Technical measures can be shown by experiment to reduce the capture of unwanted fish, but can we see the effect on the stock in a stochastic world?

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Abstract

Technical Control measures (TCM's) have the potential to reduce fishing mortality by reducing unwanted catch. Gear trials were conducted by BIM in June 2005 as part of the EU funded NECSSITY project to assess the potential benefits of using a coverless trawl. Results from these trials indicate that substantial reductions in by-catch are possible with little or no reduction in the catch of target species. However, the putative effect of this TCM on fishing mortality has received little attention to date. The analysis presented here has been conducted as part of the EU funded EFIMAS project to evaluate the potential effect of such TCM's on whitefish stocks in the Celtic Sea.

For this paper we have focused on whiting which showed the largest reduction in catch numbers with the coverless trawl in these trials. Stock projections were simulated on the whiting stock in VIIe-k using F-PRESS (Fisheries Projection & Evaluation by Stochastic Simulation), a simulation tool for evaluating fisheries management strategies. Our results indicate that while a difference in stock development can be shown deterministically, following the introduction of the coverless trawl, such a difference is difficult to detect when assessment uncertainty is added. We then try to answer, given the volume of whiting catch by the *Nephrops* fleets (putatively subject to the technical measure), and the assessment uncertainty; how big would the effect of the technical measure have to be, such that we could measure a difference (with confidence) in 10 years. The results raise some interesting questions on how we can evaluate the merit of effects we cannot measure.

Key words: *Nephrops*, Celtic Sea, Technical Control Measures, Stochastic simulation,

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1 Introduction

Here we analyse the potential impact on whiting stocks of introducing a coverless trawl into the *Nephrops* fishery in the Celtic Sea. This work has been carried out as part of the EU funded EFIMAS/NECESSITY projects in the North East Atlantic to look at alternative fisheries management strategies aimed at reducing bycatch of gadoids and hake in the *Nephrops* fishery.

In recent years a number of gear-based TCM's have been developed to reduce the levels of bycatch and increase selectivity in the *Nephrops* fishery. Many of these devices have been shown to significantly reduce the numbers of fish caught during experimental trials yet few have been taken up by the *Nephrops* fleet due to losses in marketable *Nephrops*, increased fuel costs and handling difficulties.

However, recent studies have indicated the effectiveness of the coverless trawl in reducing the numbers of whitefish species by up to 70%((Jacklin [2005])). By removing the headline, the coverless trawl utilises the tendency of fish to rise up and over the net as the trawl approaches. This significantly reduces the number of fish entering the net without compromising the catch of the target species.

This analysis aimed firstly to quantify the potential reductions in bycatch of whiting through the introduction of a coverless trawl to the Irish and French *Nephrops* directed fisheries. Secondly, stock projections were carried out to assess what impact this technical control measure, as a management measure could have on stock development in the medium term.

2 Method

2.1 Sea Trials

Data was collected for this analysis during sea trials aboard a commercial twin-rig prawn-trawler in an area colloquially known as 'The Smalls' in the Celtic Sea. This area lies within *Nephrops* functional units 20-22 (area covered by diagonal lines) within ICES area VIIg (Fig. 1). The chartered 23m fishing vessel made a total of twenty hauls from the 8th to the 18th of June 2005 with haul duration lasting on average five hours. The vessel fished an 80mm diamond mesh standard prawn trawl and an 80mm standard prawn trawl without the cover (coverless trawl).

After each tow the two nets were landed and kept separate in the pound. The catch for each net was sorted with all commercial whitefish being removed and measured. The remaining catch was sorted into baskets and the bulk catch noted, from this a random sample of prawns was taken to be measured.

