥ and < MCRS species between months.

Raised catch weights differed slightly from measured catch weights used for choke species. However, this is likely to have minimal impact on comparison of proportional catches of < MCRS fish between phases. Temporal differences and potential differences in the size distribution and quantities of fish species on the ground, however, precluded quantitative comparisons of LFDs between the two periods.

Detailed operational economic information was received for one trip undertaken during the trial from each vessel. This information was used to derive costs per trip based on the following categories:

- Capital costs -repayments;
- Fixed Costs – fuel during steaming, ship maintenance, duties, levies, port fees, insurance, vessel monitoring charges;
- Variable Costs – fuel during fishing, food, ice and transport for ≥ and < MCRS landings, port fees, net mending, crew telephone and transport costs;
- Wages – (Gross profit less total costs)/2. Capital Costs.

This information was used to carry out a detailed economic comparison of 'business as usual' (BAU), LO and 'quota uplift' (QUP) fishing scenarios. Catch values in the case of BAU consisted of all ≥ MCRS fish that did not exceed monthly quota limits. The LO scenario consisted of the value of all fish up until the first choke occurred. A nominal value of €200 per tonne was assigned to < MCRS fish defined under Article 15.1.C based on sales notes received for such fish when sold either for fish meal or bait. The three trips without information on quantities of ≥ and < MCRS fish were excluded from the economic analysis.

Article 16 of EU regulation 1380/2013 states that fishing opportunities shall be fixed taking into account the change from fixing fishing opportunities that reflect landings, to fixing fishing opportunities that reflect catches. This is likely to result in QUP based on differences between total landings and catch advice for species listed under the regulation. We explored QUP economic scenarios based on 75% of the estimated stock discards in order to account for uncertainties in discard estimates (Course *et al.*, 2011; Condie *et al.*, 2014). QUP scenarios were based on the first choke species which occurred in each ICES Division which would have obliged the vessel to leave that area under the LO scenario. Potential de minimis (De min) allowances of 7% were also applied to choke species to assess whether this reduced the economic impact of choking. Potential increases in fishing effort due to these provisions were examined in terms of extra fishing days as economic data were available on a daily basis.

3. Results

Fishing operations occurred from 05/07/15 to 31/08/15. Over this period 19 sea trips and 264 hauls were conducted (Table 1). Although Vessel 1 spent a similar number of days at sea in the two months, there was less fishing effort in the second month of the study with 43 hauls completed in August compared with 50 in July. In contrast, the number of hauls carried out by Vessel 2 increased from 82 in July to 89 in August. Vessel 1 operated in VIIa and VIIg for the duration of the study whereas Vessel 2 operated over a wider area in VIa, VIIa, VIIb and VIIg, although fishing effort was concentrated in VIIg for both months.

Table 1. Trip details

							Hauls				
Vessel	Month	Trip	Start Date	End Date	Days at sea	Days fished	VIIa	VIIg	VIa	VIIb	**Total Hauls**
1	July	1	08/07/2015	13/07/2015	6	6		14			
		2	15/07/2015	19/07/2015	5	5		14			
		3	21/07/2015	26/07/2015	5	5	5	10			
		4	27/07/2015	29/07/2015	3	3	7				
	Subtotal				19	19	12	38	0	0	**50**
	August	5	07/08/2015	10/08/2015	4	4	7				
		6	11/08/2015	14/08/2015	4	4	12				
		7	16/08/2015	20/08/2015	5	5	14				
		8	23/08/2015	27/08/2015	5	4	1	9			
	Subtotal				18	17	34	9	0	0	**43**
2	July	9	05/07/2015	09/07/2015	5	5	1	16			
		10	10/07/2015	14/07/2015	5	5		17			
		11	15/07/2015	18/07/2015	4	4	1	11			
		12	20/07/2015	23/07/2015	4	4		12			
		13	24/07/2015	26/07/2015	3	3	2	8			
		14	28/07/2015	31/07/2015	4	4			14		
	Subtotal				25	25	4	64	14	0	**82**
	August	14 cont'd	01/08/2015	03/08/2015	3	3			11		
		15	05/08/2015	10/08/2015	6	6	2	17			
		16	11/08/2015	12/08/2015	2	2		7			
		17	13/08/2015	17/08/2015	5	5		14			
		18	18/08/2015	21/08/2015	4	4	2	7	1		
		19	22/08/2015	31/08/2015	10	10			15	13	
	Subtotal				30	30	4	45	27	13	**89**
Total					**92**	**91**	**54**	**156**	**41**	**13**	**264**

Table 2. Details of total catch and over quota landings under the LO for vessels 1 and 2 during the two months of the trial (choke species are highlighted in red)

July						August					
Vessel	Area	Species	Total catch (t)	Monthly quota (t)	Δ (t)	Vessel	Area	Species	Total catch (t)	Monthly quota (t)	Δ (t)
1	VII	Angler	0.75	3.00	2.25	1	VII	Angler	0.34	3.00	2.66
		Hake	0.12	4.00	3.88			Hake	0.03	2.00	1.97
		Ling	0.11	4.00	3.89			Ling	0.03	5.00	4.97
		Megrim	0.12	20.00	19.88			Megrim	0.02	20.00	19.98
		Nephrops	19.87	22.00	2.13			*Nephrops*	24.52	18.00	-6.52
1	VIIa	Cod	0.24	0.50	0.26	1	VIIa	Cod	0.72	0.50	-0.22
		Black sole	0.004	0.72	0.716			Black sole	0.03	0.12	0.09
		Haddock	0.19	10.00	9.81			Haddock	0.45	8.00	7.55
		Whiting	0.22	1.50	1.28			Whiting	1.70	1.50	-0.20
1	VIIg	Cod	2.31	0.50	-1.81	1	VIIg	Cod	0.22	0.50	0.28
		Black sole	0.08	0.18	0.10			Black sole	0.005	0.03	0.025
		Haddock	1.76	2.00	0.24			Haddock	0.25	2.00	1.75
		Plaice	0.04	0.18	0.14			Plaice	0.00	0.03	0.03
		Whiting	3.62	54.00	50.38			Whiting	0.35	60.00	59.65
2	VI&VII	Hake	3.02	4.00	0.98	2	VI&VII	Hake	8.15	2.00	-6.15
		Ling	0.25	4.00	3.75			Ling	2.71	5.00	2.29
		Skates and Rays	0.57	2.00	1.43			Skates and Rays	1.98	3.00	1.02
2	VIa	Angler	3.37	3.00	-0.37	2	VIa	Angler	5.52	3.00	-2.52
		Cod	0.16	0.22	0.06			Cod	0.88	0.31	-0.57
		Haddock	4.43	20.00	15.57			Haddock	5.95	16.00	10.05
		Pollack	0.01	12.00	11.99			Pollack	0.01	12.00	11.99
		Saithe	0.04	30.00	29.96			Saithe	0.54	30.00	29.46
		Whiting	0.72	1.00	0.28			Whiting	1.15	1.00	-0.15
2	VII	Angler	0.90	3.00	2.10	2	VII	Angler	3.34	3.00	-0.34
		Megrim	0.57	20.00	19.43			Megrim	1.18	20.00	18.82
		Nephrops	2.30	22.00	19.70			*Nephrops*	0.52	18.00	17.48
		Pollack	0.13	12.00	11.87			Pollack	0.09	15.00	14.91
2	VIIa	Cod	0.12	0.50	0.38	2	VIIa	Cod	0.46	0.50	0.04
		Black sole	0.005	0.15	0.145			Black sole	0.013	0.21	0.20
		Haddock	4.26	10.00	5.74			Haddock	4.52	8.00	3.48
		Whiting	0.40	1.50	1.10			Whiting	0.65	1.50	0.85
2	VIIb-k	Cod	2.33	0.50	-1.83	2	VIIb-k	Cod	2.25	0.50	-1.75
		Haddock	15.70	2.00	-13.70			Haddock	12.81	2.00	-10.81
		Whiting	77.25	54.00	-23.25			Whiting	62.71	60.00	-2.71

