The “Smalls” *Nephrops* Grounds (FU22) 2013 UWTV Survey Report and catch options for 2014

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Abstract

This report provides the main results and findings of the eighth 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. The sampling intensity was reduced this year from around 100 stations in the past to 51 stations this year. A randomised isometric grid design was employed with UWTV stations at 4.5nmi or 8.3km intervals. Previously a 3.0 nmi square grid was used. The krigged burrow abundance estimate for the Smalls ground has decreased by 19% relative to 2012 and was the fourth highest in the 8 year history of the survey. Abundance estimates have been fairly stable over the time series. The 2013 randomised isometric grid design result in a CV (or relative standard error) of 7% which is well below the upper limit of 20% recommended by SGNEPS 2012. Total catches and landings options at various different fishing mortalities were calculated and fishing at F_{msy} in 2014 implies a total catch option at F_{msy} (=F_{max}) of 2,937 tonnes which results in landings of no more than 2,674 tonnes.

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

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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 2012 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, 2013). The 2012 reported landings from the Smalls (~2600 t) were estimated to be worth in the region of €13 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 & 2012a). This is the eighth in a time series of UWTV surveys in the Celtic Sea FU22 "Smalls" ground carried out by the Marine Institute, Ireland. The 2013 survey was multi disciplinary in nature; the specific objectives are listed below:

1. To complete randomised fixed isometric survey grid of ~51 UWTV with 4.5 nautical mile (Nmi) spacing stations on the "Smalls" *Nephrops* ground (FU22).
2. To carry out ~70 UWTV stations on the Porcupine Bank (FU16) if time allows.
3. To obtain 2013 quality assured estimates of *Nephrops* burrow distribution and abundance on the "Smalls" *Nephrops* ground (FU22). 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 change in survey design, the final UWTV results of the 2013 survey and also documents other data collected during the survey. The 2013 abundance are used to generate catch options for 2014 in line with the recommendations and procedures outlined in the stock annex for FU22.

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 use.. The 2013 randomised isometric grid resulted in 51 planned stations (Figure 2) overlaid on Nephrops directed fishing activity. 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.

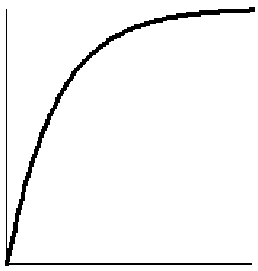
The 2013 Celtic Sea survey took place on RV Celtic Voyager between 24th June to 01st July. Survey timing was generally standardised to early July each year. The operational protocols used were those reviewed by WKNEPHTV 2007 (ICES, 2007) and employed on other UWTV surveys in Irish waters. These protocols 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 2013 the USBL navigational data was used to calculate distance over ground for 99% of stations. In addition CTD profile was logged for the duration of each tow using a Seabird SBE 37. This data will be processed later.

In line with SGNEPS recommendations all scientists were trained/re-familiarised using training material and validated using reference footage prior to recounting at sea (ICES, 2009b). Figure 4 shows individual's counting performance in 2013 against the reference counts as 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 review process the visibility, ground type and speed of the sledge during one-minute intervals were subjectively classified using a classification key. In addition 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), *Nephrops* activity in and out of burrows were counted by each scientist for each one-minute interval was recorded. 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 5. There is some variability between counters but no obvious bias or excessive deviations.

The recount data were screened for one minute intervals with any unusually large deviation between recounts. Means of the burrow and *Nephrops* recounts were standardised by dividing 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 for the majority of tows using lasers during the 2013 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 1417 and maximum lag distance of between 24-25 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

Due to weather and technical downtime the grid was reduced from the initially planned 51 stations to 41. Also it was not possible to carry out fishing operations during this survey for the same reasons. Figure 6 shows bubble plots of the variability between minutes and operators. These show that the burrow estimates are fairly consistent between minutes and counters.

A histogram of the observed burrow densities from 2006 to 2013 on the Smalls *Nephrops* Grounds is presented in Figure 8. This shows some inter-annual variation in modal burrow densities. In most years two modes are apparent at relatively high density (~0.9-1.0/m^2) and at moderate density (0.3-0.5/m^2). In 2013 the mean adjusted[1] burrow density was 0.41/m^2. There were only two observations of high burrow density 1.0/m^2.

