The "Smalls" *Nephrops* Grounds (FU22) 2014 UWTV Survey Report and catch options for 2015

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Abstract

This report provides the main results and findings of the ninth 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 52 stations UWTV stations were carried out over an isometric grid at 4.5nmi or 8.3km intervals. The krigged burrow abundance estimate for the Smalls ground increased by 22% relative to 2013 and was the highest in the 9 year time series. The final abundance estimate was 1,622 million with a CV of 8% which is well below the upper limit of 20% recommended by SGNEPS 2012. Using the 2014 estimate of abundance and recent mean weight and discard data would imply total catches at F_{msy} in 2015 of 3,797t. This implies landings of 3,409 tonnes. Temperature on the seabed varied by 2^{o}C over the *Nephrops* ground with coldest values around 9.4^{o}C in the deepest part of the area. Only one species of sea pen *Virgilaria mirabilis* was recorded as present at 46% of the stations surveyed. Trawl marks were observed at 28% 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 were the sediment is suitable for them to construct their burrows (Figure 1). The *Nephrops* fishery in VII is extremely valuable with landings in 2018 worth around € 80 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, 2014). The 2013 reported landings from the Smalls (~2300 t) were estimated to be worth in the region of €11.4 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 ninth in a time series of UWTV surveys in the Celtic Sea FU22 "Smalls" ground carried out by the Marine Institute, Ireland. The 2014 survey was carried between the 8th-27th of August 2014 on RV Celtic Voyager. The survey was multi-disciplinary in nature and also covered FU19 the results of which are presented in (Lordan et. al 2014); the specific objectives are listed below:

1. To complete randomised fixed isometric survey grid of ~52 UWTV with 4.5 nautical mile (Nmi) spacing stations on the "Smalls" *Nephrops* ground (FU22).
2. To carry out ~40 UWTV stations in FU19 South and SW Ireland if time allows.
3. To obtain 2014 quality assured estimates of *Nephrops* burrow distribution and abundance on the "Smalls" *Nephrops* ground (FU22) and FU19. 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 2014 survey and documents other data collected during the survey. The 2014 abundance estimate is used to generate catch options for 2015 in line with procedures outlined in the stock annex for FU22 (ICES, 2014).

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 was used. The 2014 randomised isometric grid resulted in 52 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, previous UWTV observations. The same boundary has been used through the time series.

The 2014 Celtic Sea survey took place on RV Celtic Voyager between 18th to 27th August. Previously the survey mainly took place in July each year, the timing of the survey was pushed back because a survey of the Labadie was carried out first in July. 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 2014 the USBL navigational data was used to calculate distance over ground for 100% of stations.

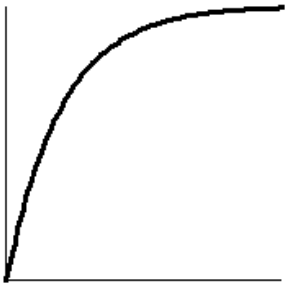
In addition CTD profile was logged for the duration of each tow using a sled mounted and calibrated Seabird SBE 37. The sensor takes readings every 5 seconds and is processed to calculate an average bottom temperature and salinity and Surfer contour plots (Figure 11) are presented in this report. CTD data for the "Banana" ground are also available but not plotted as the area of this grounds is <150 km².

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 2014 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 1) 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 2014 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).

To account for 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 the Smalls Grounds. The spatial structure of the density data was studied through variograms. The mid-points of each UWTV transect were converted to the Universal Transverse Mercator geographic coordinate system (UTM). In 2013 there was no need to include addition stations, with assumed zero density outside the known distribution of *Nephrops* or suitable sediment, in the krigging process. An unweighted and unsmoothed omnidirectional variogram was constructed with a lag width of approximately 1160 and maximum lag distance of between 24-29 km. A model variogram $\gamma(h)$, was produced with an exponential model (see below). Model fitting was via the SURFER algorithm using the variogram estimation option. Various other experimental variograms and model setting were examined before the final model choice was made.



Exponential Model
Cressie (1991, p. 61)

$$\gamma(h) = C\left[1 - e^{-h}\right]$$

The resulting annual variograms were used to create krigged grid files. The final part of the process was to limit the calculation to the known extent of the ground using a boundary blanking file. The resulting blanked grid was used to estimate the domain area and total burrow abundance.

Although SURFER was used to estimate the burrow abundance this does not provide the krigged estimation variance or CV. This was carried out using the EVA: Estimation VAriance software (Petitgas and Lafont, 1997). The EVA burrow abundance estimates were all extremely close to the Surfer estimate (+- 100 million burrows) with the exception of 2009 when the spatial coverage was poor.

Results

All 52 stations were completed successfully on the Smalls. It was not possible to carry out fishing operations during this survey due to unfavourable weather conditions. Figure 5 shows bubble plots of the variability between minutes and operators. These show that the burrow estimates are fairly consistent between minutes and counters.

A combined violin and box plot of the observed burrow densities from 2006 to 2014 on the Smalls *Nephrops* Grounds is presented in Figure 6. This shows that burrow densities tend to be negatively skewed in most years (the median is at or below the mean). 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 2014 the mean adjusted[1] burrow density was 0.53/m^2. There were 7 observations of adjusted burrow density 1.0/m^2.

The geo-statistical structural analysis is shown in the form of variograms in Figure 7. There is a weak evidence of a sill at around 25km in 2007 and 2008. The blanked krigged contour plot and posted point density data are shown 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 3 and Figure 9. The 2014 estimate of 1622 million burrows is well above the geometric mean of the series (1277 million burrows). The estimation of variance of the 2014 survey as calculated by EVA is relatively low (with a CV or RSE of 8%) 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*. *V.mirabilis* was also present at 46% of stations including stations where trawl marks were also observed. This seapen species was recorded as frequently present at 17% and occasionally present at 29% of stations. Trawl marks were noted at 28% of the stations surveyed with trawl marks present for the entire transect for 6% of stations.