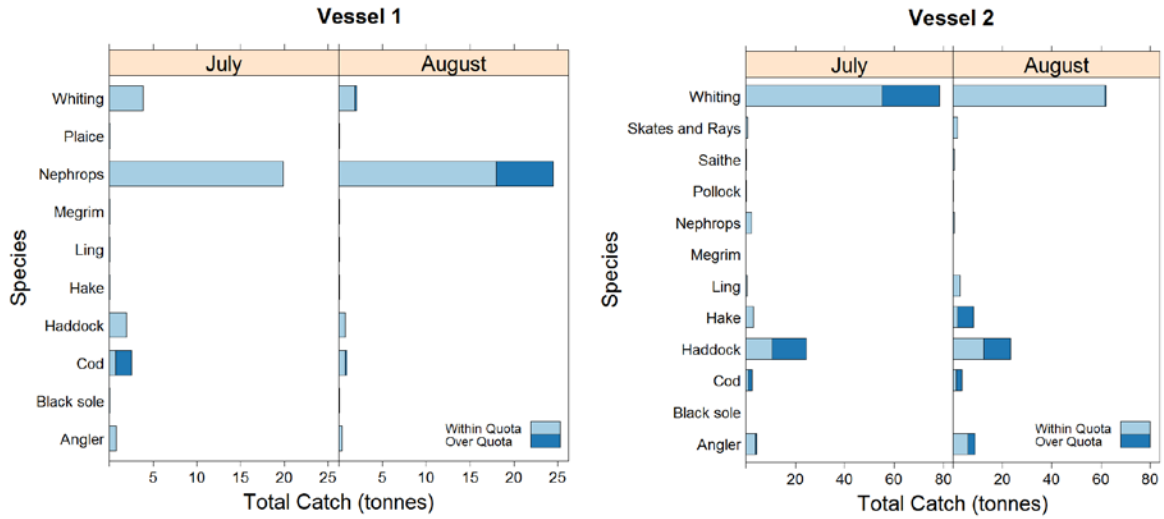

Figure 1. Total catch of quota species for vessels 1 and 2 during the two months of the trial, with a distinction between within quota landings (light blue) and over quota/<MCRS landings (dark blue)

Details of choke species encountered in each of the ICES fishing areas during the trial are outlined in Figure 1 and Table 2. Vessel 1 choked solely on cod in July whereas it choked on cod, whiting and *Nephrops* in August. Vessel 2 choked on angler, cod, haddock and whiting in July and additionally choked on hake in August.

Further details of the cumulative catches, by weight, of key quota species for Vessel 1 are outlined in Figure 2. Vessel 1 choked on cod during the 13th haul conducted in VIIg in July on the 4th day of fishing but was able to continue fishing for a further 5 days in VIIa towards the end of the month without choking. By concentrating effort in different fishing grounds in August, Vessel 1 delayed choking on cod until the 22nd haul in VIIa which took place on the 9th day of fishing. Vessel 1 did, however, also choke on whiting during the 31st haul in VIIa in August in addition to choking on the target species of *Nephrops* during this second month. Vessel 1 fished a total of 13 days in August compared with 9 days in July before choking occurred in all areas fished.

Haddock and cod were key choke species for Vessel 2 during both months of the trial (Fig. 3). Vessel 2 choked on haddock during the 13th haul conducted in VIIb-k during both July and August. Due to differing spatial fishing patterns during these two months, however, Vessel 2 choked on haddock after 4 days fished in July compared to 9 in August. Vessel 2 choked on cod during the 23rd haul in VIIb-k in July but only on the 13th haul in this area in August whilst also choking on cod during the 12th haul in VIa in August. Angler was also a key choke species in VIa with vessel 2 choking on the 12th and 13th hauls in July and August respectively. Vessel 2 also choked on whiting during the 23rd haul conducted in VIa in August in addition to choking on hake during the 49th haul. Vessel 2 fished a total of 12 days in August compared with 10 in July before choking occurred in all areas fished.

