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The "Smalls" *Nephrops* Grounds (FU22) 2015 UWTV Survey Report and catch options for 2016.

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Abstract

This report provides the main results and findings of the tenth annual underwater television survey on the ‘Smalls grounds’ ICES assessment area; Functional Unit 22. The survey was multi-disciplinary in nature collecting UWTV, CTD and other ecosystem data. A total of 33 UWTV stations were surveyed successfully (good quality video footage) carried out over an isometric grid at 4.5nmi or 8.3km intervals. Of the planned stations 17% (7) could not be completed due to very poor or nil visibility conditions encountered at seabed. For these stations density estimates were filled-in using and average of historic values within 2nmi. The resulting krigged burrow abundance estimate for the Smalls ground decreased by 16% relative to 2014. The final abundance estimate was 1,363 million. The precision, with a CV of 7%, was well below the upper limit of 20% recommended by SGNEPS 2012. Using the 2015 estimate of abundance and updated stock data implies catch of 3,027 tonnes and landings of 2634 tonnes in 2016 fishing at F_{msy} (assuming that all catch is landed). Only one species of sea pen *Virgilaria mirabilis* was recorded as present at the stations surveyed. Trawl marks were observed at 12% of the stations surveyed.

Key words: *Nephrops norvegicus*, stock assessment, geostatistics, underwater television (UWTV), benthos, CTD.

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Introduction

The prawn (*Nephrops norvegicus*) are common in the Celtic Sea occurring in geographically distinct sandy/muddy areas where the sediment is suitable for them to construct their burrows (Figure 1). The *Nephrops* fishery in VII is extremely valuable with landings in 2014 worth around € 95 m at first sale. The Celtic Sea area (Functional Units 19-22 see Figure 1) supports a large multi-national targeted *Nephrops* fishery mainly using otter trawls and yielding landings in the region of ~5,000 t annually over the last decade (ICES, 2015). The 2014 reported landings from the Smalls (~2600 t) were estimated to be worth in the region of €17 m at first sale. The Smalls ground is particularly important to the Irish demersal fleet accounting for around 13% of the fishing effort by all demersal vessels >15m between 2006 - 2009 (Gerritsen, et al. 2012). Good scientific information on stock status and exploitation rates are required to inform sustainable management of this resource.

Nephrops spend a great deal of time in their burrows and their emergence behaviour is influenced by several factors: time of year, light intensity, tidal strength, etc. Underwater television surveys and assessment methodologies have been developed to provide a fishery independent estimate of stock size, exploitation status and catch advice (ICES, 2009a & 2012). This is the tenth in a time series of UWTV surveys in the Celtic Sea FU22 "Smalls" ground carried out by the Marine Institute, Ireland. The 2015 survey was carried between the 31st August – 2nd September on RV Celtic Voyager. The survey was multi-disciplinary in nature and also covered FU19 and FU20-21 the results of which are presented in Lordan *et. al* 2015. The specific objectives of the 2015 survey are listed below:

1. To complete randomised fixed isometric survey grid of ~40 UWTV with 4.5 nautical mile (nmi) spacing stations on the "Smalls" *Nephrops* ground (FU22).
2. To carry out ~12 UWTV stations in FU19 South and SW Ireland and ~75 stations in FU20-21.
3. To obtain 2015 quality assured estimates of *Nephrops* burrow distribution and abundance on the "Smalls" *Nephrops* ground (FU22), FU19 and FU20-21. These will be compared with those collected previously.
4. To collect ancillary information from the UWTV footage collected at each station such as the occurrence of sea-pens, other macro benthos and fish species and trawl marks on the sea bed.
5. To collect oceanographic data using a sledge mounted CTD.
6. To sample *Nephrops* and macro benthos using a 4 m beam trawl deployed at ~10 stations.

This report details the final UWTV results of the 2015 survey and documents other data collected during the survey. Operational survey details are available in form of a survey narrative available from the scientist in charge (CL). The 2015 abundance estimate is used to generate catch options for 2016 in line with procedures outlined in the stock annex for FU22 (ICES, 2015).

Material and methods

To maintain a CV < 20%, to achieve good spatial coverage over the ground and to generate burrow surface that reflects the underlying abundance a grid spacing of 4.5nmi has been used since 2012. The 2015 randomised isometric grid resulted in 40 planned stations. These are overlaid on *Nephrops* directed fishing activity in Figure 2 (Gerritsen & Lordan, 2011). The boundary use to delineate the edge of the ground was based on information from VMS, habitat maps, and previous UWTV observations. The same boundary has been used through the time series.

The 2015 Celtic Sea survey took place on RV Celtic Voyager between the 31st August to 2nd September. Previously the survey mainly took place in July each year. The timing of the survey was delayed as the RV Celtic Voyager broke down in the early summer. The operational protocols used were those reviewed by WKNEPHTV 2007 (ICES, 2007) and employed on other UWTV surveys in Irish waters. These protocols can be summarised as follows: At each station the UWTV sledge was deployed. Once stable on the seabed a 10 minute tow was recorded onto DVD. Time referenced video footage was collected by one video camera with a field of view or 'FOV' of 75 cm. Vessel position (DGPS) and position of sledge (using a USBL transponder) were recorded every 1 to 2 seconds. The navigational data was quality controlled using an "r" script developed by the Marine Institute (ICES, 2009b) an example is shown in Figure 3. In 2015 the USBL navigational data was used to calculate distance over ground for 100% of stations.

Seven stations were not surveyed successfully in 2015 due to very poor visibility conditions encountered as a result of strong tides (Figure 2). These conditions produced a heavy sediment loading in the water column and practically nil visibility at the seabed. In line with standard operating procedures these 7 stations were only abandoned completely after 2 attempts were made at each station. For robust geostatistical analysis ideally all stations on the grid need to be surveyed. The following fill-in procedure was used: Two buffer zones of 1 nmi and 2 nmi distance were generated around the missing stations. The counts and mean of historic density estimates within the 1 and 2 nmi buffers were calculated (Table 1). The standard kriging procedure was carried out and summary results were computed for the 1 and 2 nmi "fill-ins". (Table 2). In the end the mean of historic densities within 2 nmi of the planned stations were used in the calculation of the 2015 abundance estimate presented in this report.

In addition CTD profile was logged for the duration of each tow using a sled mounted and calibrated Seabird SBE 37. The sensor takes readings every 5 seconds and will be processed at a later date. Due to time constraints fishing operations were not carried out this year.