A total of 52 CTD stations were carried on the "Smalls". Plots of temperature and salinity are presented for the bottom depth profile in Figure 11. The bottom temperatures varies by around 2^{o}C across the Smalls *Nephrops* ground. The coldest temperatures are in the deepest part of the ground with highest temperatures in the east. The highest salinities were also observed to the east of the ground. A dense layer of phytoplankton, estimated to be between 30-150cm in depth, was observed around the thermocline at most stations across the ground. This was a noteworthy observation because it has not been observed on surveys to date.

[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).

Discussion

This survey series was commenced by Ireland in 2006 to address the data deficiencies and improve the scientific basis for managing the stock. Survey data up to 2013 was used by ICES assessment to assess the state of the stock (ICES, 2014). This analysis showed that the stock was fished at a sustainable rate and that abundance was relatively stable (ICES, 2014). The 2014 burrow abundance estimates have increased by 22% relative to 2013 but the long term trend is fairly stable. Table 4 gives the various inputs to the catch option calculations based on recent sampling and the 2014 survey results (ICES, 2014). Table 5 is an updated management option table giving catch options at various levels of fishing mortality for 2015. Using the 2014 estimate of abundance would imply the catches at F_{msy} ($=F_{35\%spr}$) of 3,797t and landings of 3,409 tonnes.

In recent years "the Smalls" (FU 22) has accounted for around 50% or 2,300 t of the total landings (~ 5,000 t) from the wider Celtic Sea (FU19, 20, 21 & 22) (ICES, 2014). The Smalls represents around 24% of the total area where *Nephrops* are currently fished in the Celtic Sea (based on areas shown in Figure 1). While it is likely that the *Nephrops* populations in the Celtic Sea are linked in a meta-population sense (O'Sullivan et. al, 2014), further information is needed to estimate stock size and exploitation rates for the other *Nephrops* grounds. The diverse nature of the habitat and wide spatial distribution means designing and routinely executing an UWTV survey for the remaining areas particularly challenging. The time saved by decreasing sampling intensity on the Smalls since 2012 has been used to extend survey coverage in FU16, FU19 and FU20-21 (in line with SGNEPS recommendations). The cost was reduction in survey precision from around 3 to 8% which remains well below the limit of 20% established by SGNEPS (ICES, 2012).

An important objective of this UWTV survey is 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 most of the objectives of the survey were successfully met for the ninth successive year. The UWTV coverage and footage quality was excellent on "the Smalls". The survey estimates themselves are very precise notwithstanding the change in design and reduced survey effort since 2012. Downtime also meant that the beam trawl tows were not carried out. UWTV stations surveyed in FU19 during this schedule will be presented in a separate report. The multi-disciplinary nature of the survey means that the information collected is highly relevant for a number of research and advisory applications.

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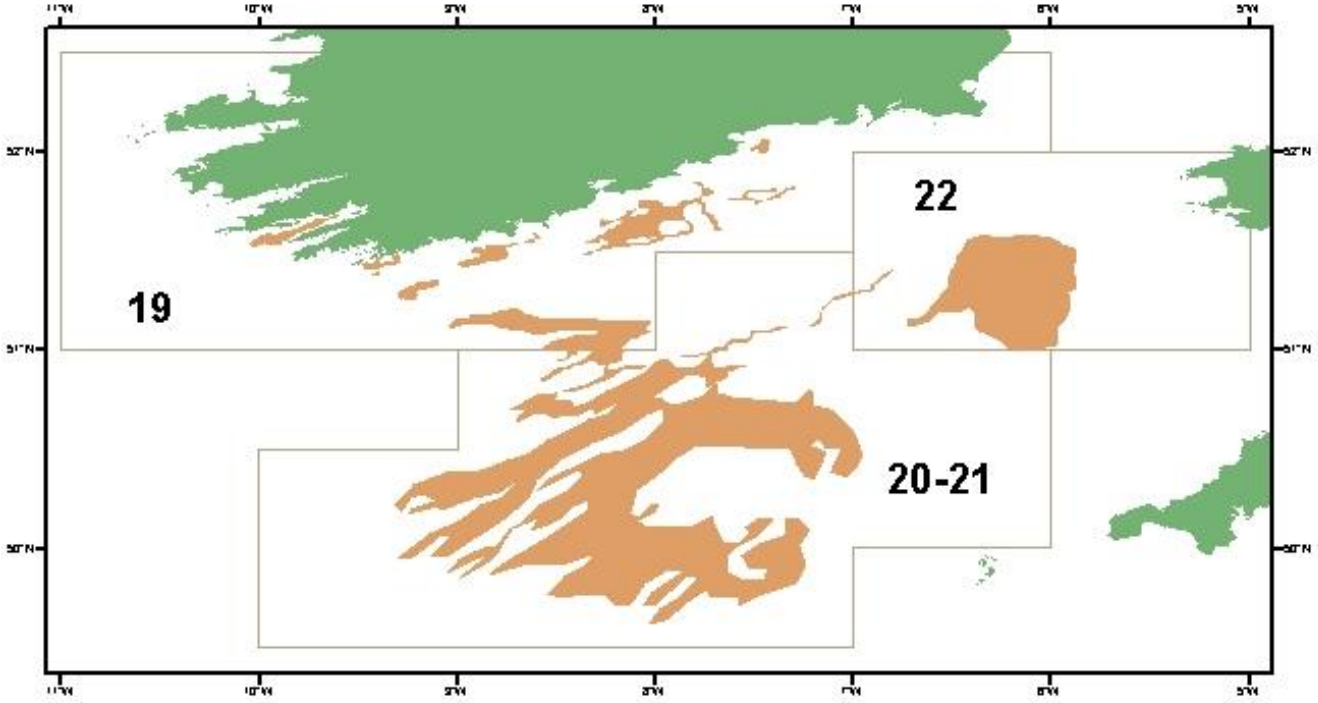

Figure 1: FU22 Smalls grounds: *Nephrops* Functional Units (FUs) in the greater Celtic Sea and area polygons.