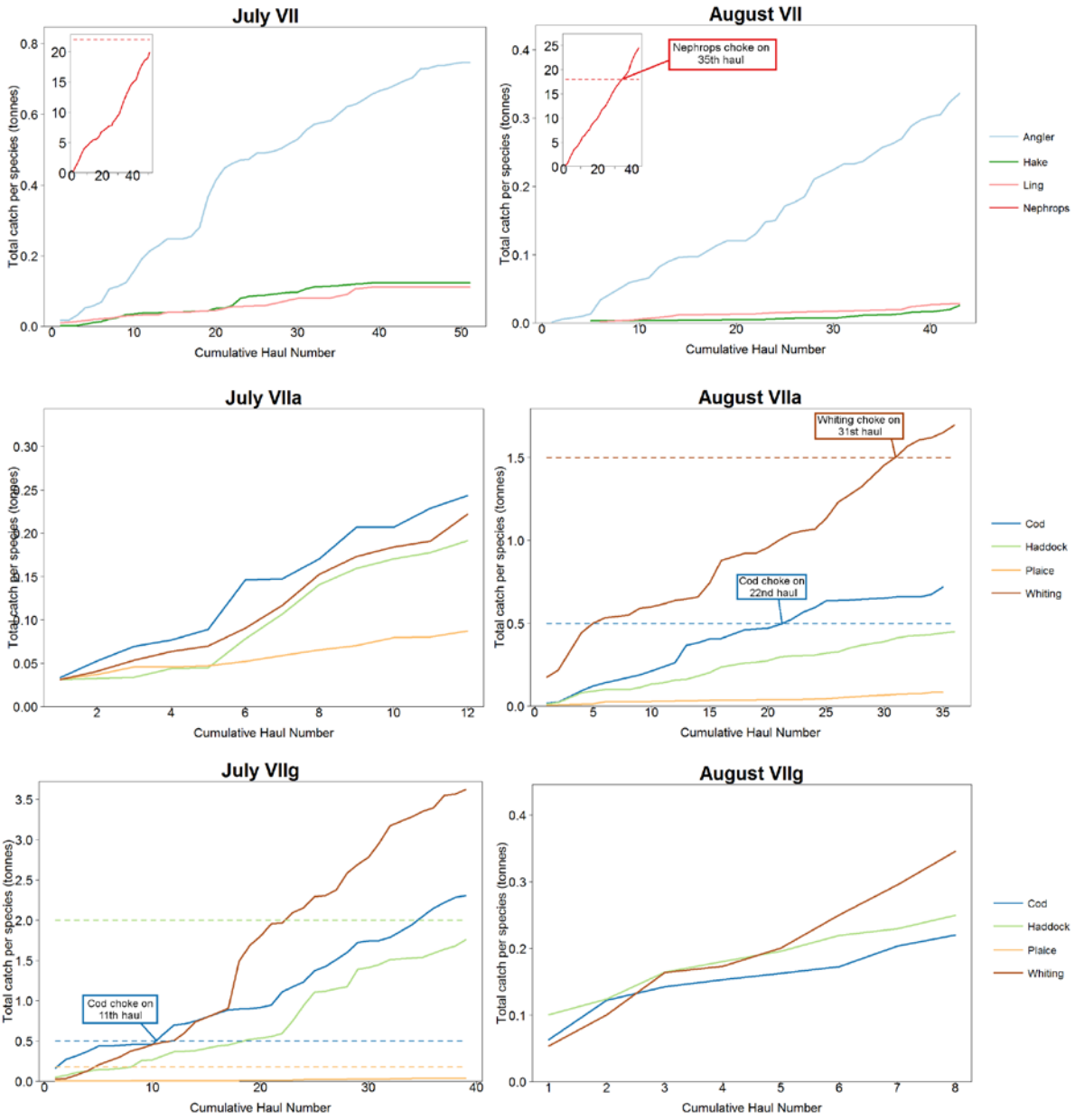

Figure 2. Cumulative catches of key quota species caught by Vessel 1 during July and August based on consecutive hauls in separate quota management areas (species quotas are marked with horizontal dashed lines)

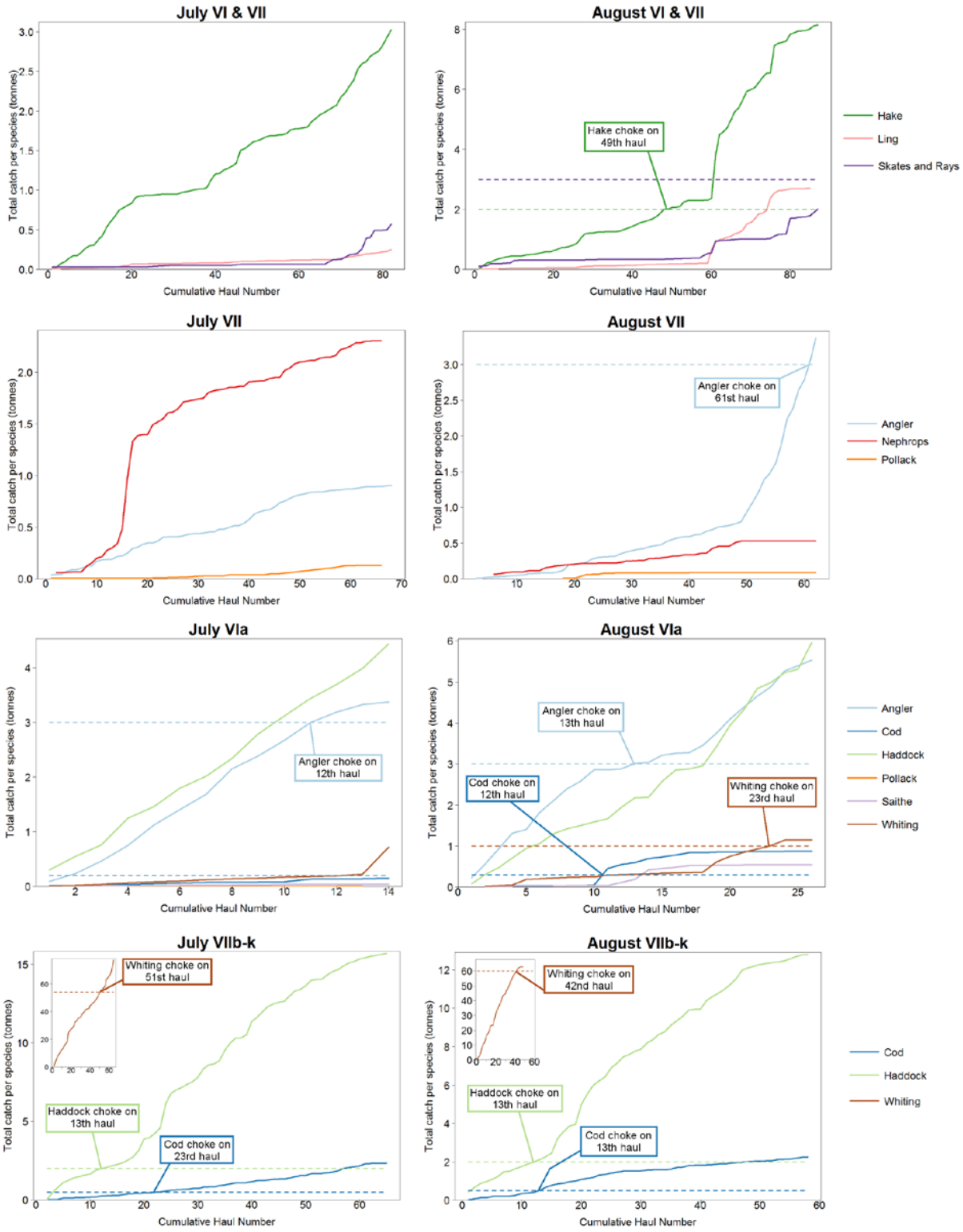

Figure 3. Cumulative catches of key quota species caught by Vessel 2 during July and August based on consecutive hauls in separate quota management areas (species quotas are marked with horizontal dashed lines)

Table 3. Quantities of key species above and below minimum conservation reference size (MCRS) retained during the two phases of the trial, July and August

		July					August				
Vessel	Species	Catch haul^{-1} (t)	Total catch (t)	≥ MCRS (t)	< MCRS (t)	∝ Total catch < MCRS (%)	Catch haul^{-1} (t)	Total catch (t)	≥ MCRS (t)	< MCRS (t)	∝ Total catch < MCRS (%)
1	Cod	0.05	2.55	2.31	0.24	9.44	0.02	1.05	0.94	0.10	9.93
	Haddock	0.09	4.28	2.64	1.64	38.33	0.07	3.00	1.30	1.70	56.77
	Nephrops	0.39	19.66	17.78	1.88	9.58	0.53	22.60	19.15	3.45	15.25
	Whiting	0.15	7.56	4.92	2.64	34.90	0.09	4.01	1.17	2.85	70.95
2	Cod	0.01	0.44	0.37	0.07	15.49	0.01	0.34	0.32	0.02	7.18
	Haddock	0.24	19.45	17.28	2.17	11.18	0.11	5.67	4.35	1.32	23.34
	Whiting	0.80	65.81	64.04	1.77	2.69	0.22	11.64	11.53	0.11	0.93

Total catch per haul of cod haddock and whiting were reduced, while total catches per haul of *Nephrops* increased for Vessel 1 in August compared to July. However, the proportions of < MCRS fish per haul caught by Vessel 1 increased for all of these species in August compared with July. For Vessel 2, total catch per haul remained the same for cod but decreased for haddock and whiting for Vessel 2 in August compared with July. Proportionally less < MCRS cod and whiting, and proportionally more < MCRS haddock were caught by Vessel 2 during observed trips in August compared with July (Table 3).