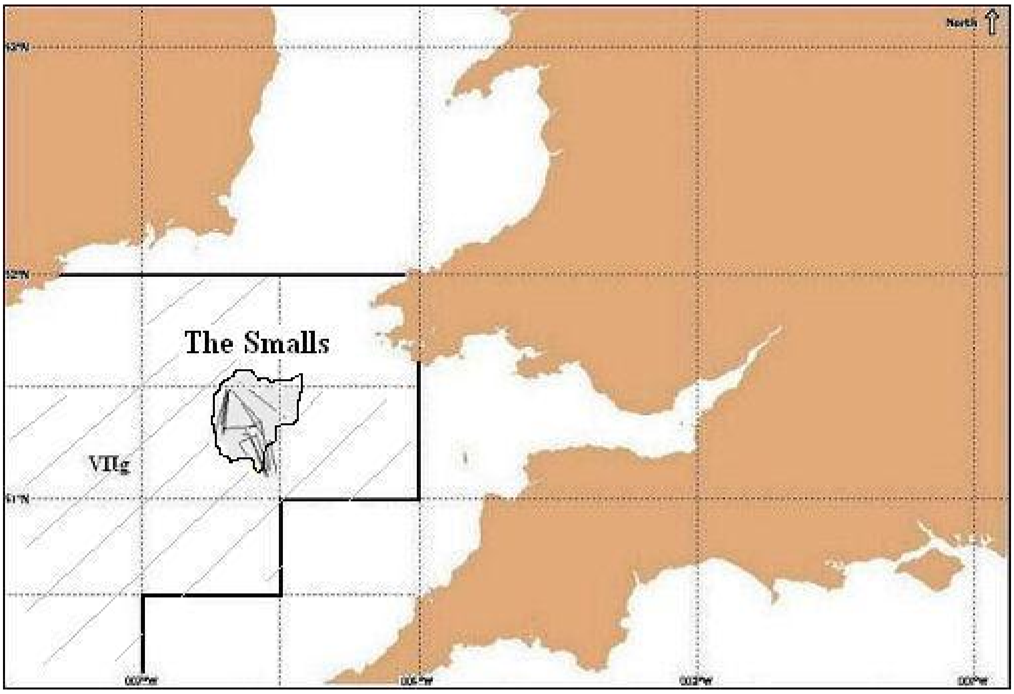

Fig. 1. Map of the trial area including haul tracks over 'The Smalls' *Nephrops* fishing grounds in the Celtic Sea.

2.2 Construction of an age length key

An age-length-key (ALK) was constructed using length at age data from Irish discard trips, the 2005 Irish Biological Survey and Irish observer trip data from 2002-2005. The datasets used are described in table 1.

Data Source	ICES Area	Year	Period	Lengths (cm)	Number aged
Discard Data	VIIj	2005	Quarter 1-4	22-34	31
Biological Survey	VIIj	2005	Quarter 1	11-54	10
Observer Data	VIIg	2002-05	Quarter 2	27-59	447

Table 1
Length at age data used for the construction of an age-length-key for whiting in the Celtic Sea.

2.3 Numbers At Age Landed

Official numbers of whiting landed at age by all fleets in VIIe-k in 2005 were taken from the 2006 ICES working group report on southern shelf demersal stocks (SSDS). This technical control measure is intended only for those fleets directly targeting *Nephrops*, therefore numbers at age for these fleets was specifically required. Two fleets were identified to be directly targeting *Nephrops* in the Celtic Sea. A French *Nephrops* OTB fleet, for which numbers at age landed were also available from the working group report and a small subset of the Irish OTB fleet operating in ICES Area VIIg. Numbers at age for the total Irish OTB fleet in VIIg were available however these were not disaggregated by métier.

2.3.1 Analysis of numbers at age for the Irish OTB Nephrops métier.

An analysis of Irish logbooks data returned total landings of 196.48 tonnes of whiting from those OTB trips targeting *Nephrops* in VIIg during 2005. A trip was assigned to this métier where landings of *Nephrops* comprised 30% or more of the catch by weight.

For the purpose of this analysis it is assumed that the Irish OTB *Nephrops* métier follows the same proportion of weight at age in the landings as the official VIIg OTB/TWR landings total (Table 2).

Age	Number At Age	Weight At Age (Kg)	Total Weight (t)	Proportion of Weight At Age
0	0	0.000	0	0
1	337800	0.256	87	0.024
2	2523200	0.302	762	0.211
3	2853400	0.366	1044	0.289
4	1287500	0.516	665	0.184
5	1386600	0.500	693	0.192
6	781000	0.442	345	0.095
7	344000	0.569	195	0.005
8	2800	0.845	2	0.001

Table 2
Numbers landed at age and proportion of landings at age (by weight) for all Irish OTB/TWR vessels in VIIe-k in 2005.

2.4 Fishing Mortality At Age

Stock projections in F-PRESS require fishing mortality to be provided for each age class. As the sea-trial took place in 2005 the fishing mortality vector for

2005 was taken from the 2006 ICES WG SSDS report. Historical uncertainty was calculated for each age class by calculating the CV between fishing mortality estimates at age for the years 2001-2004 as documented in the SSDS WG reports from 2004, 2005 and 2006.