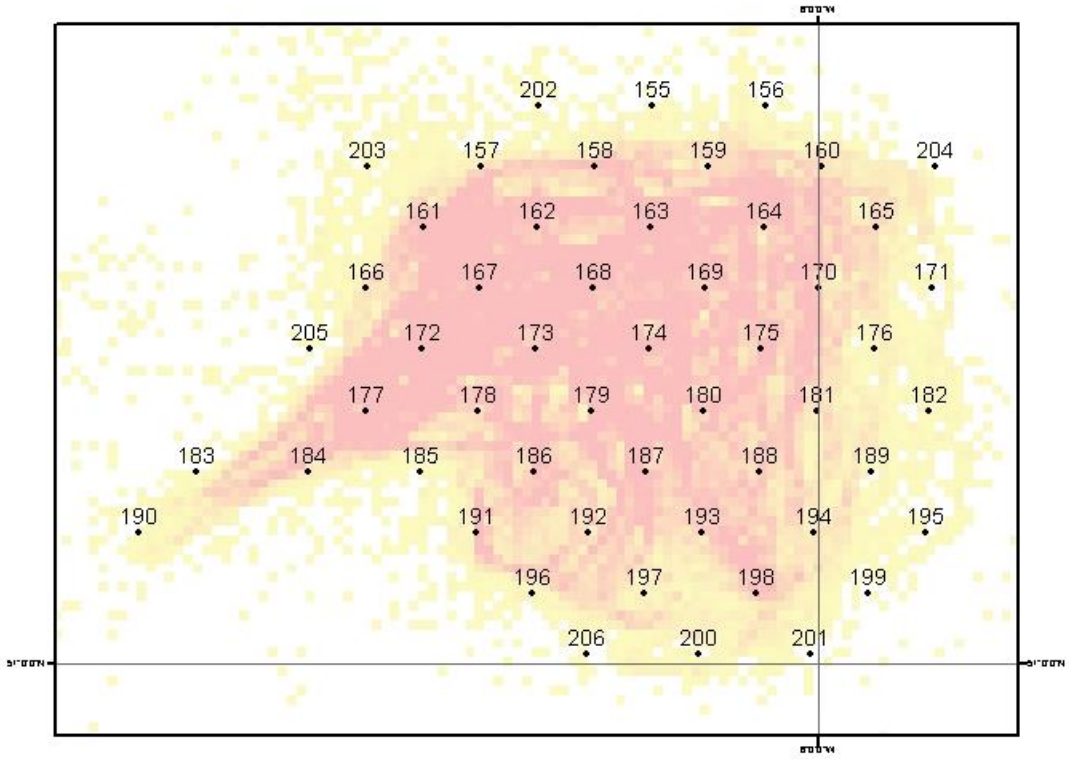

Figure 2: FU22 Smalls grounds: TV stations completed on the 2014 survey overlaid on a heat map of *Nephrops* directed Irish fishing activity.

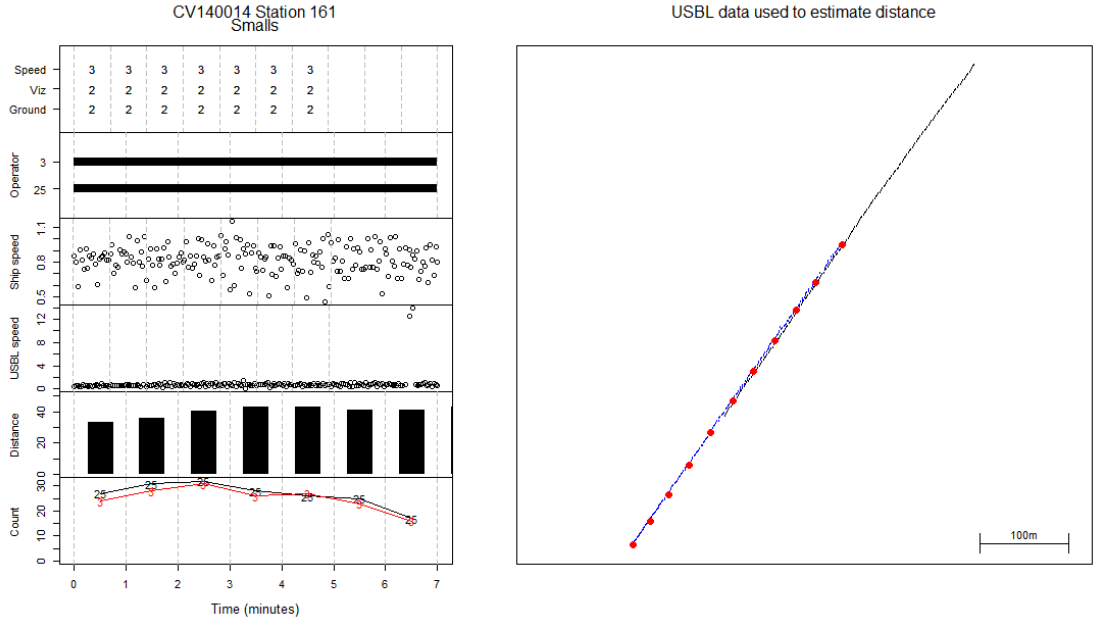

Figure 3 : FU22 Smalls grounds: r - tool quality control plot for station 161 of the 2014 survey.