The geo-statistical structural analysis is shown in the form of variograms in Figure 9. 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 10. 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 2013 survey covered all of the area of higher stock density within the stock boundary used so despite only achieving partial coverage of the planned 51 stations the accuracy of the estimate is likely to be high.

The summary statistics from this geo-statistical analysis are given in Table 3 and Figure 11. The 2013 estimate of 1254 million burrows is close to the geometric mean of the series (1240 million burrows). The estimation of variance of the 2013 survey as calculated by EVA is relatively low (with a CV or RSE of 7%) which is well below the SGNEPS recommendation for a CV <20% (ICES, 2012c).

Sea-pen distribution across the Smalls *Nephrops* grounds is mapped in Figure 12. All sea-pens were identified from the video footage as *Virgularia mirabilis*. *V.mirabilis* was also present at stations where trawl marks were recorded. This seapen species was recorded as frequently present at 2% and occasionally present at 27% of total stations. Trawl marks were noted at 41% of the stations surveyed with trawl marks present for the entire transect for 11% of stations.

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 2012 was used by ICES assessment to assess the state of the stock (ICES, 2013). This analysis showed that the stock was fished at a sustainable rate and that abundance was stable (ICES, 2013). The 2013 burrow abundance estimates have decreased by 19% but the overall trend is stable. Table 4 is an updated management option table giving total catches and landings options at various levels of fishing mortality for 2014. Using the 2013 estimate of abundance would imply total catch at F_{msy} (=$F_{35\%spr}$) of 2,937 tonnes which results in landings of no more than 2,674 tonnes.

In recent years “the Smalls” (FU 22) has accounted for around 38% or 2,300 t of the total landings (~ 5,500 t) from the wider Celtic Sea (FU19, 20, 21 & 22) (ICES, 2013). The Smalls represents around 32% 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, 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

[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).

remaining areas particularly challenging. The time saved by decreasing sampling intensity on the Smalls since 212 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 7% which remains well below the limit of 20% established by SGNEPS (ICES, 2012c).

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 will be processed at a later stage. This information is 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 eighth successive year. The UWTV coverage and footage quality was excellent on "the Smalls". Weather and technical downtime meant that the grid was reduced from 51 to 41 stations. The survey estimates themselves are very precise notwithstanding the change in design and reduced survey effort in 2013. Downtime also meant that the beam trawl tows were not carried out. UWTV stations surveyed in FU16 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.

Acknowledgments

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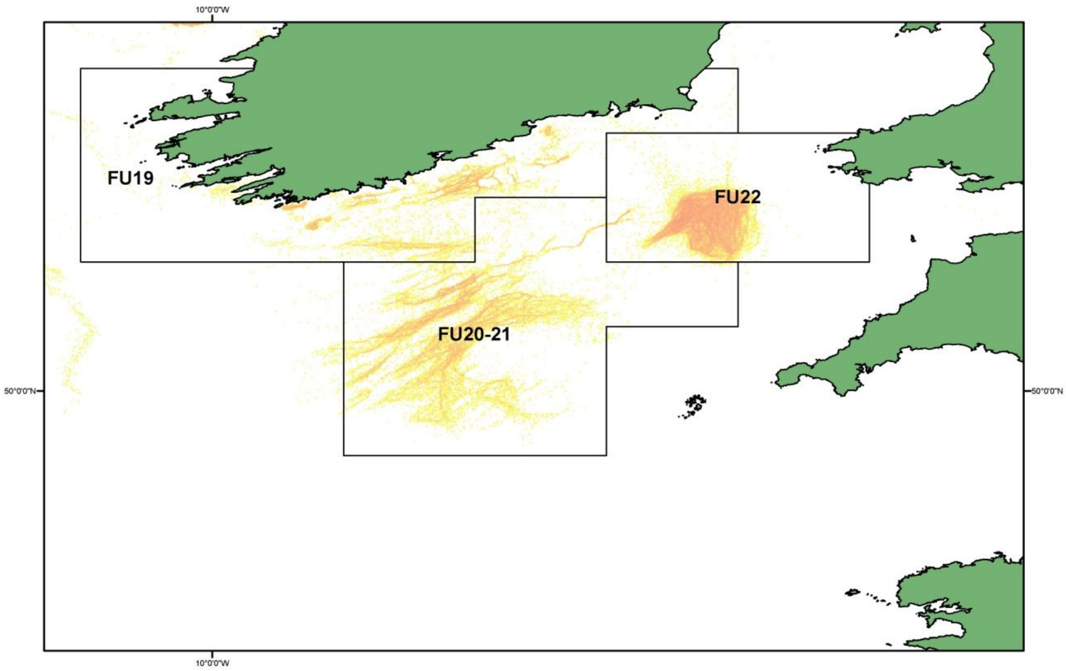