A new F vector (F') was calculated to describe fishing mortality following the introduction of the TCM on the *Nephrops* directed fleets. The TCM effect was applied to the total landings at age for both the French and Irish *Nephrops* targeting fleets. A goal-seek was then performed in microsoft excel using the standard catch equation (Eq. 1) to calculate F' for each age class based on the adjusted numbers landed at age (Table 7).

$$C_t = (1 - e^{F'+M})(F'/(F'+M)) \tag{1}$$

Ct = Catch numbers at age (Discards were not included)
Nt = Population Numbers
F' = Fishing Mortality
M = Natural Mortality

2.5 Weights At Age, Natural Mortality and Maturity Ogive

F-PRESS also requires a number of stock characteristics to model the stock. These were taken from the 2006 SSDS working group report. Natural mortality is assumed to be 0.2 over all age groups from age 1. At age 0 natural mortality is taken to be 0.4, which is seen as more realistic due to the higher mortality of juvenile whiting.

The maturity ogive from the 2006 SSDS WG report was used (Table 3).

Age	0	1	2	3	4	5+
Maturity	0	0.39	0.90	0.99	0.99	1.0

Table 3
Whiting Maturity at age in VIIe-k. ICES [2006b]

2.6 Stock Projections

A segmented regression was carried out based on the Julius Algorithm using historical recruitment and spawning stock biomass data from 1982-2005 as given in the 2006 SSDS WG report. Hockey stick parameters were calculated from which to draw recruitment values during each year of the projection.

This algorithm gave a residual standard error of 0.5127 on 23 degrees of freedom with a slope of 3.753856 and an inflection point at 18751 x 10^3. Mean recruitment was calculated at 70388.56 x 10^3.

Four stock projections were conducted in F-PRESS to assess the effect of introducing a coverless trawl into the French and Irish *Nephrops* fleets on whiting stocks in the Celtic Sea (Table 4). All runs projected the stock forward from 2005 to 2014 and each year ran for 100 iterations. The 2005 F vector taken from the 2006 SSDS working group report was used in Run 1 and Run 2. In Run 1 there was no uncertainty/noise on F or any of the other model parameters (other than that of recruitment). For run 2 a layer of uncertainty was introduced by providing a CV for fishing mortality based on the level of historical uncertainty from previous WG assessments. Run 3 and Run 4 projected the stock forward based on the adjusted fishing mortality vector (F') calculated as a result of introducing the TCM on the *Nephrops* targeting fleets. There was no uncertainty placed on the F' vector in run 3 while run 4 included historical uncertainty.

	Recruitment	Fishing Mortality Vector		Uncertainty		
Run	Segmented Regression	F	F'	Absent	Historical	Figure
1	x	x		x		2
2	x	x			x	3
3	x		x	x		4
4	x		x		x	5

Table 4
Stock projections of whiting in ICES VIIe-k

2.7 Projected spawning stock biomass analysis

To assess the impact of introducing the coverless trawl on whiting stocks, spawning stock biomass vectors for each iteration of each year were directly compared between stock projections.

The first comparison was between Run 1 and Run 3. The only uncertainty/noise in both of these projections came when drawing recruitment. The second comparison between Run 2 and Run 4 added a layer of uncertainty /noise around F by providing CV values based on historical uncertainty. Significance difference was tested for each comparison using Student's paired t-test (Table 8).

3 Results

3.1 Sea Trials

There were 18 valid hauls, during which a total of 7308 whiting were caught with an average CV of 0.51 between hauls. Table 5 gives the total numbers of each species caught by gear and the average CV between hauls for each species. Only whiting was considered to have been caught in large enough numbers and with an acceptable CV between hauls.

	Number caught by trawl			
Species	Standard	Coverless	TCM Effect	Average CV Between Hauls
Whiting	4895	2413	- 51%	0.51
Cod	382	340	- 11%	0.66
Hake	738	426	- 42%	0.95
Haddock	35	63	+ 80%	1.2

Table 5
Numbers of four commercially important whitefish species caught by the standard *Nephrops* trawl and the coverless trawl during gear trials on the Smalls in June 2005.

All whiting caught were measured during the sea-trial and the length frequencies from both the standard trawl and coverless trawl were passed through the ALK constructed from the data in table 1. Numbers at age for both trawls were established and the TCM effect was calculated. Results indicate a greater reduction in catch numbers with an increase in age. There appeared to be an increase in numbers caught of 7 year-old whiting, however this is most likely as a result of sampling error/ small sample size. Therefore, in our analysis we have replaced this value with the average TCM effect from age 4-6 (-54.7%).

3.2 Whiting numbers at age

Age	0	1	2	3	4	5	6	7
Standard Trawl	0.0	331.7	1083	1987.7	967.1	460.4	61.5	1.7
Coverless Trawl	0.0	207.7	567.6	951.5	445	210.8	27.2	3.3
TCM Effect	0.0	-37.4%	-47.6%	-52.1%	-54%	-54.2%	-55.8%	+97%*

Table 6
Numbers of whiting at age caught using a standard *Nephrops* trawl and a coverless trawl showing the TCM effect on each age class. +97% was replaced by -54.7% in the analysis.