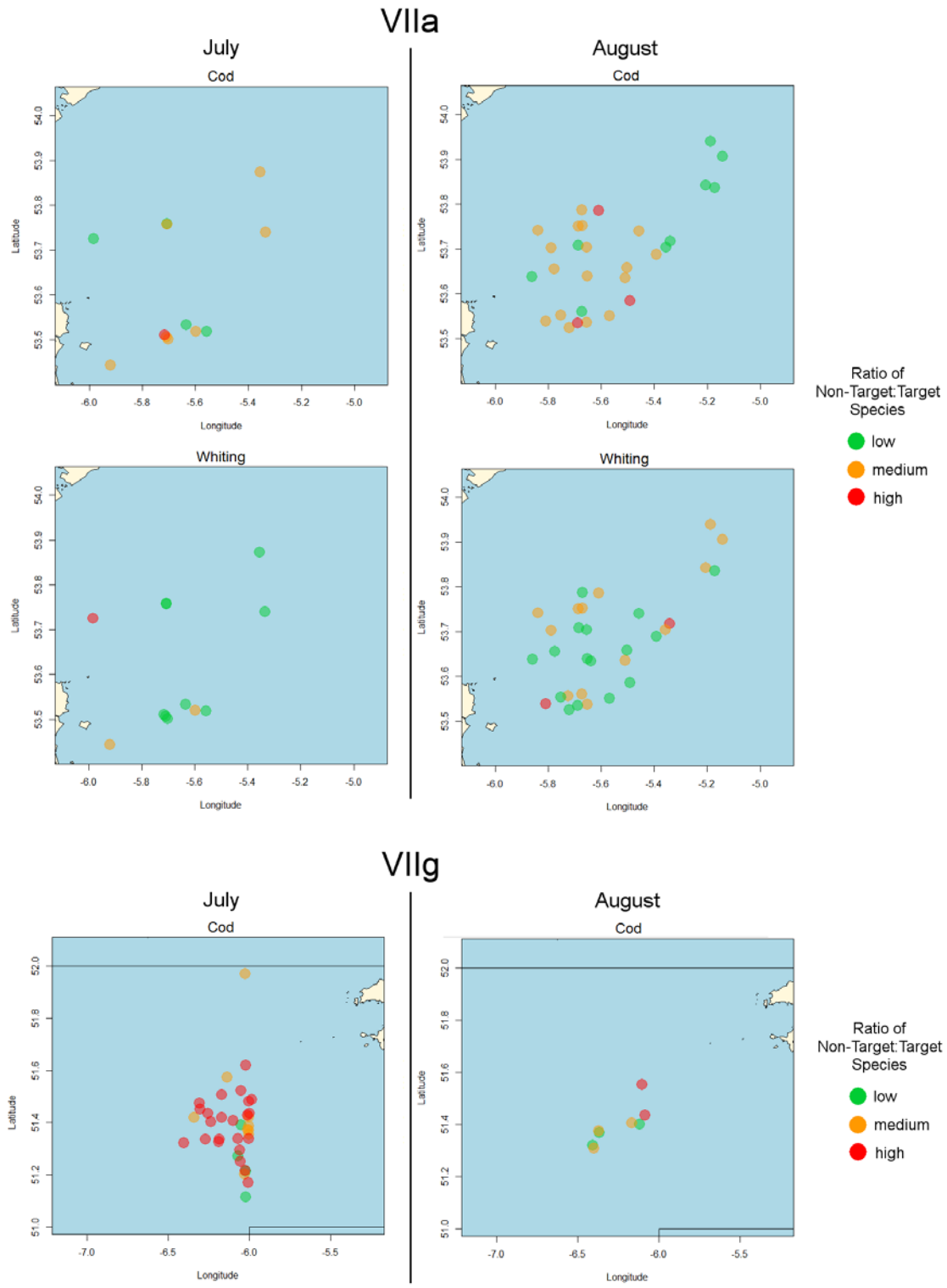

Figure 4. Ratio of non-target to target species for key choke species based on the location of individual hauls conducted by vessel 1 in July and August (low ratios = no over-quota catches of non-target species; medium ratios = over-quota catches of non-target species by up to five times current quotas; high ratios = over-quota catches of non-target species by greater than five times current quotas).

Figures 4 and 5 highlight that it is difficult to identify specific areas where non-target species are less likely to be caught in comparison to target species. When Vessel 1 was fishing in VIIa the ratio of the catch of whiting to the target *Nephrops* was often low but the location of these hauls coincide with areas where the ratio of cod to *Nephrops* was high (Fig. 4). In VIIg a larger whiting quota means that this species is no longer a choke but cod remains a problem with the majority of catches in VIIg in both months of the trial showing a very poor ratio between cod and the target. For Vessel 2 although there is variation in the ratio between the two main choke species (cod and haddock) with the target species (whiting) during separate hauls in VIIg there is no distinct spatial variation between the low, medium and high ratio hauls (Fig. 5).