Figure 1: FU22 Smalls grounds: *Nephrops* Functional Units (FUs) in the greater Celtic Sea on heat map of *Nephrops* directed Irish fishing activity.

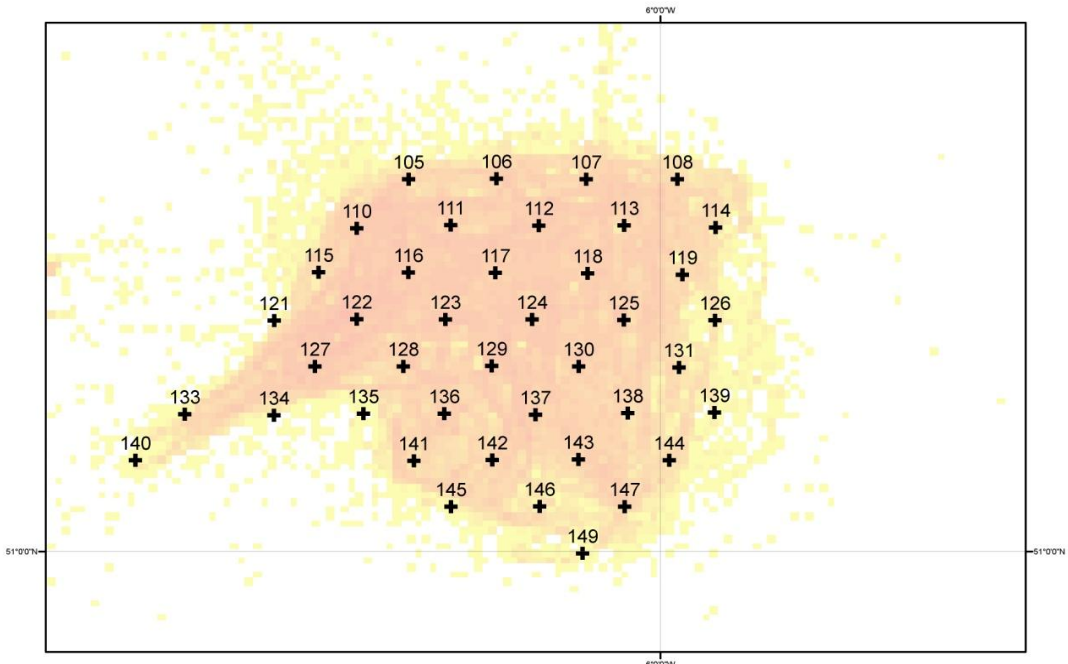

Figure 2: FU22 Smalls grounds: TV stations completed on the 2013 survey overlaid on a heat map of *Nephrops* directed Irish fishing activity.