In line with SGNEPS recommendations all scientists were trained/re-familiarised using training material and then were tested by counting reference footage for FU22 prior to recounting 2015 footage (ICES, 2009b). Individual's counting performance against the reference counts was measured by Linn's concordance correlation coefficient (CCC). A threshold of 0.5 was used to identify counters who needed further training. Once this process had been undertaken, all recounts were conducted by two trained "burrow identifying" scientists independent of each other on board the research vessel during the survey. During this verification process the visibility, ground type and speed of the sledge during one-minute intervals were subjectively classified using a standard classification key. In addition to the numbers of *Nephrops* burrows complexes (multiple burrows in close proximity which appear to be part of a single complex which are only counted once) the *Nephrops* activity in and out of burrows were also counted and recorded for each one-minute interval. Following the recommendation of SGNEPS the time for verified recounts was 7 minutes (ICES, 2009b).

Notes were also recorded each minute on the occurrence of trawl marks, fish species and other species. Numbers of sea-pen species were also recorded due to OSPAR Special Request (ICES 2011). A key was devised to categorise the densities of seapens based SACFOR abundance scale (Table 3) after ICES (2011). Finally, if there was any time during the one-minute where counting was not possible, due to sediment clouds or other reasons, this was also estimated so that the time window could be removed from the distance over ground calculations. Consistency and bias between individual counters was examined using Figure 4. There is some variability between counters but no major bias or excessive deviations.

The recount data were screened for one minute intervals with any unusually large deviation between recounts. Mean density was calculated by dividing the total number of burrow systems by the survey area observed. The USBL data were used to calculate distance over ground of the sledge. The field of view of the camera at the bottom of the screen was estimated at 75cm assuming that the sledge was flat on the seabed (i.e. no sinking). This field of view was confirmed using lasers during the 2015 survey. Occasionally the lasers were not visible at the bottom of the screen due to sinking in very soft mud (the impact of this is a minor under estimate of densities at stations where this occurred). From 2006-2014 the spatial co-variance and other spatial structuring a geo-statistical analysis of the mean and variance was carried out using SURFER Version 10.7.972. In 2015 the geostatistical analysis was carried out using RGeostats package (Renard D., *et al*, 2015) and is available as a separate R markdown document. The same basic steps were carried out as in previous years; construction of experimental variogram, a model variogram $\gamma(h)$, was produced with an exponential model, create krigged grid file using all data points as neighbours, same boundary used to estimate the domain area, mean density, total burrow abundance and calculate survey precision.

Results

In 2015 33 stations were completed successfully on the Smalls, planned 7 stations could not be survey due to very poor visibility. These were filled in using the procedure outlined above. A summary of the results is presented in Table 4.

Figure 5 shows bubble plots of the variability between minutes and operators. These show that the burrow estimates are very consistent between minutes and counters.

A combined violin and box plot of the observed burrow densities is presented in Figure 6. This shows that median and mean burrow densities are similar in most years. The inter-quartile range between 0.2- 0.7 in most years. In most years two modes are apparent at relatively high density (~0.7 /m^2) and at moderate density (0.25/m^2). In 2015 the mean adjusted[1] burrow density was 0.49/m^2. There were 3 observations of adjusted burrow density 1.0/m^2.

The blanked krigged SURFER contour plot and posted point density data for 2006-2014 are shown in Figure 7. The RGeostats contour plot for 2015 in Figure 8. The krigged contours correspond well to the observed data. Highest densities are in the centre of the ground in all years. In general the densities are higher towards the south and central area of the ground.

The summary statistics from this geo-statistical analysis are given in Table 4 and Figure 9. The 2015 estimate of 1363 million burrows is above the geometric mean of the series (1277 million burrows). The estimation of variance of the 2015 survey as calculated by RGeostats is

[1] Note the “adjusted” density estimates in this report are adjusted by dividing by 1.3 (Table 2) to take account of edge effect over estimation of area viewed during UWTV transects (see Campbell et al 2009).

relatively low (with a CV or RSE of 7%) which is well below the SGNEPS recommendation for a CV <20% (ICES, 2012).

Sea-pen distribution across the Smalls *Nephrops* grounds is mapped in Figure 10. All sea-pens were identified from the video footage as *Virgularia mirabilis*. This seapen species was recorded as frequently present at 6% and occasionally present at 15% of stations. Trawl marks were noted at 12% of the stations surveyed.

Table 5 and 6 gives the various inputs to the catch option calculations based on recent sampling and the 2015 survey results (ICES, 2015). The catch and landings options at various different fishing mortalities are calculated in line with the stock annex using the 2015 survey abundance. Fishing at F_{msy} in 2016 would result in catches of 3027 tonnes and landings of 2634 t assuming that all catch is landed (Table 7).

Discussion

Since 2006 a dedicated annual UWTV survey has taken place which gives abundance estimates for this ground with high precision. The 2015 burrow abundance estimates have decreased by 16% relative to 2014. However in 2015 there is added uncertainty, not accounted for in the model or CV estimate, because 17% of the planned TV stations could not be successfully surveyed due to poor visibility on the seabed. Having said that the spatial distributions of densities have been fairly consistent over time. The overall density has also been relatively stable. The fill in procedure used to generate density estimates for the 7 missing stations should be a good approximation.

Discard rates for this FU have fluctuated but in the last three years are now around 21% (by number). The stock has been exploited below the proposed Fmsy proxy of 10.9 % in recent years. Because harvest rates are calculated on the basis of numbers and 25% of the *Nephrops* in this area are assumed to have survived discarding up to now this presents a problem in calculating catch options for 2016. *Nephrops* in this area will be covered under the landings obligation in 2016 but it is not yet clear how this will be implemented in practice. Under the Landings Obligation scenario in Table 7 it is assumed that all catches will be landed in 2016 so the discards that would have survived up to now are also removed from the fishery. In this scenario fishing at F_{msy} in 2016 would imply total catches of 3027 t which implies; landings or in ICES terminology “wanted catch” of 2634 t and discards or “unwanted catch” of 393 t. Under the discarding is allowed scenario, two options are presented. The first assumes that discarding continues at its current rate, here total catches would be higher (3194 t). This is because 25% of the discards are assumed to survive increasing the mean weight of the dead removals (L +DD). The second scenario assumes that discards are around 7% by weight in 2016. This scenario implies that there will be a selectivity change in the fishery to reduce discards to the *de minimus* level of 7%. Total catch advice under that scenario is higher again (3257 t).