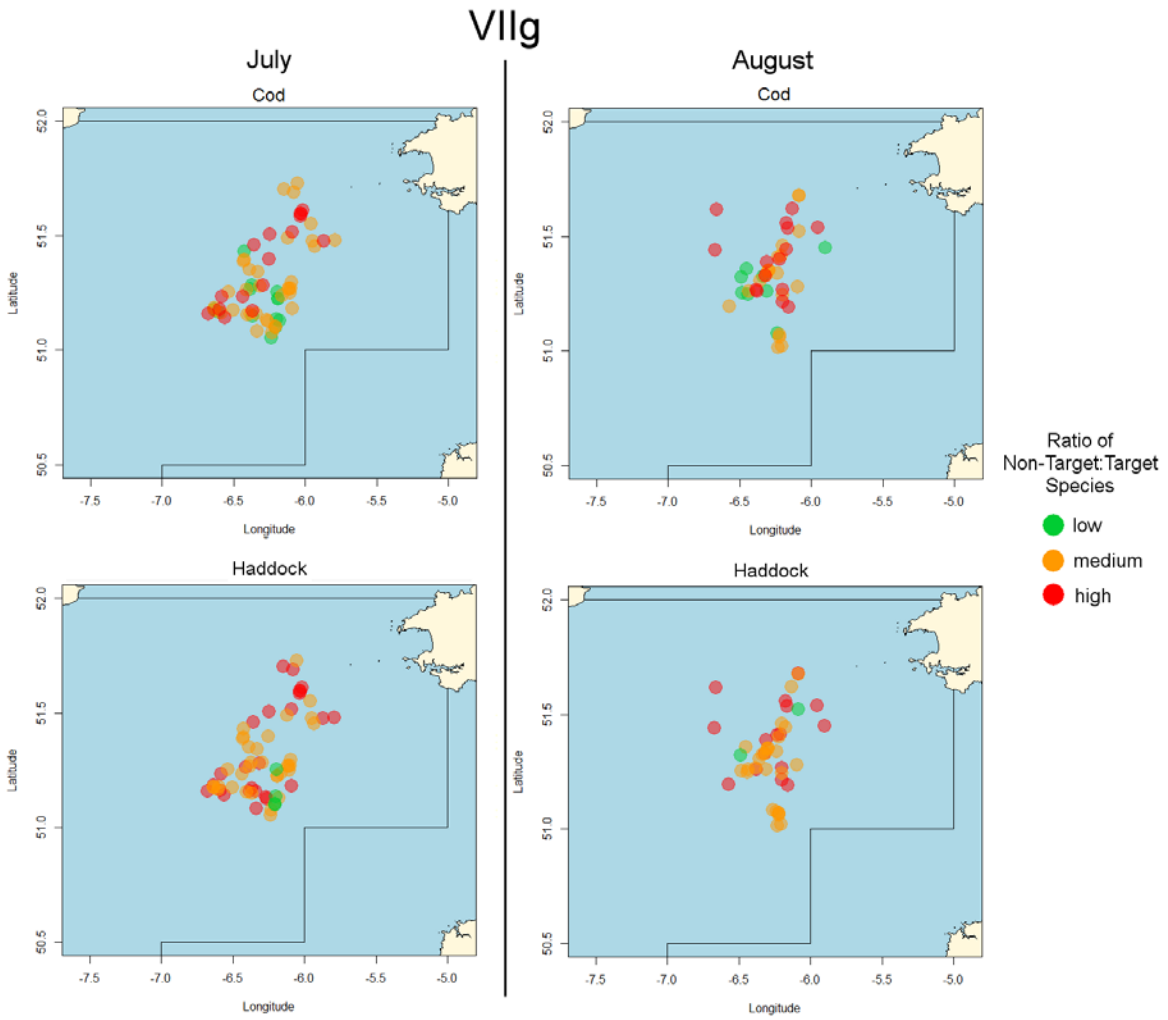

Figure 5. Ratio of non-target to target species for key choke species based on the location of individual hauls conducted by vessel 2 in July and August (low ratios = no over-quota catches of non-target species; medium ratios = over-quota catches of non-target species by up to five times current quotas; high ratios = over-quota catches of non-target species by greater than five times current quotas).

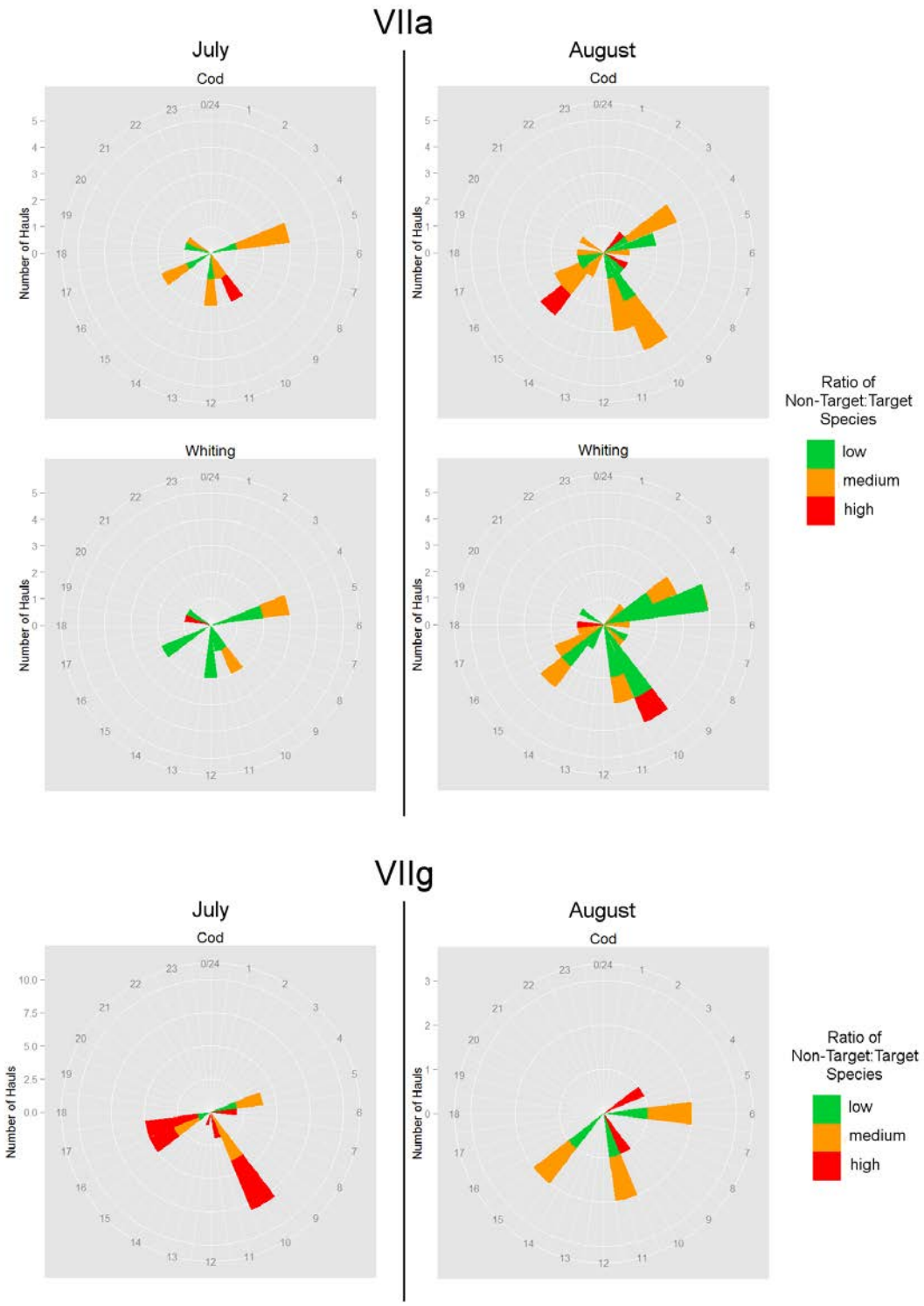

Figure 6. Ratio of non-target to target species for key choke species based on the time of day individual hauls were shot by vessel 1 in July and August (low ratios = no over-quota catches of non-target species; medium ratios = over-quota catches of non-target species by up to five times current quotas; high ratios = over-quota catches of non-target species by greater than five times current quotas). Each segment of the dial represents the hour (within a 24 hour day) in which a haul was shot. Multiple colours can occur within each segment if different hauls shot at the same time of day caught differing ratios of non-target to target species. The scale bar on the left hand side of each

plot indicates how the length of the segment (or each coloured chunk within a segment) equates to the total number of individual hauls shot at that hour, throughout each month, in each ICES division.

It is also difficult to identify times of day when non-target species are less likely to be caught in comparison to target species. Again when Vessel 1 was fishing in VIIa the ratio of whiting to the target *Nephrops* was often low but the time of day when these hauls were shot coincides with times when the ratio of cod to *Nephrops* was high in hauls (Fig. 6). For Vessel 2, even when examining the ratio for either just cod or haddock in comparison to whiting, there are numerous instances of hauls being shot at the same time of day showing variation between low, medium and high non-target to target ratios (Fig. 7). It is only between 19:00 and 05:00 that no low ratios are recorded for either cod or haddock in VIIg for Vessel 2, which corresponds with a reduction in fishing effort during this time period in an attempt to reduce catches of these choke species.