Nephrops fleets accounted for just under 5% of total whiting landings by number from ICES VIIe-k in 2005. F_{bar} for this stock is calculated at ages 2-5 and was estimated to be 0.6768 in 2005. When the TCM was applied to landings from the *Nephrops* fleet alone this resulted in 647523 fewer whiting landed which corresponded to a reduction in F_{bar} of 0.0363 (Table 7).

	All Fleets VIIe-k		*Nephrops* Targeting Fleets		Adjusted Total	
Age	Landings	F	Landings	TCM Effect	Landings	F'
0	0	0	0	0	0	0
1	779000	0.0345	29872	-11165	767835	0.0339
2	6384000	0.2914	274554	-130654	6253346	0.2825
3	8378000	0.611	359381	-187359	8190641	0.5833
4	5321000	0.7641	190406	-102788	5218212	0.7274
5	4737000	1.041	208454	-113026	4623974	0.9689
6	3608000	0.7914	176164	-98228	3509772	0.7436
7	166000	0.7914	7865	-4302	161698	0.7599
F_{2-5}		.6768				0.6405

Table 7
ICES Area VIIe-k 2005: Number of whiting landed at age with the corresponding fishing mortality vector for all fleets (F). Total landings by *Nephrops* directed fleets are also shown with the TCM effect in number at age. Adjusted totals at age are then shown for landings of all fleets with the TCM applied only to those fleets targeting *Nephrops* and the corresponding fishing mortality vector (F').

3.3 Stock Projections

Summary plots of each of the four stock projections are presented in figures 2-5.

Student's paired t-test was carried out to compare Run1 with Run3 and also to compare Run2 with Run4. The results are presented in table 8. Year on year both tests showed no significant difference (at the 5% level) between spawning stock biomass with or without the introduction of the TCM (with the exception of 2006 in Run1-Run3). The introduction of uncertainty on F' in the second t-test (Run2-Run4) reduced the significance further. This show us that despite taking all of the uncertainty out of the system, and assuming that the TCM is taken up by 100% of the vessels targetting *Nephrops* in the Celtic Sea it is still not possible to detect any significant increase in spawning stock biomass following the introduction of this TCM.

4 Discussion

The sea trials conducted for this analysis have demonstrated the potential for a coverless trawl to reduce the bycatch of whitefish species and provide a

Welch Two Sample T-Test Results				
	Run1-Run3		Run2-Run4	
Projection Year	p-value	t	p-value	t
2006	**0.0213**	**-2.3208**	0.9429	0.0717
2007	0.207	-1.266	0.6866	0.4041
2008	0.3991	-0.8451	0.8432	0.198
2009	0.3048	-1.0289	0.8126	0.2374
2010	0.1571	-1.4203	0.7966	0.2582
2011	0.1366	-1.4948	0.985	0.0189
2012	0.1946	-1.3014	0.7108	0.3714
2013	0.1645	-1.3952	0.7073	0.3761
2014	0.2904	-1.061	0.5159	0.6508
Critical Value	1.972			

Table 8
p-Values and t-test results on stock projections with(Run2-Run4) and without(Run1-Run3) uncertainty. Values in bold indicate significance (i.e. where there is less than 5% chance of there being a difference between SSB if the TCM is introduced.

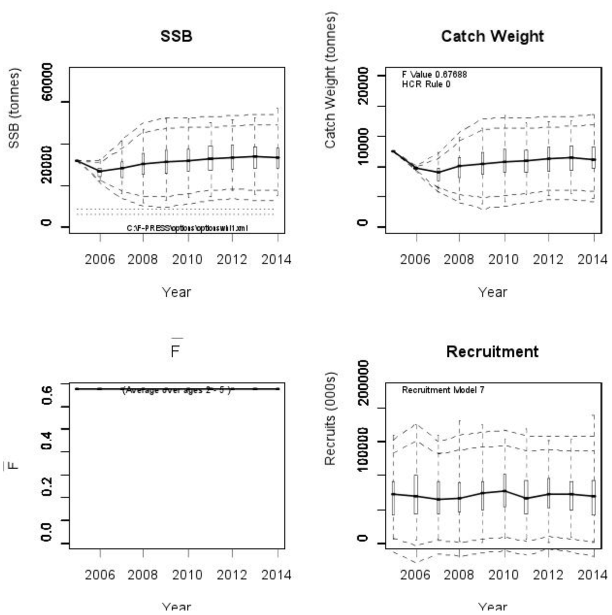

Fig. 2. Time series plots of SSB, catch, F and recruitment, for projection of Celtic Sea Whiting from 2005 to 2014. Recruitment is modeled using a Hockey stick function based on historical recruitment data.

cleaner catch of the target species. There was a significant reduction in the number of whiting (51%) and hake (42%) accompanied by a 13% increase in *Nephrops* numbers.