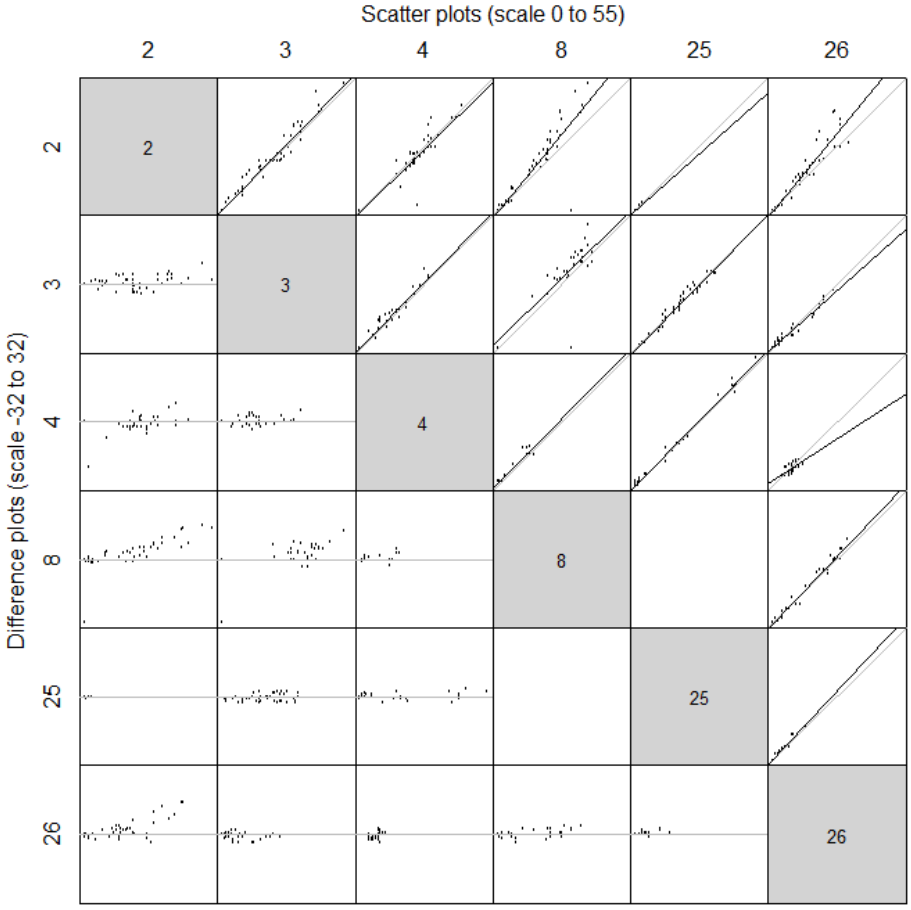

Figure 4: FU22 Smalls grounds: Scatter plot analysis of counter correlations for the 2014 survey.

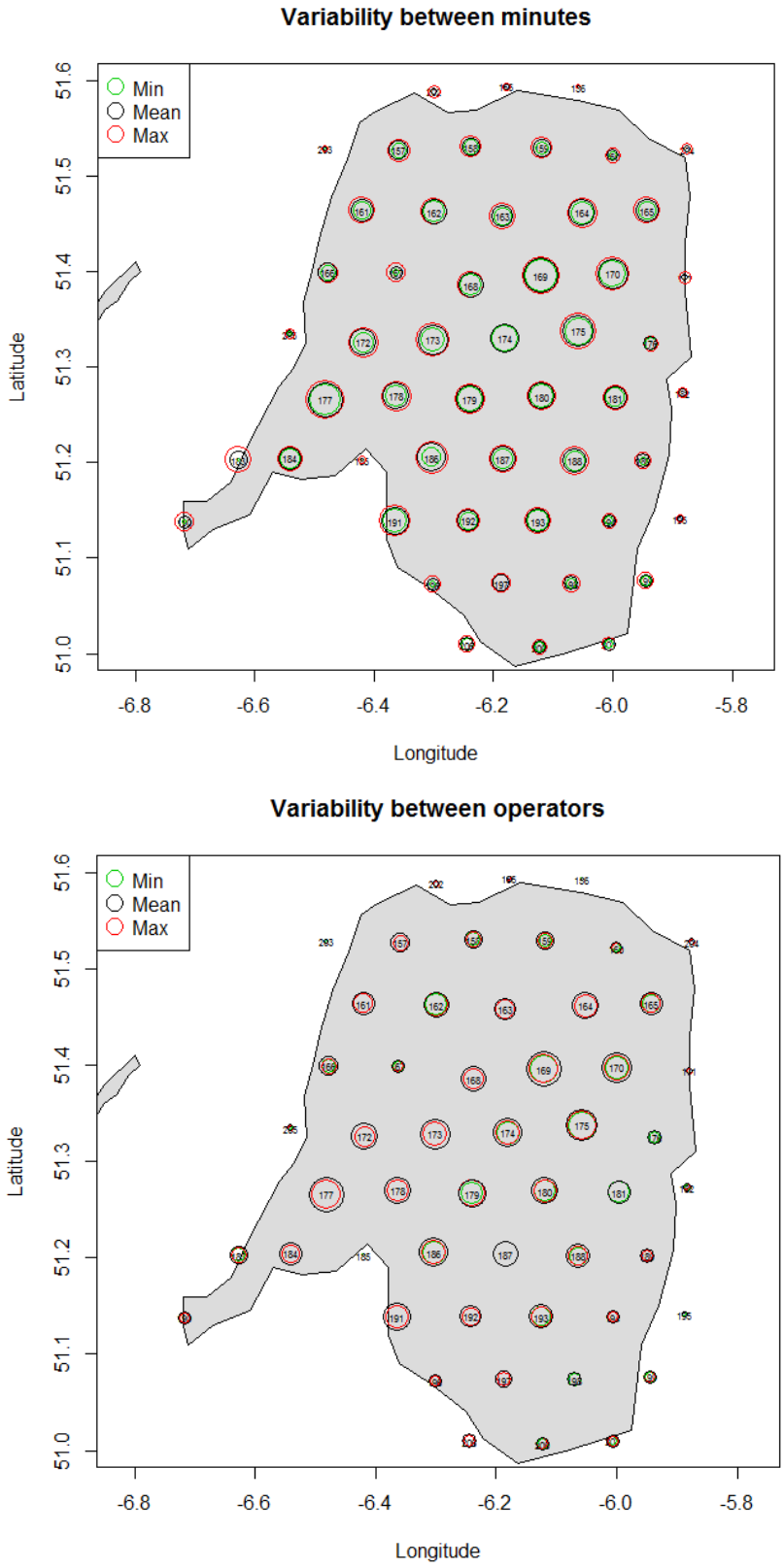

Figure 5: FU22 Smalls grounds: Plot of the variability in density between minutes (top panel) and between operators (counters) (bottom panel) for each station in 2014.