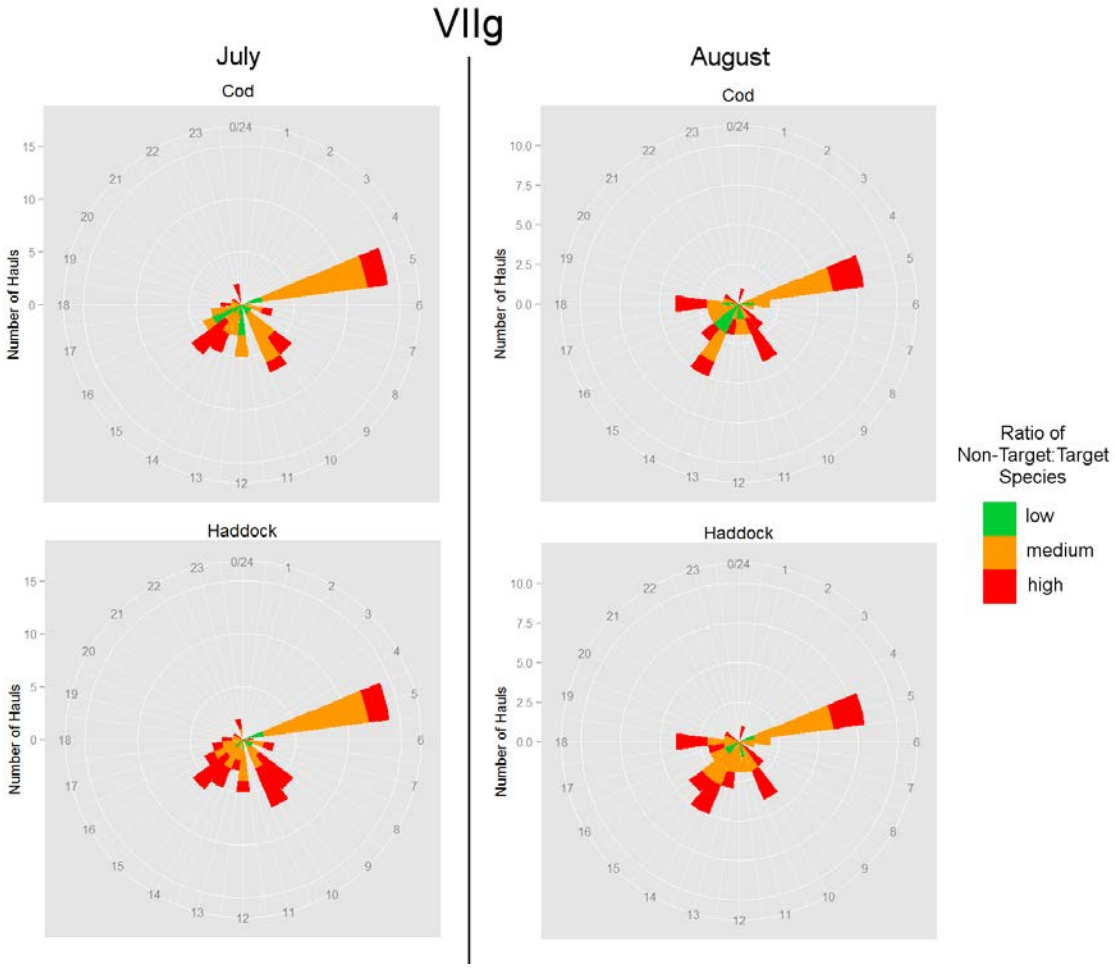

Figure 7. Ratio of non-target to target species for key choke species based on the time of day individual hauls were shot by vessel 2 in July and August (low ratios = no over-quota catches of non-target species; medium ratios = over-quota catches of non-target species by up to five times current quotas; high ratios = over-quota catches of non-target species by greater than five times current quotas).

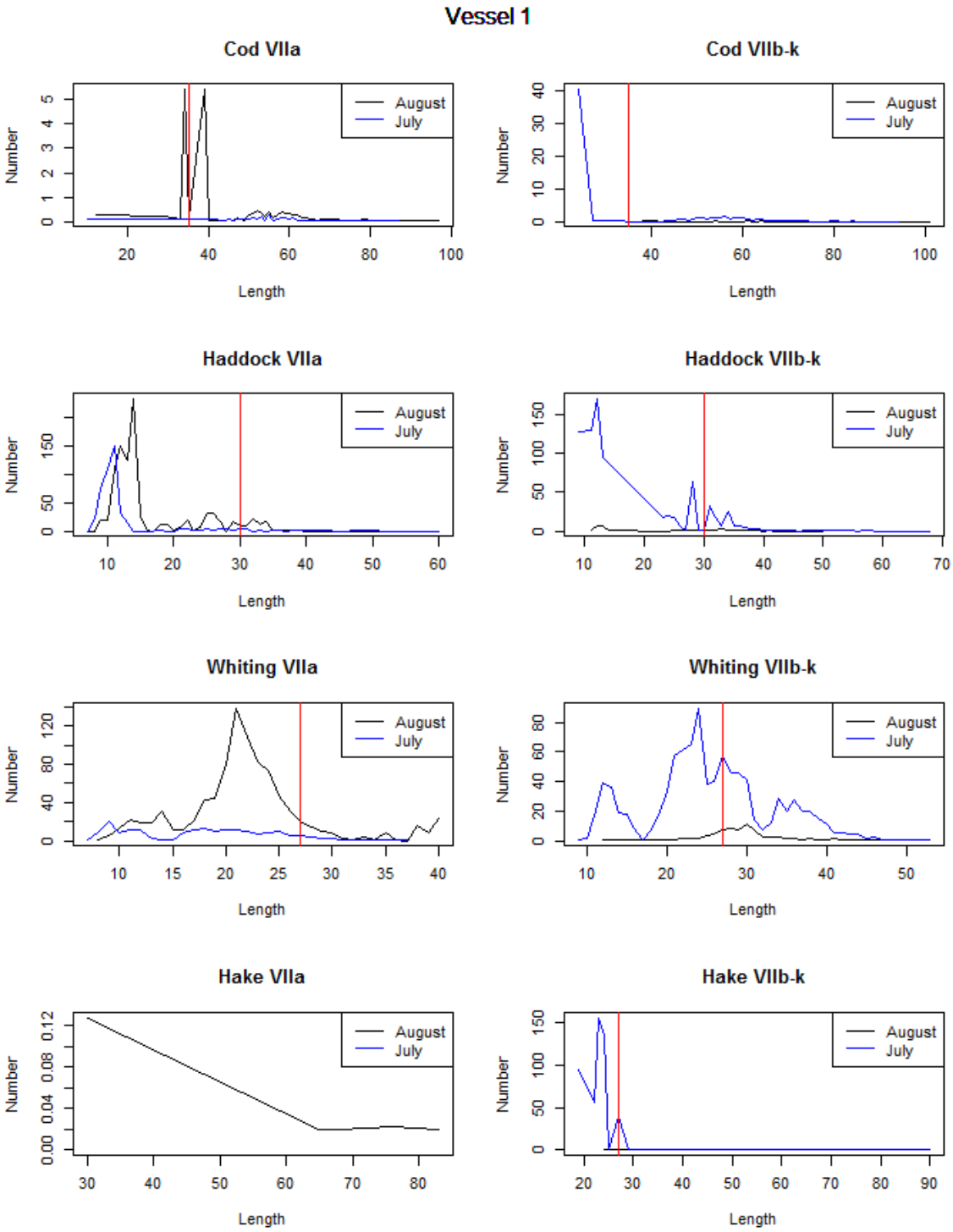

Figure 8. Standardized length frequencies of Cod, Haddock, Whiting and Hake, measured on Vessel 1 in July (blue) and August (black) with the MCRS line in red. The red line indicates minimum conservation reference size.