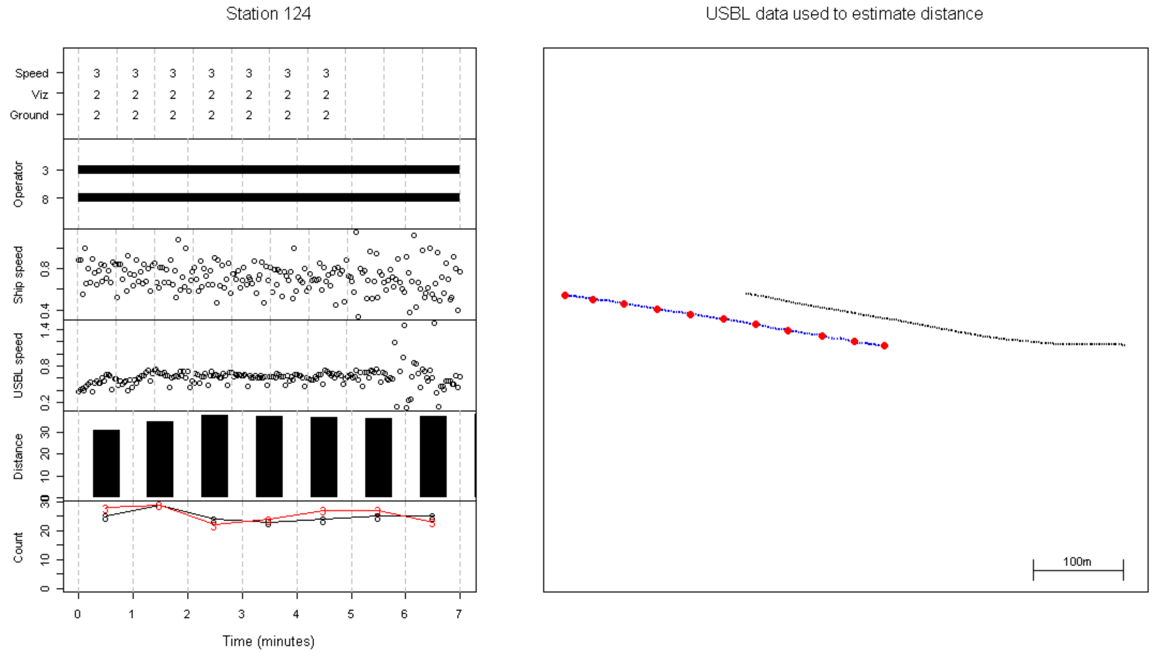

Figure 3 : FU22 Smalls grounds: r - tool quality control plot for station 124 of the 2013 survey.

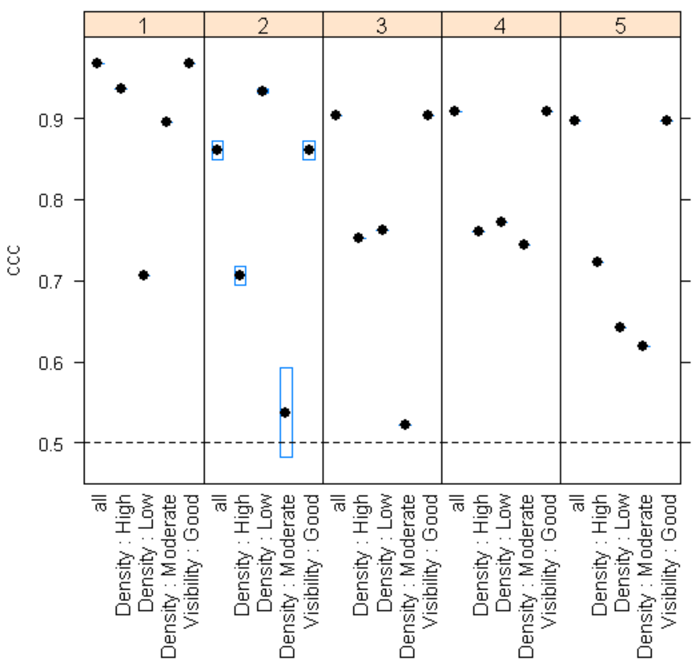

Figure 4: FU22 Smalls grounds: 2013 Counting performance against the reference counts as measured by Linn's CCC for FU22 Smalls reference set. Each panel represents an individual. The x-axis (from left to right), all stations pooled, high density, low density, medium density and visibility good.