The imposition of the landings obligation on *Nephrops* fisheries in 2016 should result in changes in selectivity. This is not taken into account in any of the catch advice because it is not possible to predict exactly what might happen. The main message is that any improvements in selectivity in the fishery and reductions in discards will result in increased mean weight in the catches. This will in turn reduce overall mortality on the stocks and allow for catch increases in the future.

An important objective of this UWTV survey was to collect various ancillary information. The occurrence of trawl marks on the footage is notable for two reasons. Firstly, it makes identification of *Nephrops* burrows more difficult as the trawl marks remove some signature features making accurate burrow identification more difficult. Secondly, only occupied *Nephrops* burrows will persist in heavily trawled grounds and it is assumed that each burrow is occupied by one individual *Nephrops* (ICES 2008). The CTD data relatively easy to collect and over time will augment the knowledge base on habitat and oceanographic regime.

The objectives of the survey were only partially met this year due to a combination of factors. The UWTV footage quality was very good for most stations. Future survey scheduling should be cognisant of the potential for strong tides to re-suspend sediment into the water column. The multi-disciplinary nature of the survey means that the information collected is highly relevant for a number of research and advisory applications.

Acknowledgments

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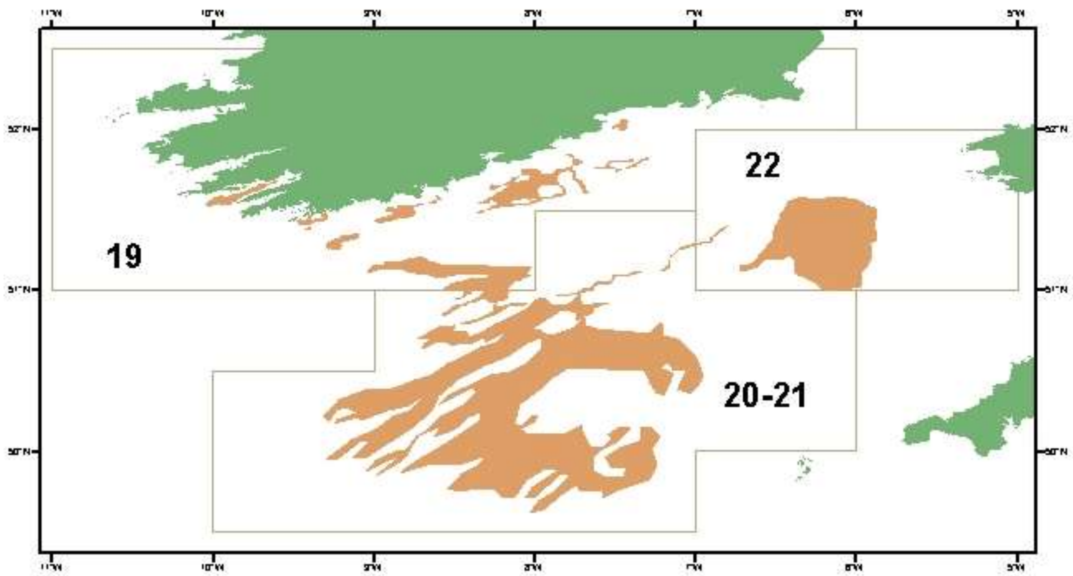

Figure 1: FU22 Smalls grounds: *Nephrops* Functional Units (FUs) in the greater Celtic Sea and area polygons.

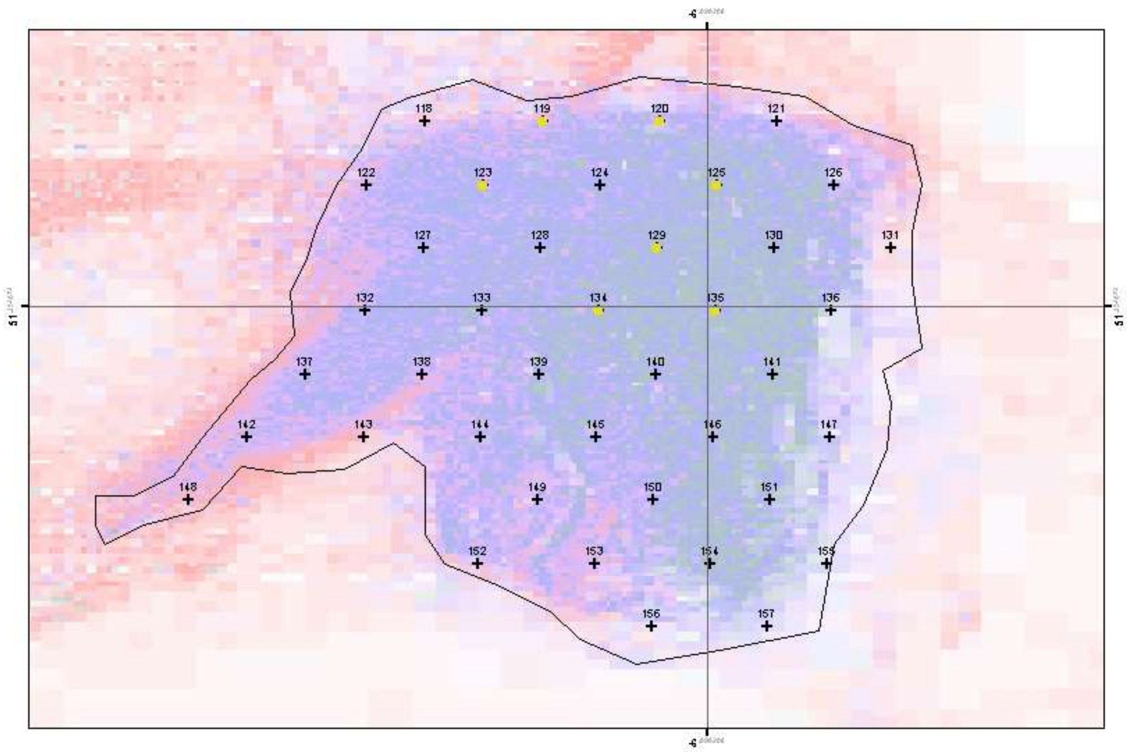

Figure 2: FU22 Smalls grounds: TV stations completed on the 2015 survey overlaid on a heat map of *Nephrops* directed Irish fishing activity. Stations not surveyed shown as yellow dots.