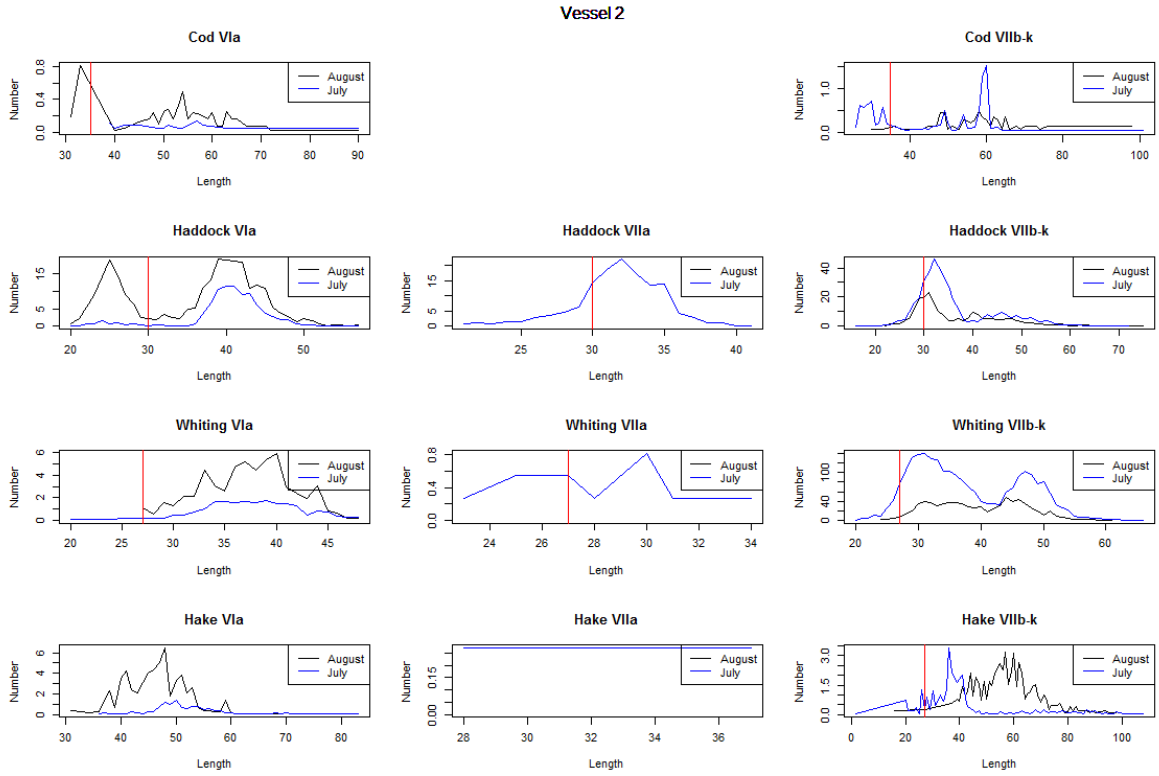

Figure 9. Standardized length frequencies of Cod, Haddock, Whiting and Hake, measured on Vessel 2 in July (blue) and August (black) with the MCRS line in red. The red line indicates minimum conservation reference size.

Some trends are apparent in compiled length frequency data in different areas but they are not consistent (Figures 8, 9) likely due to changes in the size composition of fish on the grounds months. For Vessel 1 in VIIa there was an increase in < MCRS whiting and haddock caught in August. Catches of these species > MCRS were consistent between the two months in VIIa. For Vessel 1 in VIIb-k, catches of whiting both above and below the MCRS were higher in July. Haddock catches > MCRS were similar in both months but haddock catches < MCRS were slightly lower in August. Catches of < MCRS hake in VIIb-k were also lower August.

For Vessel 2, the size composition of cod in VIa catches of cod was similar between months. Increased quantities of haddock, whiting and hake were caught in VIa in August. Few hauls were carried out in VIIa during July and August and fish were only measured in July. For Vessel 2 in VIIb-k, catches of cod, haddock and whiting were lower in August compared with July. Length distributions were consistent across months as might be expected given that the Vessel used tactical instead of gear based measures to try and reduce unwanted catches.

Table 4. Detailed economics for Business As Usual (BAU) and Landing Obligation (LO)

Vessel	Month	Scenario	Catch value (€)	Trips (no.)	Days fished (No.)	Variable cost (€)	Capital cost (€)	Fixed cost (€)	Total expenses (€)	Wages (€)	Total cost (€)	Net profit (€)
1	7	BAU	157170	4	19	49077	7300	28040	84417	36376	120793	36376
1	8	BAU	130258	4	17	43911	7300	28040	79251	25503	104754	25503
2	7	BAU	112252	6	25	24500	7244	22200	53944	29154	83098	29154
2	8	BAU	53899	3	18	17640	7244	11100	35984	8958	44942	8958
1	7	LO	71122	3	9	23247	7300	21030	51577	9773	61350	9773
1	8	LO	104646	4	13	33579	7300	28040	68919	17863	86782	17863
2	7	LO	68155	4	10	9800	7244	14800	31844	18156	50000	18156
2	8	LO	37255	3	11	10780	7244	11100	29124	4065	33189	4065

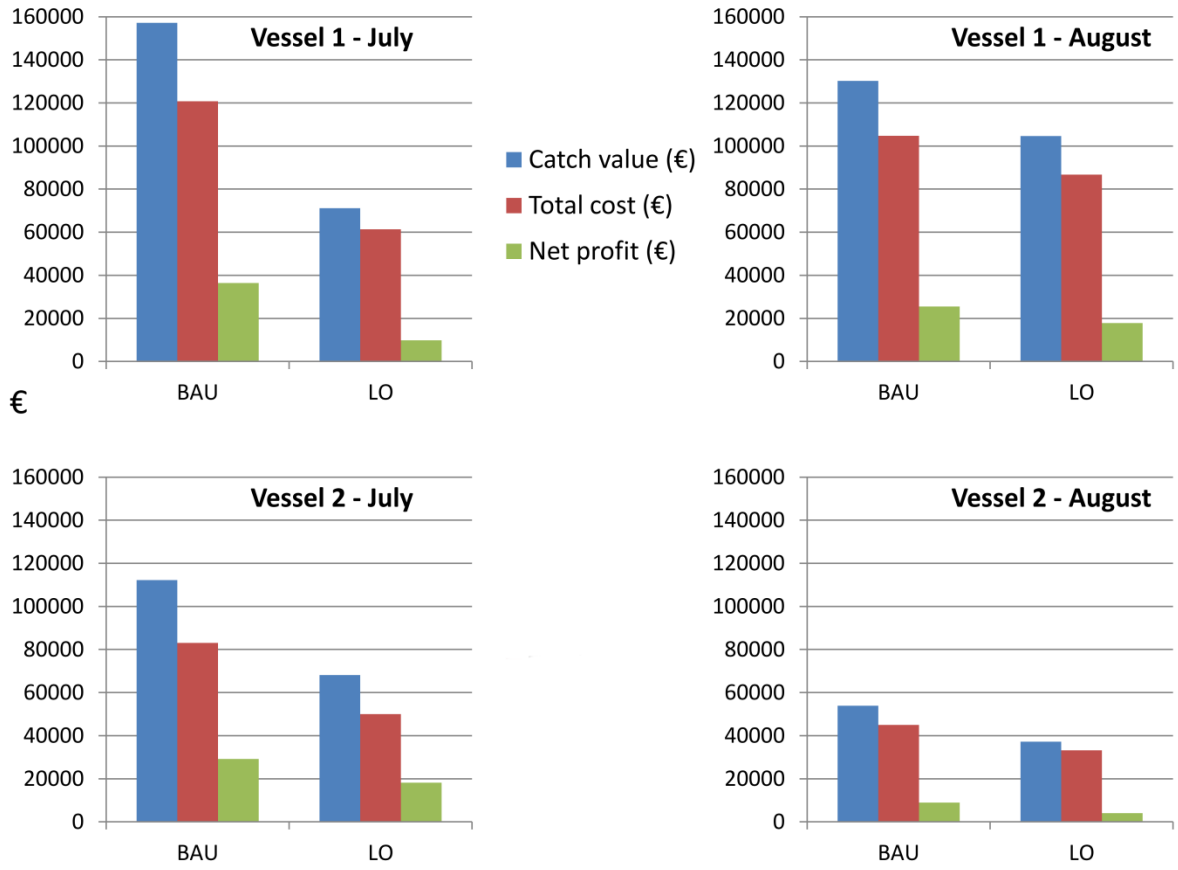

Figure 10. Summary economic results for trial vessels under Business As Usual (BAU) and Landing Obligation (LO) scenarios