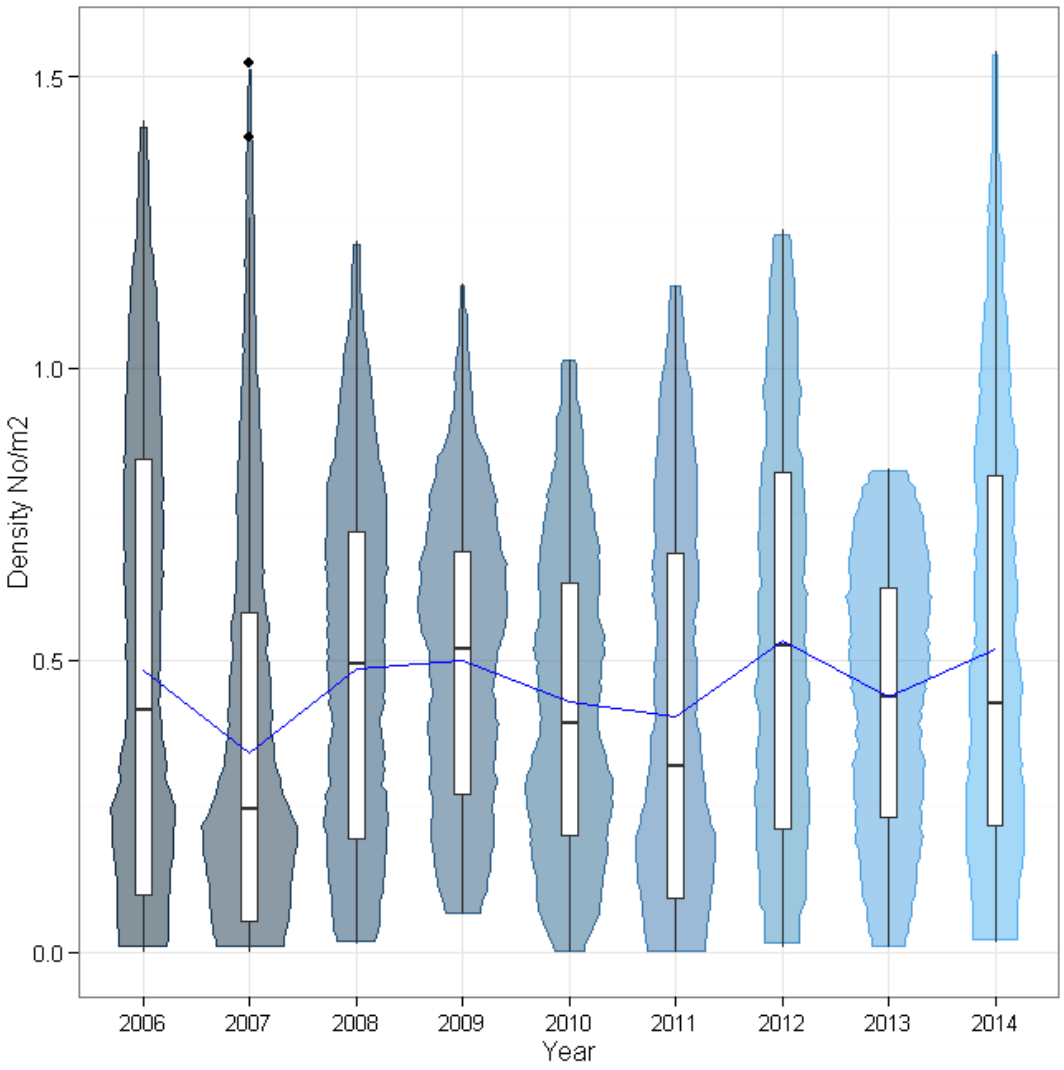

Figure 6: FU22 Smalls grounds: Violin and box plot of adjusted burrow density distributions by year from 2006-2014. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range and the black vertical line is the range.