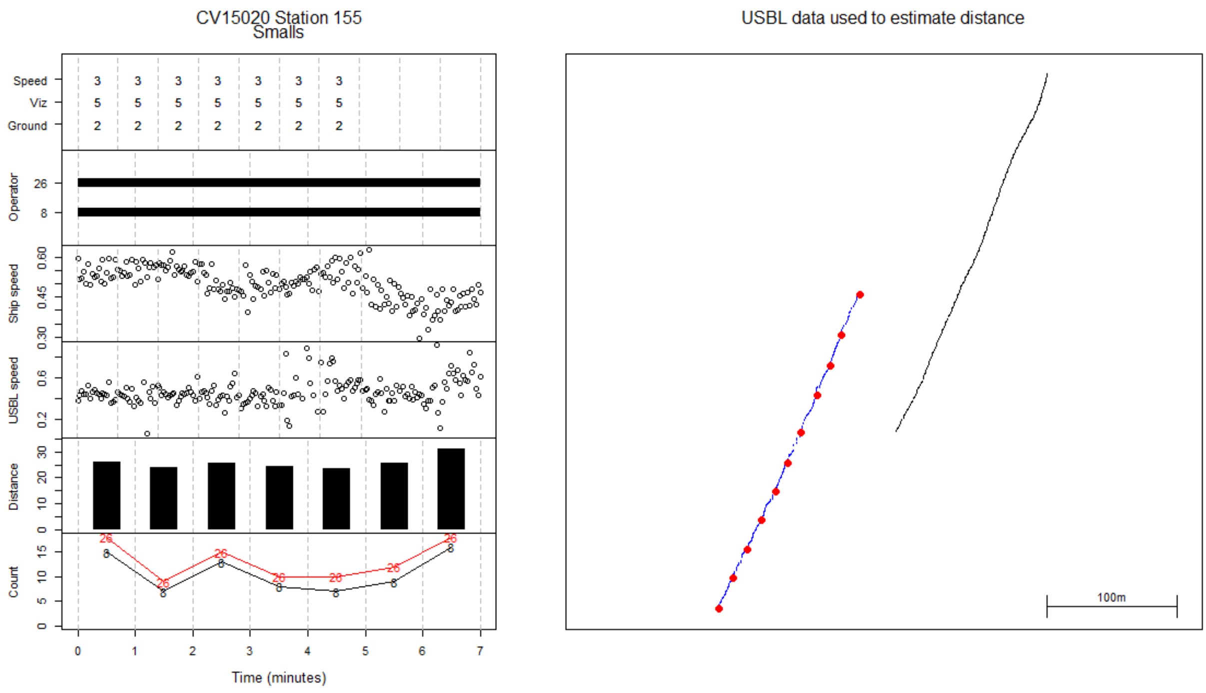

Figure 3 : FU22 Smalls grounds: r - tool quality control plot for station 161 of the 2015 survey.

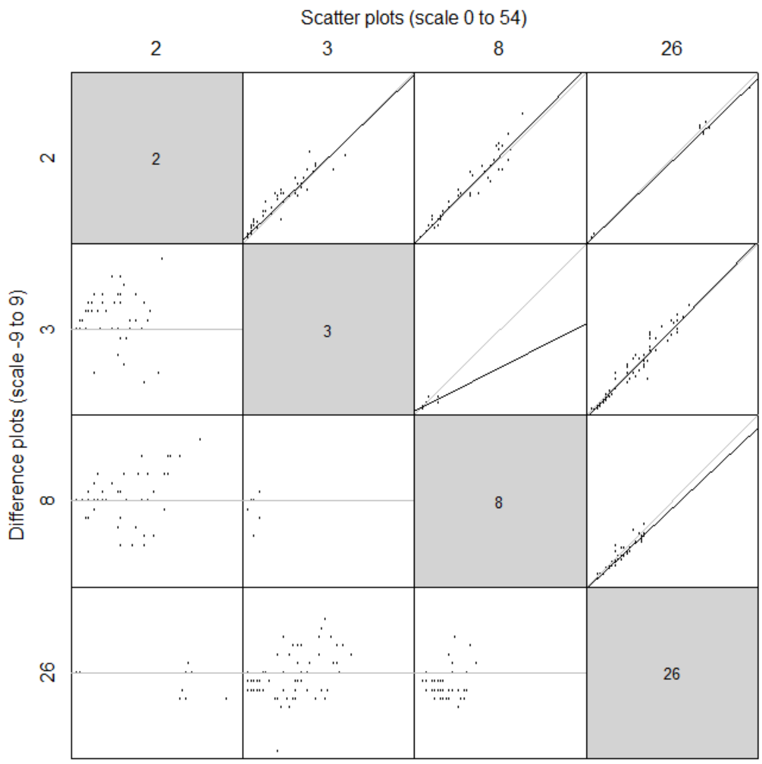

Figure 4: FU22 Smalls grounds: Scatter plot analysis of counter correlations for the 2015 survey.