Table 5. Details of additional catch allowances under potential Quota uplift (QUP) and De minimis (De min) scenarios

Vessel	Month	Scenario	ICES Division	Choke species	Monthly quota	Catch increase (%)	Increased quota (t)	Daily choke point (t)
1	7	De min	VIIg	cod	0.50	7	0.54	0.71
1	8	De min	VIIa	cod	0.50	7	0.54	0.59
2	7	De min	VIIg	haddock	2.00	7	2.14	2.27
2	8	De min	VIa	cod	0.31*			
2	8	De min	VIIg	haddock	2.00	7	2.14	2.47
2	8	De min	VIIg	cod	0.50	7	0.54	0.77
1	7	QUP	VIIg	cod	0.50	6	0.53	0.71
1	8	QUP	VIIa	cod	0.50	6	0.53	0.59
2	7	QUP	VIIg	haddock	2.00	9	2.18	2.27
2	8	QUP	VIa	cod	0.31*			
2	8	QUP	VIIg	haddock	2.00	9	2.18	2.47
2	8	QUP	VIIg	cod	0.50	6	0.54	0.77

* 1.5 % bycatch of total landings allowed

Detailed business as usual (BAU) and Landing Obligation (LO) scenarios are outlined in Table 4 and Figure 10. For Vessel 1 in July, a reduction in days fished from 19 under BAU to 9 under LO resulted in a 73% reduction in net profit from €36,373 to €9,773. In August, profitability was reduced from €25,503 under BAU to €17,863 under LO. A reduction in catch per haul of cod by 60% (Table 3) delayed choking by 4 days in August compared with July. In addition catch per haul of the target species, Nephrops, increased by 36% during August. These factors lead to a much lower reduction in profitability under LO in August (30%) compared with July (73%). For Vessel 2 in July, a reduction in fishing effort from 19 days under BAU to 10 days under LO resulted in a 36% reduction in profitability from €25,503 to €18,156. A total of 18 days were fished under BAU compared with 11 days under LO for the three observed trips in August. A 55% reduction in profits from €8,958 under BAU to €4,065 under LO occurred during this period. Vessel 2 would have achieved just one extra days fishing before choking occurred if the additional unobserved trips had been included. Hence omission of these trips had minimal impact on the LO scenario for Vessel 2 in August. No increase in days fished occurred under de minimis and quota uplift scenarios for either vessel in either month (Table 5).

4. Discussion

This study aimed to carry out a detailed simulation of the operational and economic impacts of the LO with a particular focus on the impacts of choke species. A number of choke species were identified throughout the trial including cod, haddock, angler, whiting and *Nephrops*. For Vessel 1 cod proved to be the principal choke species in both months of the study, primarily due to a relatively limited monthly quota allowance for this fishery. Haddock and cod proved to be the key choke species for Vessel 2 in both months of the trial, again primarily as a result of the limited quotas available for these two species relative to whiting quotas.

Reduced catches of cod and, related to this, delayed choking in the second month of operations by Vessel 1 may have been due to use of the 300 mm SMP, or temporal or spatial variability in cod abundance. In addition to the 300 SMP, other technical measures such as an inclined separator panel or rigid sorting grid can be used by vessels targeting *Nephrops* to reduce catches of whitefish species where required. Reduced catches of cod by Vessel 1 assisted in increasing profitability in August compared to July under the LO scenario. This was complemented by increased catches of *Nephrops* which also contributed to improved profitability in August.

Whether achieved through tactical changes in fishing behaviour or differences in fish abundance, Vessel 2 extended fishing effort by two days before choking occurred in August compared with July. In spite of this, profitability was negatively impacted under both BAU and LO scenarios in August due to comparatively low catch rates of whiting and haddock, the main target species. Similar to the 2014 study, attempts to reduce impacts of the LO likely contributed to reduced profitability in Phase 2 of the study. Results of the two simulation studies conducted to date demonstrate that tactical changes are unlikely to represent a comprehensive strategy for mitigating impacts of the LO in mixed demersal whitefish fisheries. Technical measures such as increasing the height of the fishing line (Krag *et al.*, 2010) have good potential to reduce catches of cod while maintaining catches of whiting and haddock. However, haddock and whiting generally behave the same way in the trawl, generally precluding the use of technical devices to select one species over the other (Catchpole and Revill, 2008). Furthermore, as demonstrated in this study, quota uplift and de minimis provisions are also unlikely to significantly reduce the impact of the Landing Obligation for low quota species such as cod and haddock.

Much of the difficulty in addressing the issues associated with the LO are as a result of the current mismatch in the relative quota of non-target species e.g. haddock in relation to the target species e.g. whiting and their relative availability on the fishing grounds. In VIIb-k in August for example 0.5 tonnes of cod and 2 tonnes of haddock were available compared to 60 tonnes of whiting. This means that the ratio of whiting to haddock quota is 30:1 whereas the actual ratio of the catches of whiting to haddock in VIIb-k during August was 5:1. This problem is likely to be compounded in 2016 due to an increase in whiting quota and decrease in haddock quota for Irish vessels operating in the Celtic Sea. The two vessels involved in this study currently have the same quota entitlements for whitefish species and *Nephrops*. The *Nephrops* vessel is less reliant on whitefish and has the ability to reduce catches of whitefish species which are susceptible to choking. The ability of the whitefish vessel to reduce catches of choke species such as haddock while maintaining commercially viable catch rates of other species is much more compromised. Hence, reducing the quota imbalance between whitefish species such as haddock and whiting will likely be required if mixed demersal whitefish boats are to remain commercially viable when the LO is fully implemented. If this issue is not addressed, then it is highly likely that there will be an influx of mixed demersal whitefish vessels to the *Nephrops* fishery as soon as their whitefish entitlement is exhausted and choked which will also have negative impacts on the *Nephrops* fishery.

A fishery based quota management system which facilitates allocation of more quotas of species such as haddock and cod to the vessels which target mixed demersal whitefish, and less to vessels which target *Nephrops* would assist in addressing this issue. A temporary rather than a permanent approach may be required to gain acceptance by Industry of such a major change to management of their operations. For example, vessels could sign up for a particular fishery for a set period e.g. 2

months, with maximum vessel participation to prevent excessive quota uptake (Davie and Lordan, 2011). Consideration should be given to exploring the practicalities and economics of such a fishery based quota allocation system.

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