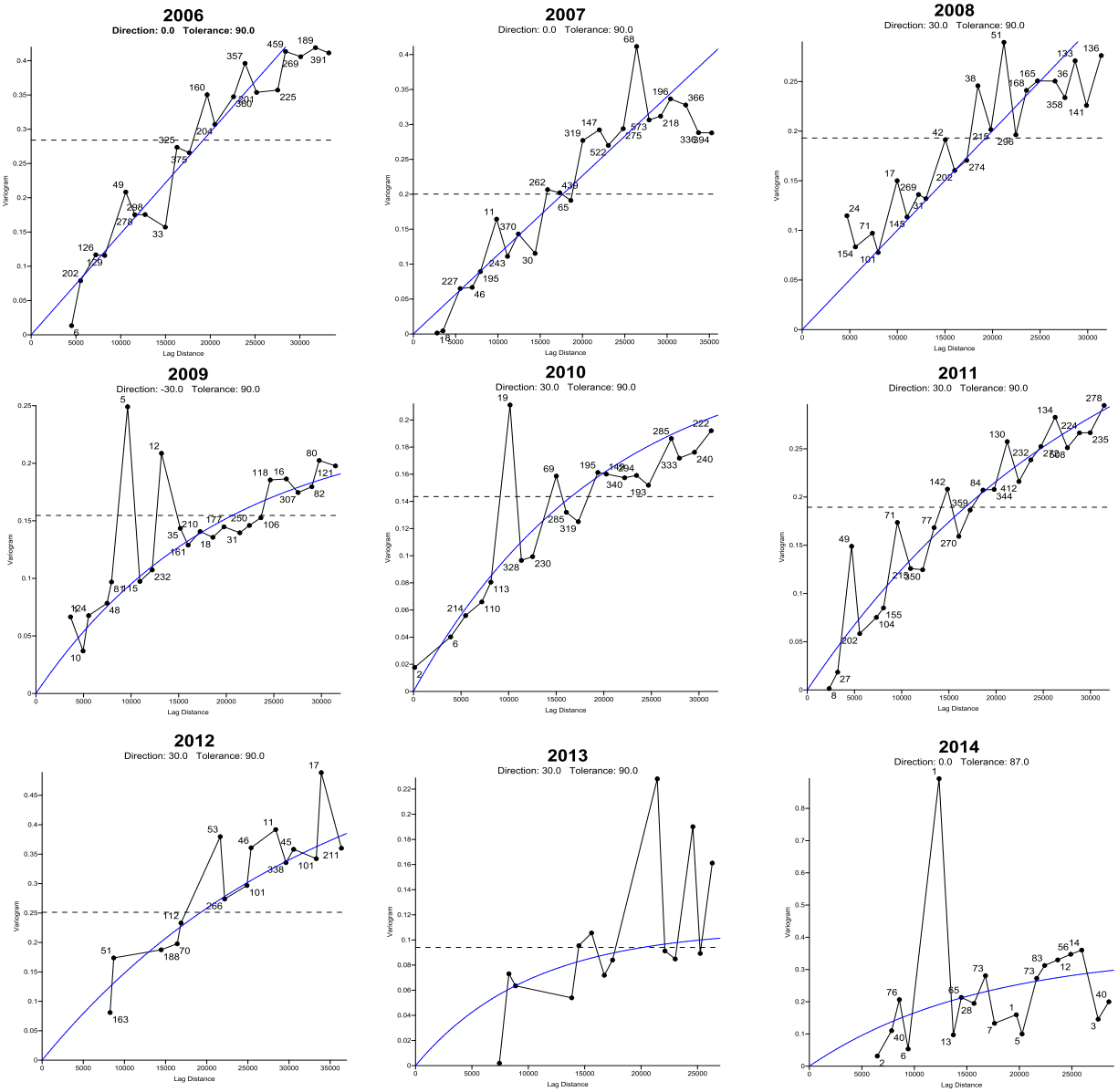

Figure 7: FU22 Smalls grounds: Omnidirectional mean variograms by year from 2006 (top left) - 2014 (bottom right).

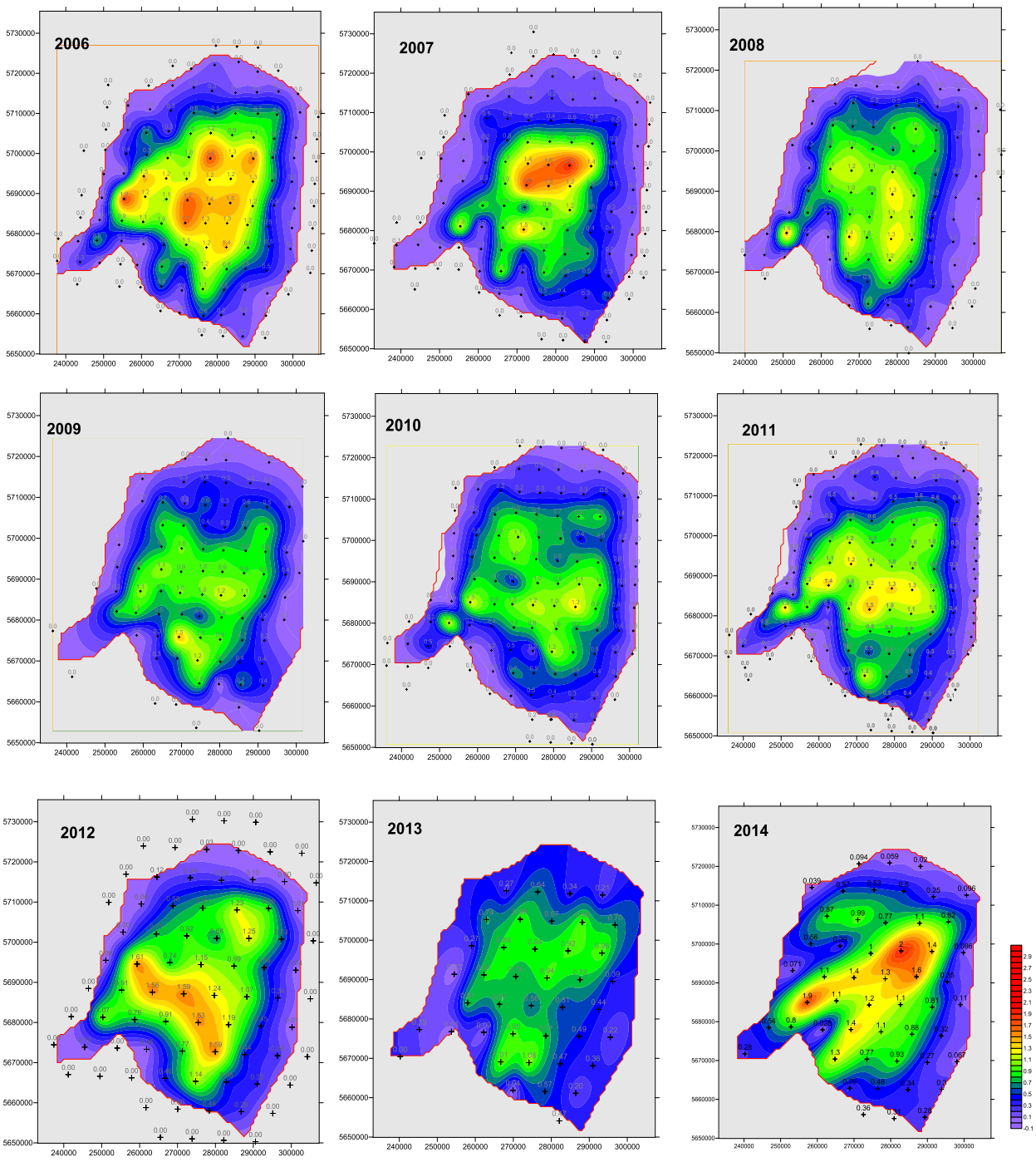

Figure 8: FU22 Smalls grounds: Contour plots of the krigged density estimates by year from 2006 (top left) - 2014 (bottom right). Note: these are based on unadjusted densities