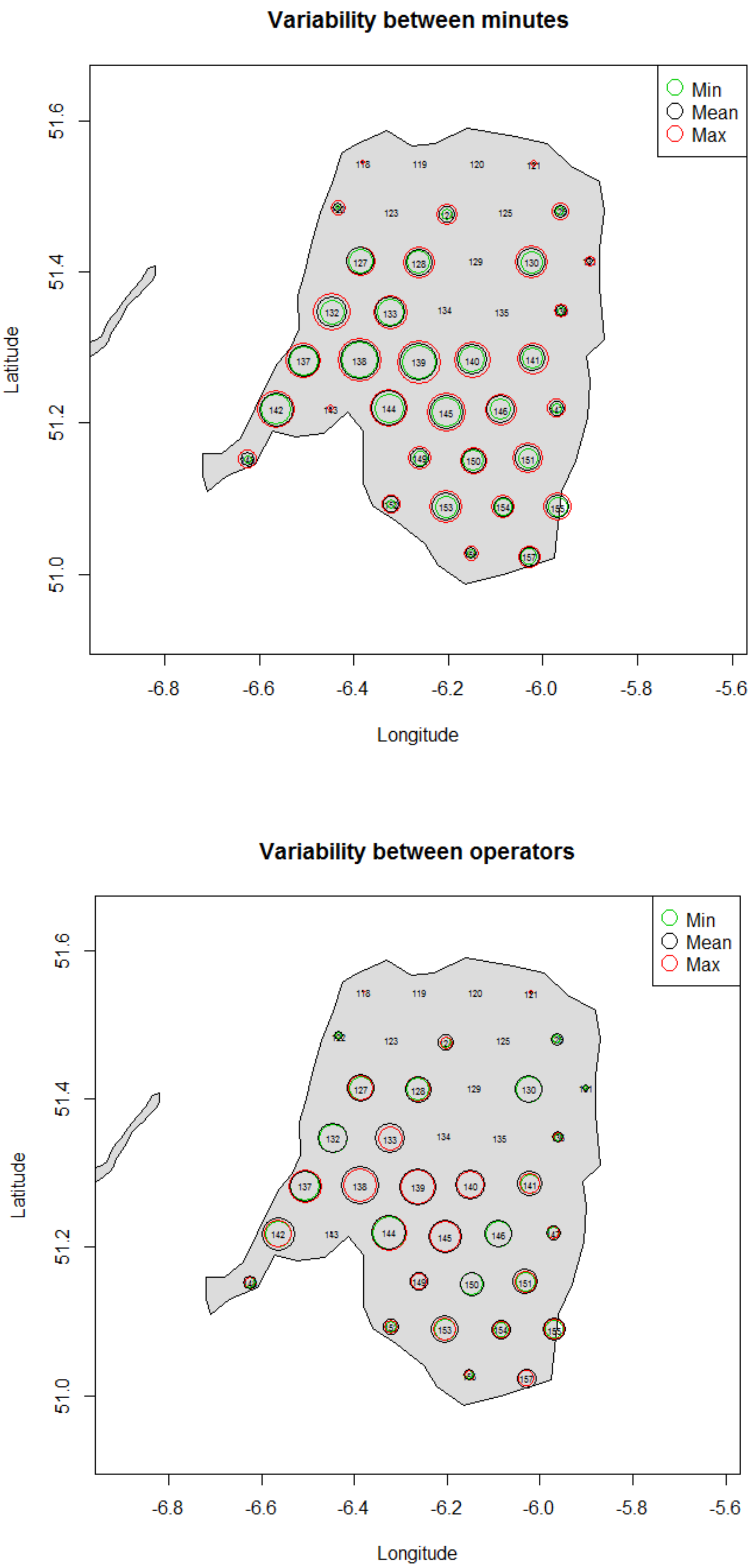

Figure 5: FU22 Smalls grounds: Plot of the variability in density between minutes (top panel) and between operators (counters) (bottom panel) for each station in 2015.

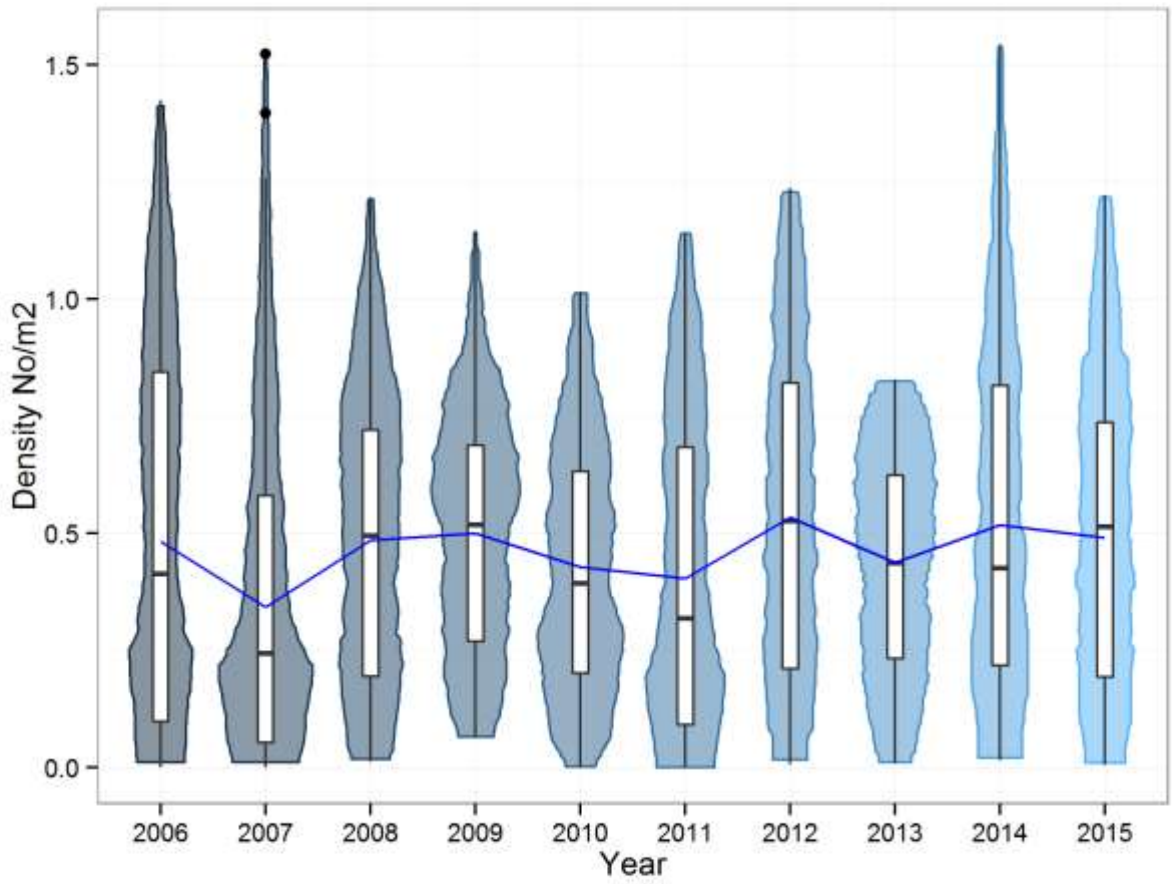

Figure 6: FU22 Smalls grounds: Violin and box plot of adjusted burrow density distributions by year from 2006-2015. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range and the black vertical line is the range.