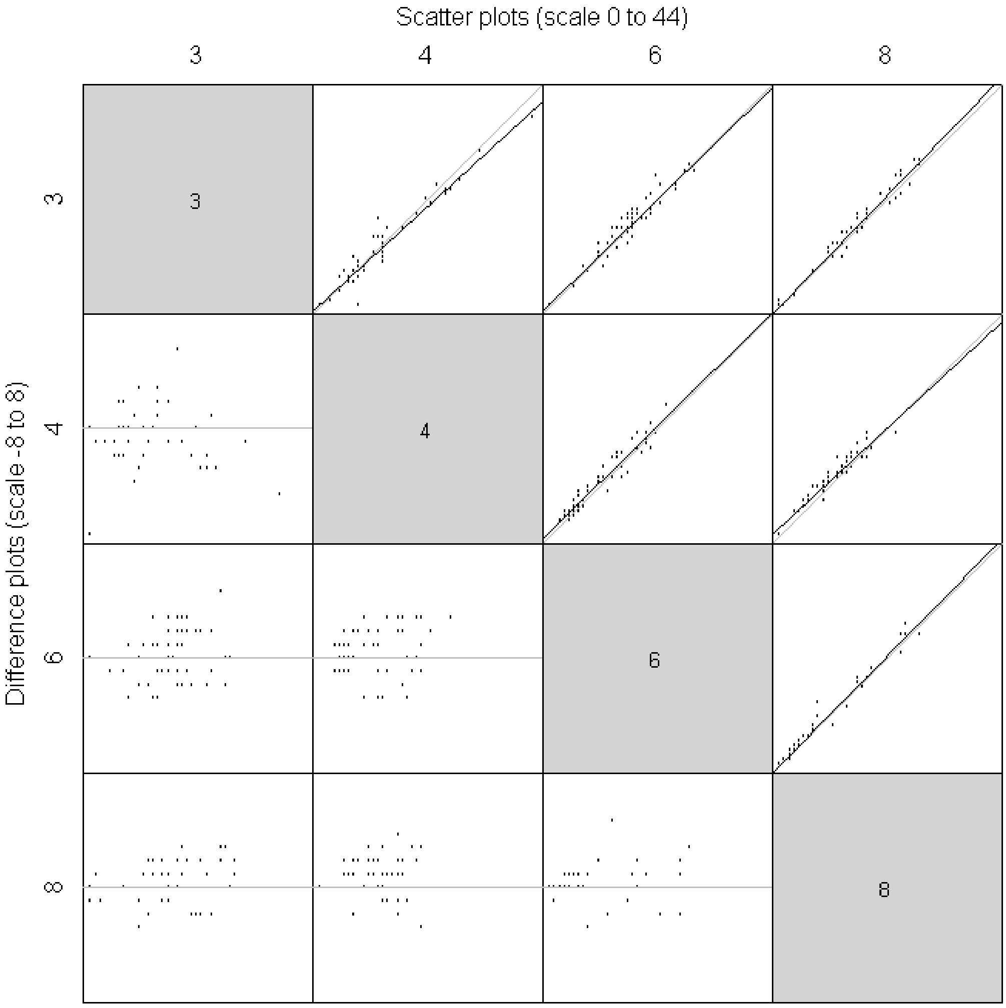

Figure 5: FU22 Smalls grounds: Scatter plot analysis of counter correlations for the 2013 survey.