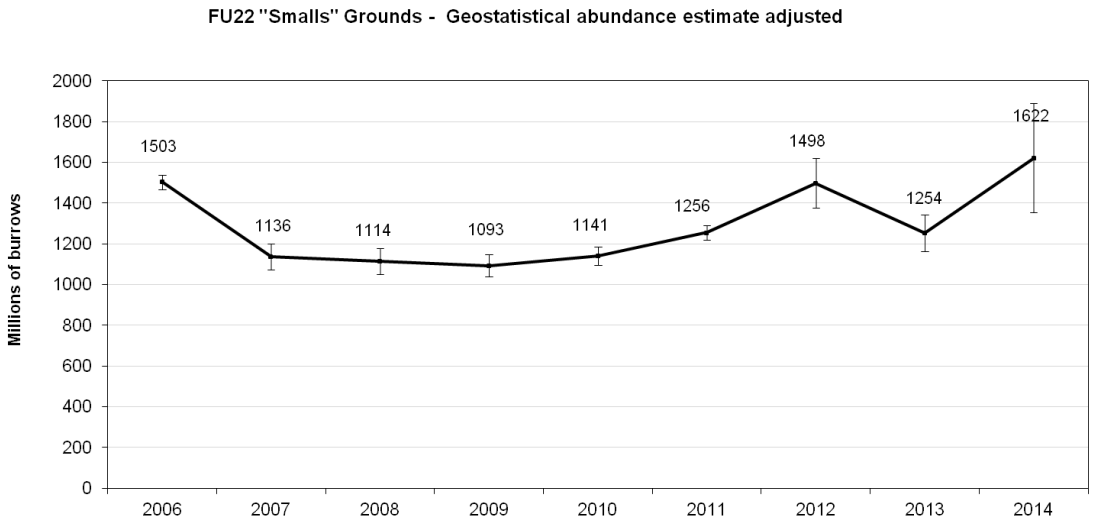

Figure 9: FU22 Smalls grounds: Time series of geo-statistical adjusted abundance estimates (in millions of burrows). The error bars indicate the 95% confidence intervals.

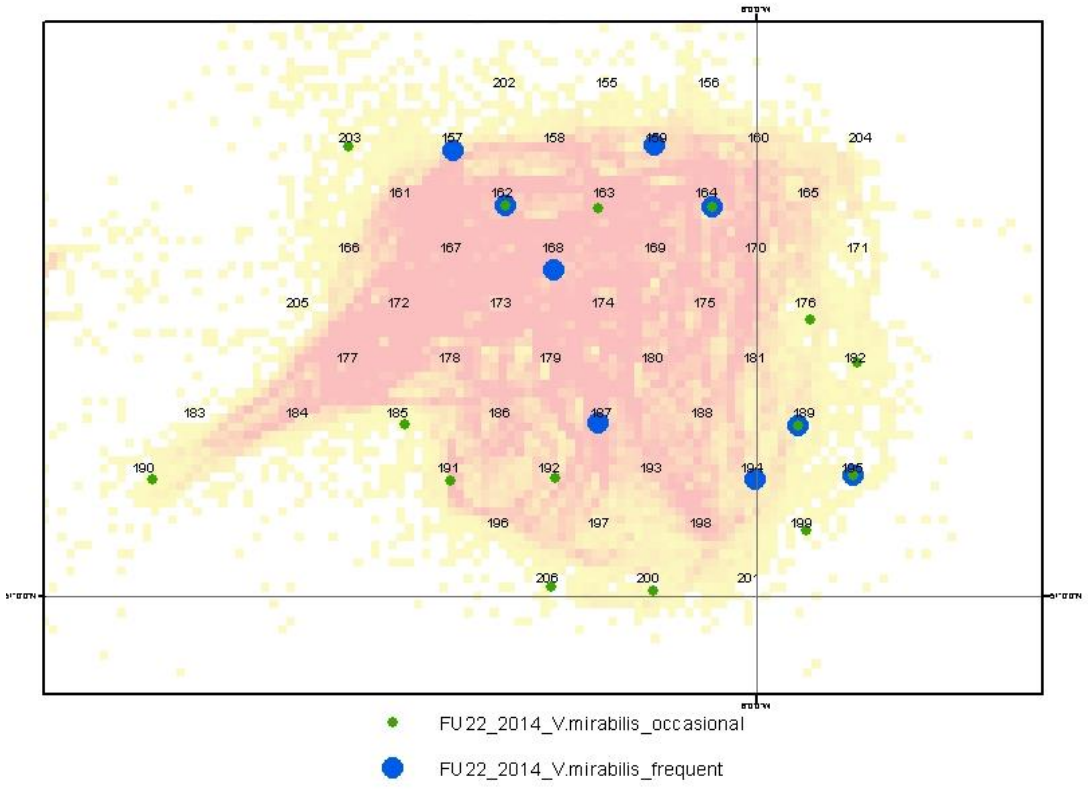

Figure 10: FU22 Smalls grounds: Stations where *Virgilaria mirabilis* was identified during the 2014 survey overlaid on a heat map *Nephrops* directed fishing activity.