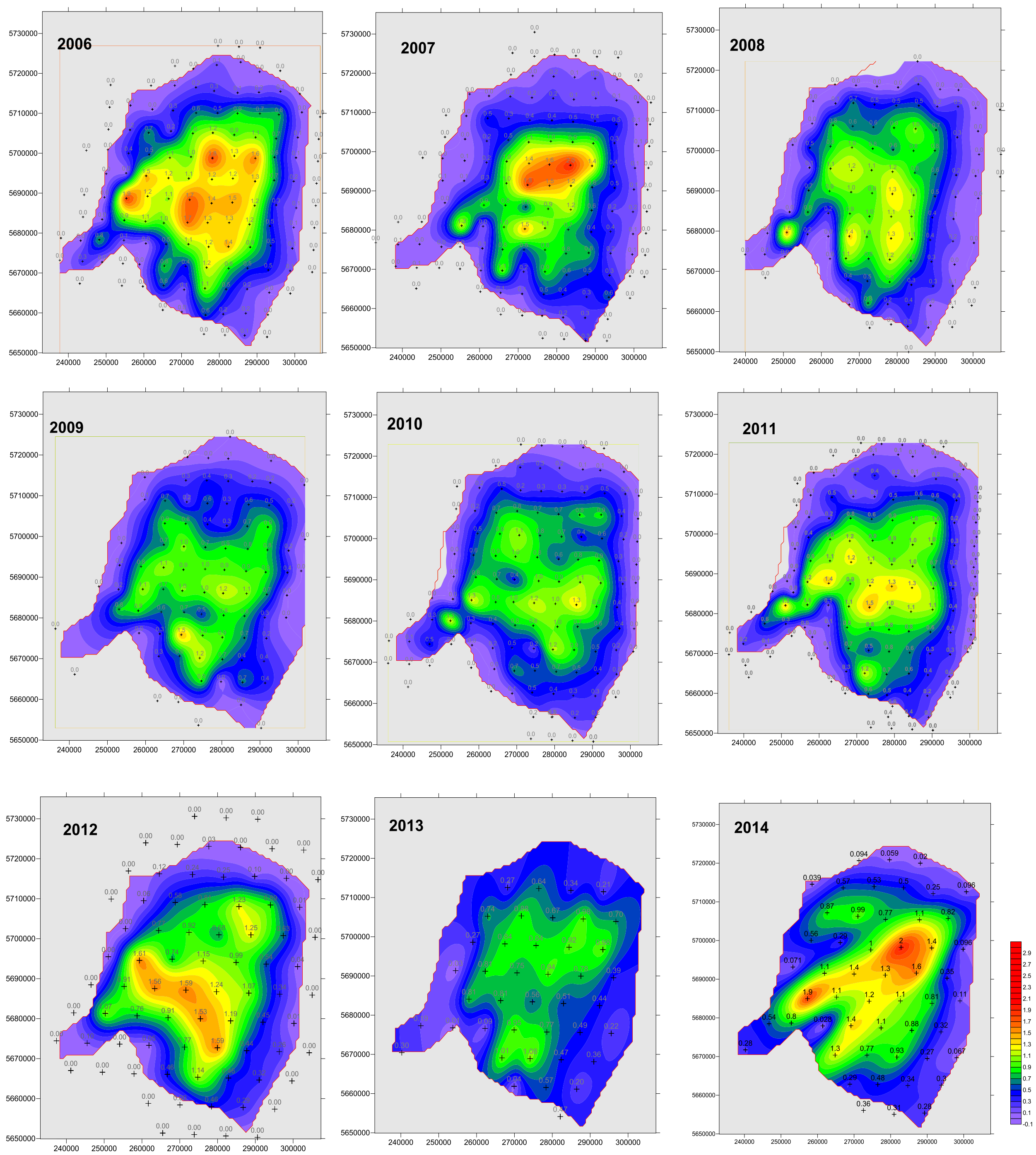

Figure 7: FU22 Smalls grounds: Contour plots of the krigged density estimates by year from 2006 (top left) - 2014 (bottom right). Note: these are based on unadjusted densities. Surfer10 procedure graphical output.