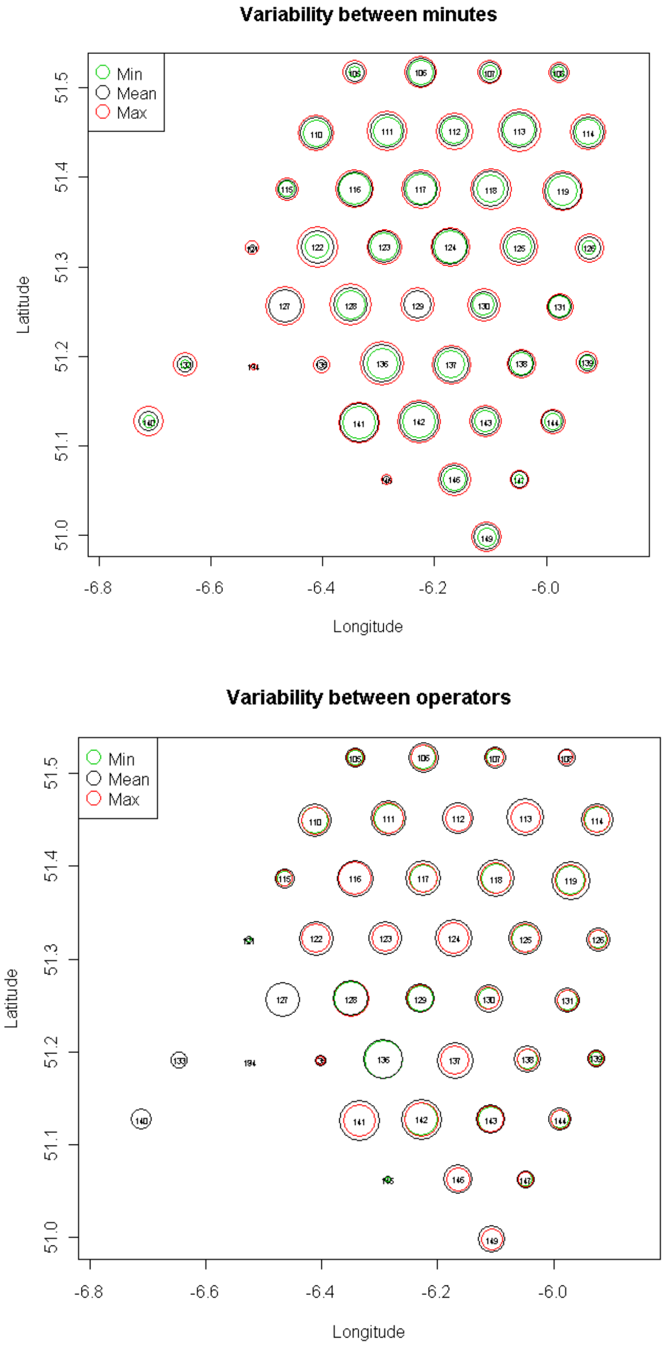

Figure 6: FU22 Smalls grounds: Plot of the variability in density between minutes (top panel) and between operators (counters) (bottom panel) for each station in 2013.

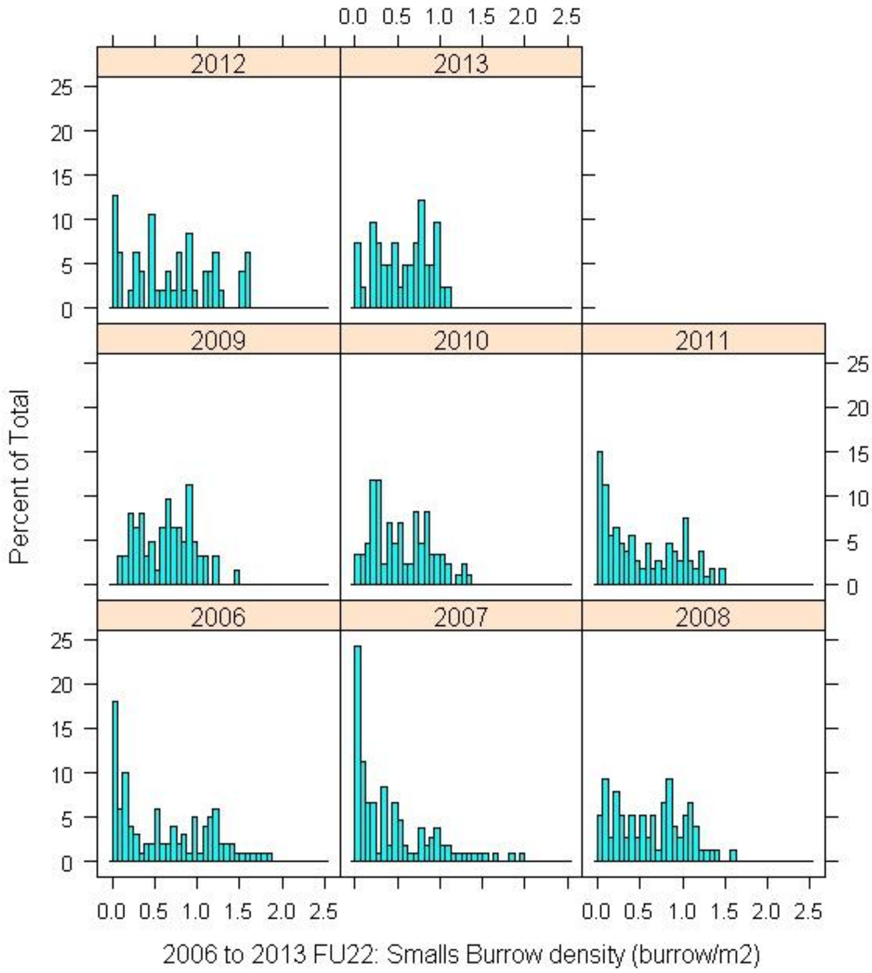

Figure 8 : FU22 Smalls grounds: Histogram of burrow density distributions by year from 2006-2013.