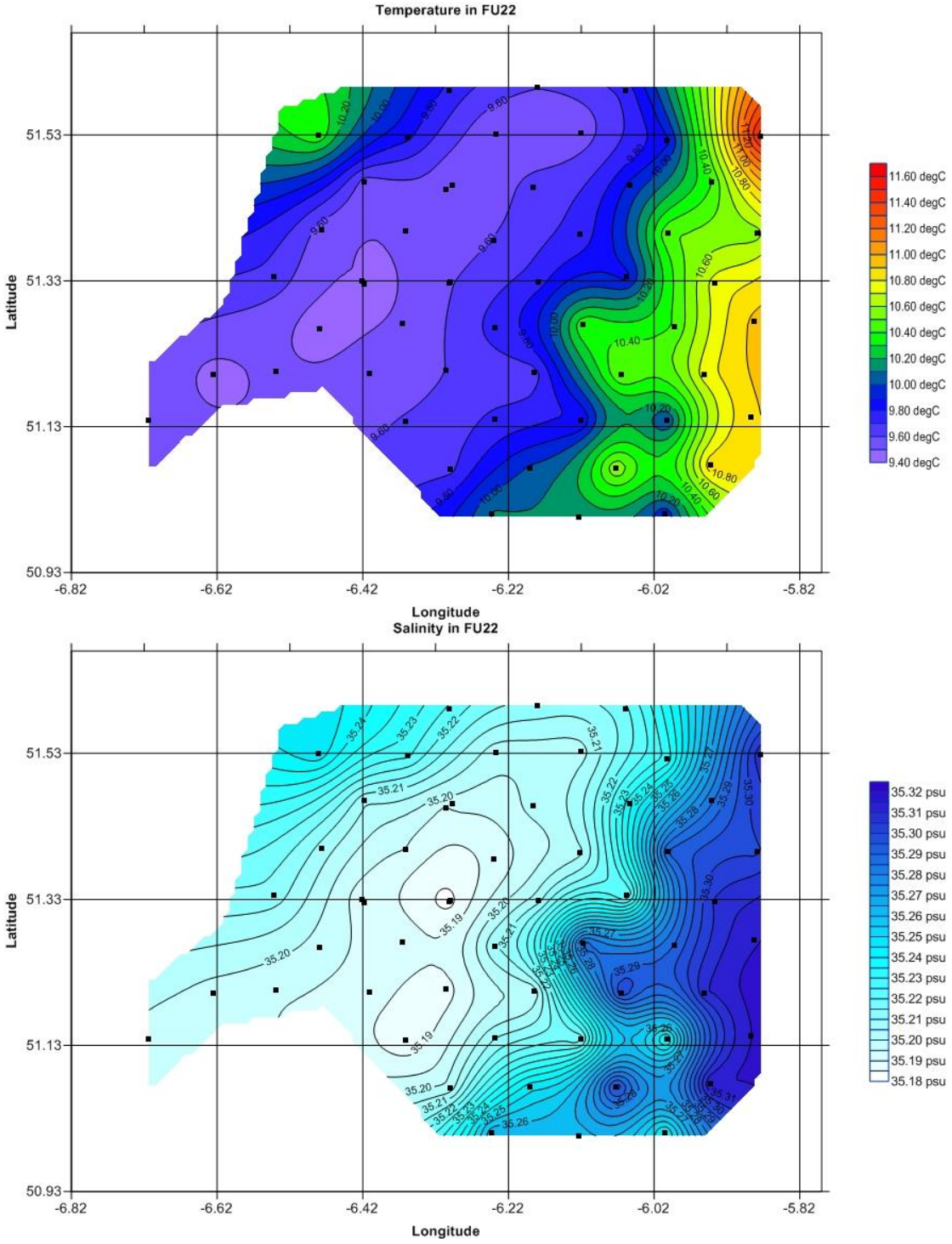

Figure 11: FU22 Smalls grounds: 2014 Bottom temperature and salinity compiled from CTD. Station positions shown as black dots.

Table 1: 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 2: Cumulative bias factors for each *Nephrops* stock surveyed by UWTV method.

	FU	Edge effect	Burrow detection	Burrow identification	Burrow occupancy	*Cumulative Bias*
3&4 Skagerrak and Kattegat (IIIa)	FU3	1.3	0.75	1.05	1	1.1
6:Farn Deeps	FU6	1.3	0.85	1.05	1	1.2
7:Fladen	FU7	1.45	0.9	1	1	1.35
8:Firth of Forth	FU8	1.23	0.9	1.05	1	1.18
9:Moray Firth	FU9	1.31	0.9	1	1	1.21
10: Noup	FU10	1.31	0.9	1	1	1.21
11:North Minch	FU11	1.38	0.85	1.1	1	1.33
12:South Minch	FU12	1.37	0.85	1.1	1	1.32
13:Clyde	FU13	1.19	0.75	1.25	1	1.19
14: Irish Sea East	FU14	1.3	0.85	1.05	1	1.2
15:Irish Sea West	FU15	1.24	0.75	1.15	1	1.14
16: Porcupine	FU16	1.26	0.95	1.05	1	1.26
17:Aran	FU17	1.35	0.9	1.05	1	1.3
19:South Coast	FU19	1.25	0.9	1.15	1	1.3
20&21 Labadie	FU20	1.25	0.9	1.15	1	1.3
22:Smalls	FU22	1.35	0.9	1.05	1	1.3
34: Devil's Hole	FU34	1.3	0.85	1.05	1	1.2

Table 3: FU22 Smalls grounds: Overview of geostatistical results from 2006-2014.

FU	Ground	Year	Number of stations	Mean Density adjusted (burrow/m²)	Domain Area (km²)	Geostatistical Abundance adjusted (millions of burrows)	CV on Burrow estimate
22	Smalls	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%

*reduced randomised isometric grid

Table 4 : FU22 Smalls grounds: Inputs to short-term catch option table.

Year	Landings in Number (millions)	Discards in Number (millions)	Removals in Number (millions) 25% discard survival	Prop Removals Retained	Adjusted Survey (millions)	Harvest Ratio	FU 22 Landings (t)	FU 22 Discards (t)	Mean Weight in landings (gr)	Mean Weight in discards (gr)
2003	95.71	54.22	136.4	0.70	Na		2,050	535	21.4	9.9
2004	71.65	8.53	78.1	0.92	Na		1,828	76	25.5	8.9
2005	114.71	90.81	182.8	0.63	Na		2,425	647	21.1	7.1
2006	97.18	54.67	138.2	0.70	1503	9.2%	1,752	593	18.0	10.8
2007	164.78	149.88	277.2	0.59	1136	24.4%	2,880	1,513	17.5	10.1
2008	131.90	60.52	177.3	0.74	1114	15.9%	3,114	764	23.6	12.6
2009	92.75	31.08	116.1	0.80	1093	10.6%	2,245	589	24.2	19.0
2010	129.70	28.36	151.0	0.86	1141	13.2%	2,840	439	21.9	15.5
2011	61.55	6.65	66.5	0.93	1256	5.3%	1,617	144	26.3	21.7
2012	123.82	24.00	141.8	0.87	1498	9.5%	2,633	256	21.3	10.7
2013	96.63	30.68	119.6	0.81	1254	9.5%	2,255	362	23.3	11.8
2014					**1622**					
			Average 2011-13	**0.87**				Avg 03-13	**22.20**	**12.55**

Table 5 : FU22 Smalls grounds: Short-term management option table giving catch options for 2015 using 2014 UWTV estimate.

Basis: F2011-13 = average harvest rate 2011-2013 = 8.1%; absolute survey index 2015 = 1622 million (2014 index); Mean weight in landings (2003–2013) = 22.20g; Mean weight in discards (2003–2013) = 12.6g.

Basis	Total Catches*	Landings	Dead Discards**	Surviving Discards**	Harvest Rate
	L+DD+SD	L	DD	SD	for L+DD
MSY Approach = $F_{35\%SpR}$	3797	3409	291	97	10.9%
$F_{2011\text{-}13}$	2822	2533	217	72	8.1%
F0.1 Combined	2613	2345	201	67	7.5%
F_{max}	4285	3846	329	110	12.3%

* Total catches are the landings including dead and surviving discards

** Total discard rate is assumed to be 17.9% of the catches (in number, last 3 years average, 2011-2013), discard survival is assumed 25%