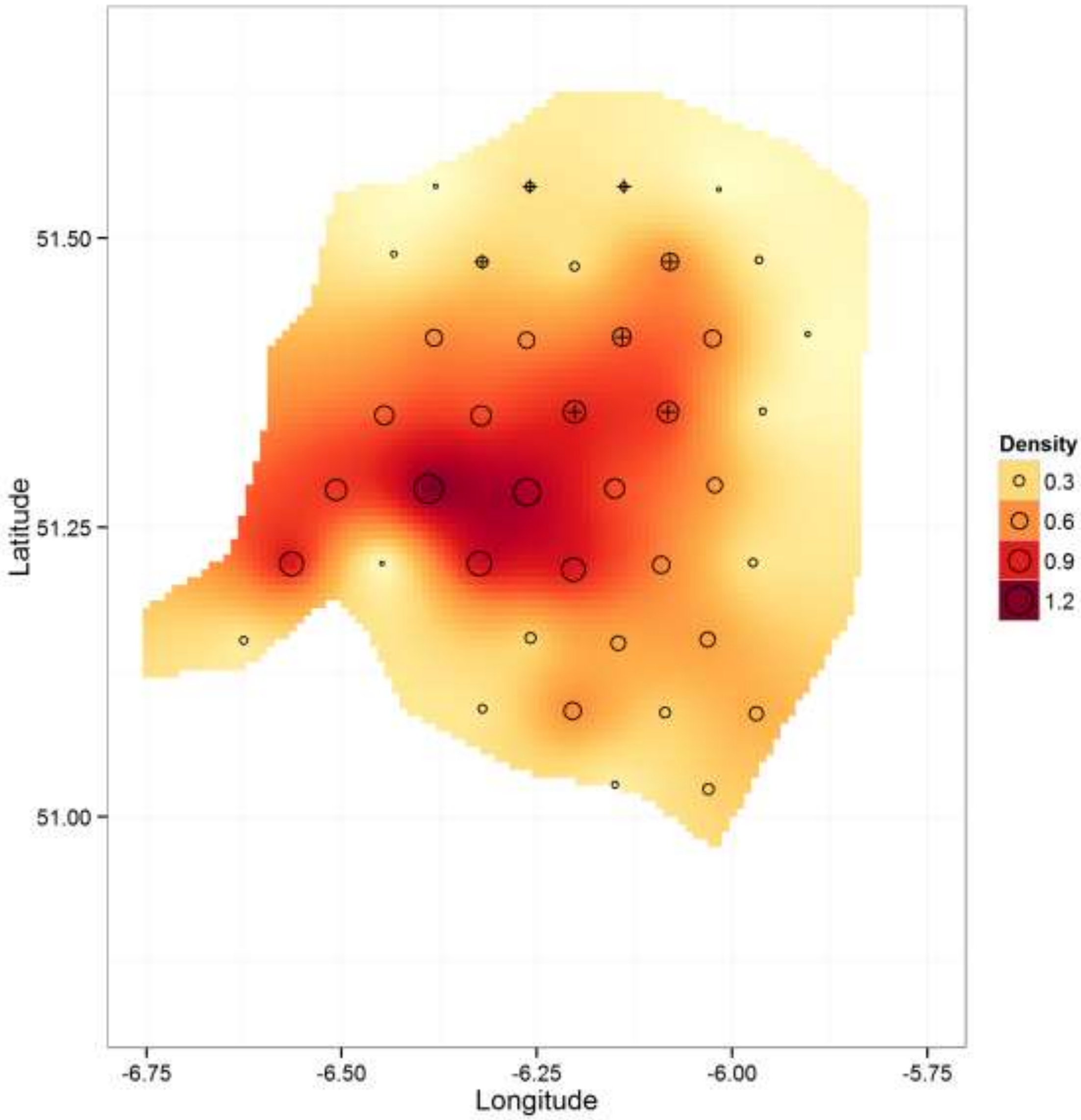

Figure 8: FU22 Smalls grounds: 2015 Contour plot of the krigged adjusted density estimates including the fill-ins for missing stations shown as black cross. RGeostats procedure graphical output.

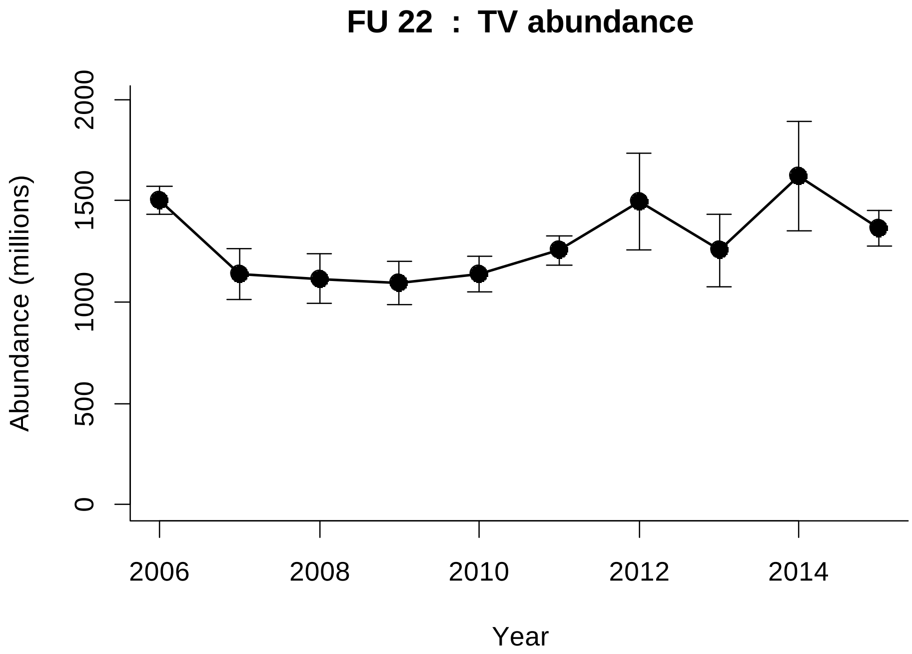

Figure 9: FU22 Smalls grounds: Time series of geo-statistical adjusted abundance estimates (in millions of burrows). The error bars indicate the 95% confidence intervals.

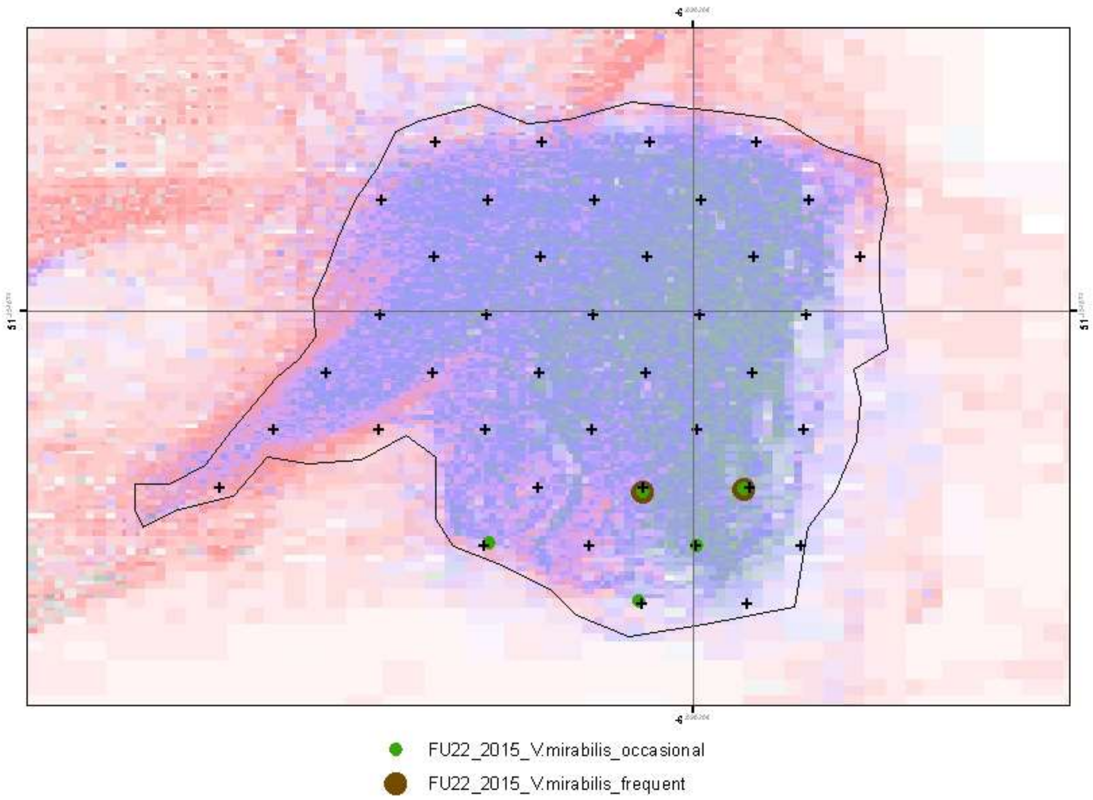

Figure 10: FU22 Smalls grounds: Stations where *Virgilaria mirabilis* was identified during the 2015 survey overlaid on a heat map *Nephrops* directed fishing activity.