Despite this, the likelihood of the coverless trawl being adopted by the whole *Nephrops* fleet and the potential benefits to whitefish stocks are less certain.

Fig. 3. Time series plots of SSB, catch, F and recruitment, for projection of Celtic Sea Whiting from 2005 to 2014. Recruitment is modeled using a Hockey stick function based on historical recruitment data. Historical uncertainty has been applied to F

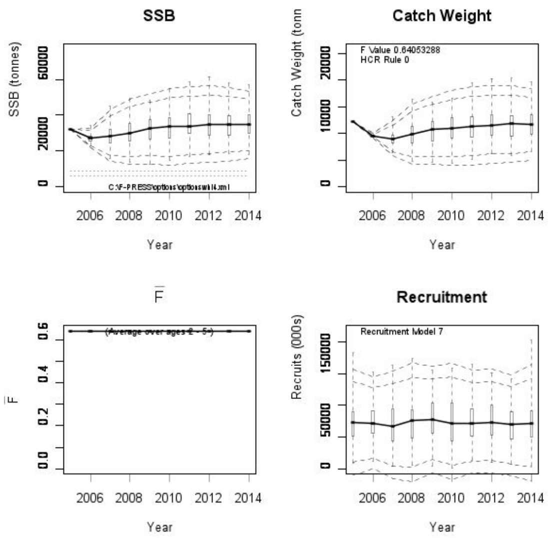

Fig. 4. Time series plots of SSB, catch, F and recruitment, for projection of Celtic Sea Whiting from 2005 to 2014. Recruitment is modeled using a Hockey stick function based on historical recruitment data. The TCM has been applied to the *Nephrops* fleet only.

Results indicate that while there are reductions in numbers at all ages, a smaller proportion of large whiting are retained in the catch. It is doubtful whether this would appeal to fishermen unless the returns from increased numbers and perhaps better quality *Nephrops* could be shown to offset this loss.Furthermore, whiting discards in the *Nephrops* fishery consists mainly of whiting aged 1 and 2ICES [2006b]. For these age groups the average TCM

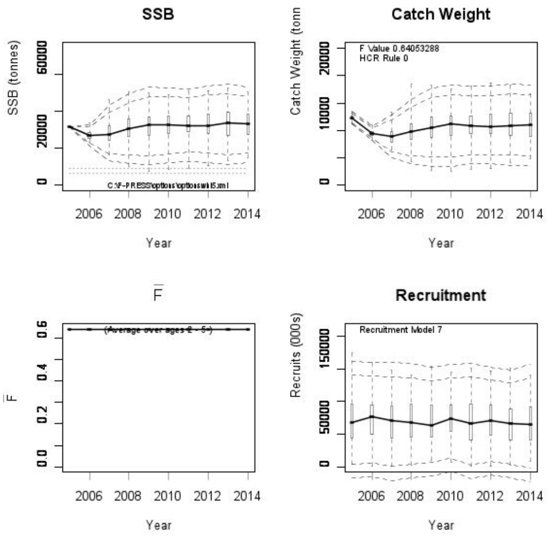

Fig. 5. Time series plots of SSB, catch, F and recruitment, for projection of Celtic Sea Whiting from 2005 to 2014. Recruitment is modeled using a Hockey stick function based on historical recruitment data. Historical uncertainty has been applied to F'. The TCM has been applied to the *Nephrops* fleet only.

effect was shown to be -42.5%. Although this is a significant reduction it is still less than the older age groups (3+) where an average reduction in numbers of 54.2% was recorded.

From an economical perspective it would appear that the coverless trawl could provide a relatively simple, viable alternative for use in the *Nephrops* fishery, provided the loss of whitefish is compensated for by the increased volume or quality of the *Nephrops* landed.

However, from a biological perspective it would appear from this analysis that despite large reductions in bycatch across all ages, the reduced mortality through applying this TCM to the Nephrops fleet alone is unlikely to achieve any noticeable results in stock assessments. The impact of a reduction in F_{2-5} of 0.0363 as a result of introducing this TCM in isolation is unlikely to achieve any protective management objectives on whitefish stocks.

Further analysis is currently being carried out to see exactly how much F would need to be reduced in order to be able to detect a change in F in a WG assessment in the short-medium term.

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