Table 1: Number of historic stations selected by buffer zone and mean density adjusted values calculated.

Buffer 1 nmi		
Station to replace	Count of Stations within Buffer	Mean Density Adjusted (burrow/m²)
119	4	0.183
120	3	0.282
123	4	0.326
125	3	0.610
129	2	0.549
134	2	0.916
135	3	0.721

Buffer 2 nmi		
Station to replace	Count of Stations within Buffer	Mean Density Adjusted (burrow/m²)
119	8	0.235
120	11	0.174
123	12	0.347
125	10	0.630
129	11	0.707
134	11	0.900
135	8	0.822

Table 2: Geostatistical summary of sensitivity analysis of buffers.

Buffer	mean	n	sd	se	ci	area	abund	upper	lower	CViid	meanGeo	CVgeo
1 nmi	0.48	40	0.121	0.036	85.902	3063.957	1352.302	1438.204	1266.401	0.224	0.441	7%
2 nmi	0.49	40	0.124	0.036	88.499	3063.957	1362.680	1451.179	1274.181	0.227	0.445	7%

Table 3: Key for classification of Seapen abundance as used on Irish UWTV surveys.

	Number/Min
Common	20-200
Frequent	2-19
Ocasional	<2

Species
Virgularia mirabilis
Pennatula phosphorea
Funiculina quadrangularis

Sea Pens								
V. mirabilis			*P. phosphorea*			*F. quadrangularis*		
C	F	O	C	F	O	C	F	O

Table 4: FU22 Smalls grounds: Overview of geostatistical results from 2006-2015.

Year	Number of stations	Mean Density adjusted (burrow/m²)	Domain Area (km²)	Geostatistical Abundance adjusted (millions of burrows)	CV on Burrow estimate
2006	100	0.49	2962	1503	2%
2007	107	0.37	2955	1136	6%
2008	76	0.36	2698	1114	6%
2009	67	0.36	2824	1093	5%
2010	90	0.37	2861	1141	4%
2011	107	0.41	2881	1256	3%
*2012	47	0.49	2934	1498	8%
*2013	41	0.41	2975	1254	7%
*2014	52	0.53	2970	1622	8%
*2015	40**	0.49	3064	1363	7%

*reduced randomised isometric grid

** In 2015 7 of the stations were filled in with an estimate based on the mean density of historical stations within 2nmi of the planned station.

Table 5 : FU22 Smalls grounds: Inputs to short-term catch option table.

Year	Landings in Number (millions)	Discards in Number (millions)	Discard proportion D/(L+D)	Removals in Number (millions)	Dead discard rate (prop. by number)	Adjusted Survey (millions)	95% Conf. intervals (millions)	Harvest Ratio	Landings (t)	Discards (t)	Discard % of catch by weight	Mean Weight in landings (gr)	Mean Weight in discards (gr)	Mean Weight in catch (gr)
2003	95.7	54.2	0.36	136.4	0.30	Na	Na	Na	2,050	535	21%	21.4	9.9	13.7
2004	71.7	8.5	0.11	78.1	0.08	Na	Na	Na	1,828	76	4%	25.5	8.9	22.8
2005	114.7	90.8	0.44	182.8	0.37	Na	Na	Na	2,425	647	21%	21.1	7.1	11.8
2006	97.2	54.7	0.36	138.2	0.30	1503	59	9.2%	1,752	593	25%	18.0	10.8	11.5
2007	164.8	149.9	0.48	277.2	0.41	1136	134	24.4%	2,880	1,513	34%	17.5	10.1	9.2
2008	131.9	60.5	0.31	177.3	0.26	1114	131	15.9%	3,114	764	20%	23.6	12.6	16.2
2009	92.8	31.1	0.25	116.1	0.20	1093	107	10.6%	2,245	589	21%	24.2	19.0	18.1
2010	129.7	28.4	0.18	151.0	0.14	1141	89	13.2%	2,840	439	13%	21.9	15.5	18.0
2011	61.6	6.7	0.10	66.5	0.07	1256	74	5.3%	1,617	144	8%	26.3	21.7	23.7
2012	123.8	24.0	0.16	141.8	0.13	1498	235	9.5%	2,633	256	9%	21.3	10.7	17.8
2013	96.6	30.7	0.24	119.6	0.19	1254	172	9.5%	2,255	362	14%	23.3	11.8	17.7
2014	104.5	30.4	0.23	127.3	0.18	1622	254	7.8%	2,615	415	14%	25.0	13.7	19.4
2015						**1363**	**88**							
	Average 2012-14		**0.21**					**9.0%**		Avg 2003-2014		**22.43**	**12.64**	**16.65**

Table 6 : The basis for the catch options.

Variable	Value	Notes
Stock Abundance	1363	UWTV 2015
Mean weight in landings	22.43	Average 2003-2014
Mean weight in discards	12.64	Average 2003-2014
Discard proportion	21%	Average (proportion by number) 2012-2014
Discard survival rate	25%	Only applies in scenarios where discarding allowed
Dead discard rate	83.4%	Average (proportion by number) 2012-2014, only applies in scenarios where discarding allowed; calculated as dead discards divided by dead removals.

Table 7 : FU22 Smalls grounds: Short-term management option table giving catch options for 2016 using 2015 UWTV estimate.

Landing obligation

Basis	Total catch	Wanted catch*	Unwanted catch*	Harvest rate**
MSY Approach	3027	2634	393	10.9%
F_{MSY}	3027	2634	393	10.9%
$F_{current}$ (2012-2014)	2486	2163	323	9.0%

Discarding allowed

Basis	Total catch	Dead removals	Landings	Dead discards	Surviving discards	Harvest rate*
	L+DD+SD	L+DD	L	DD	SD	for L+DD
MSY Approach	3194	3090	2778	312	104	10.90%
MSY approach (F_{MSY} proxy) assuming 7% discard rate in weight	3257	3200	3029	171	57	10.9%