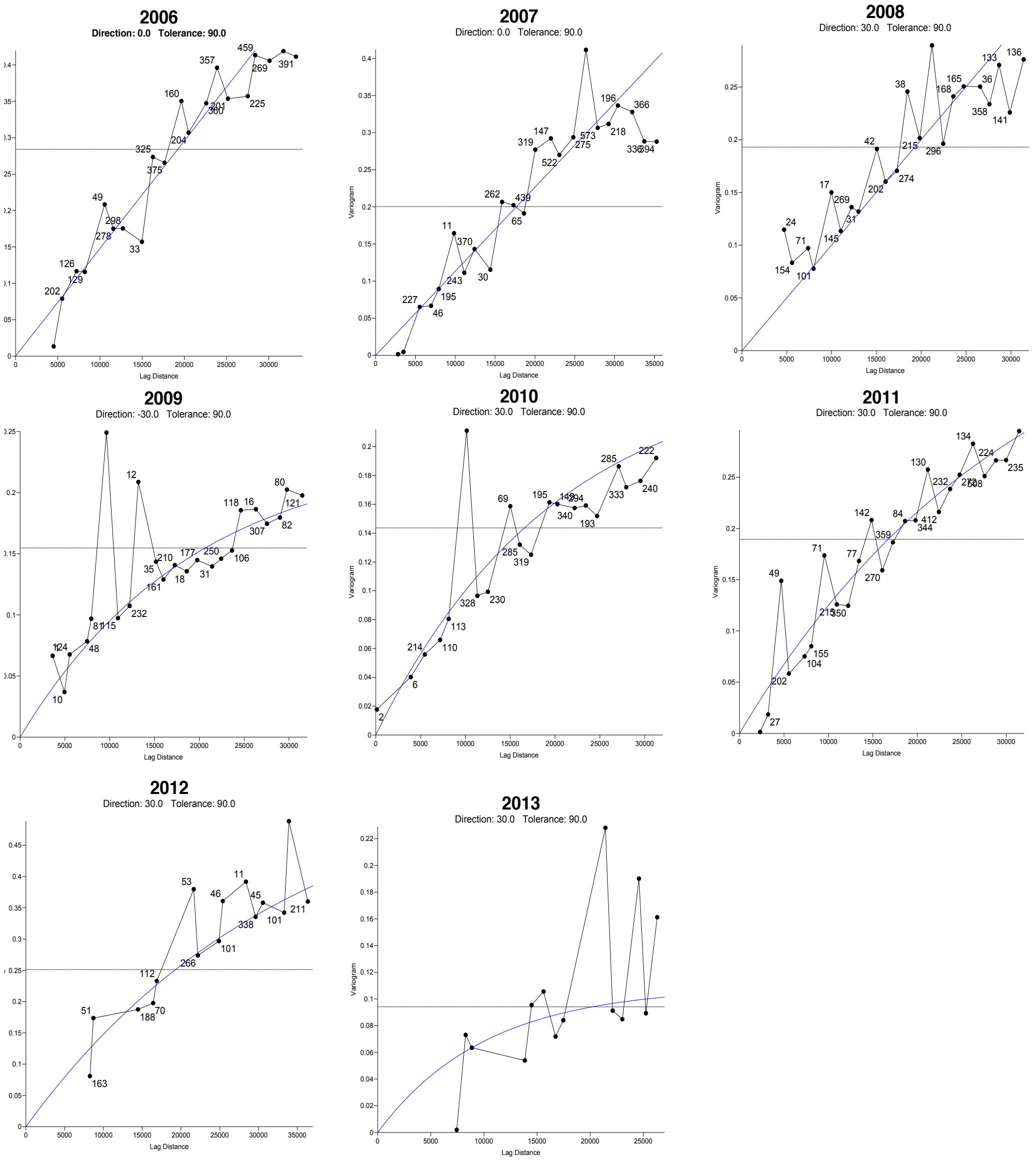

Figure 9: FU22 Smalls grounds: Omnidirectional mean variograms by year from 2006-2013.

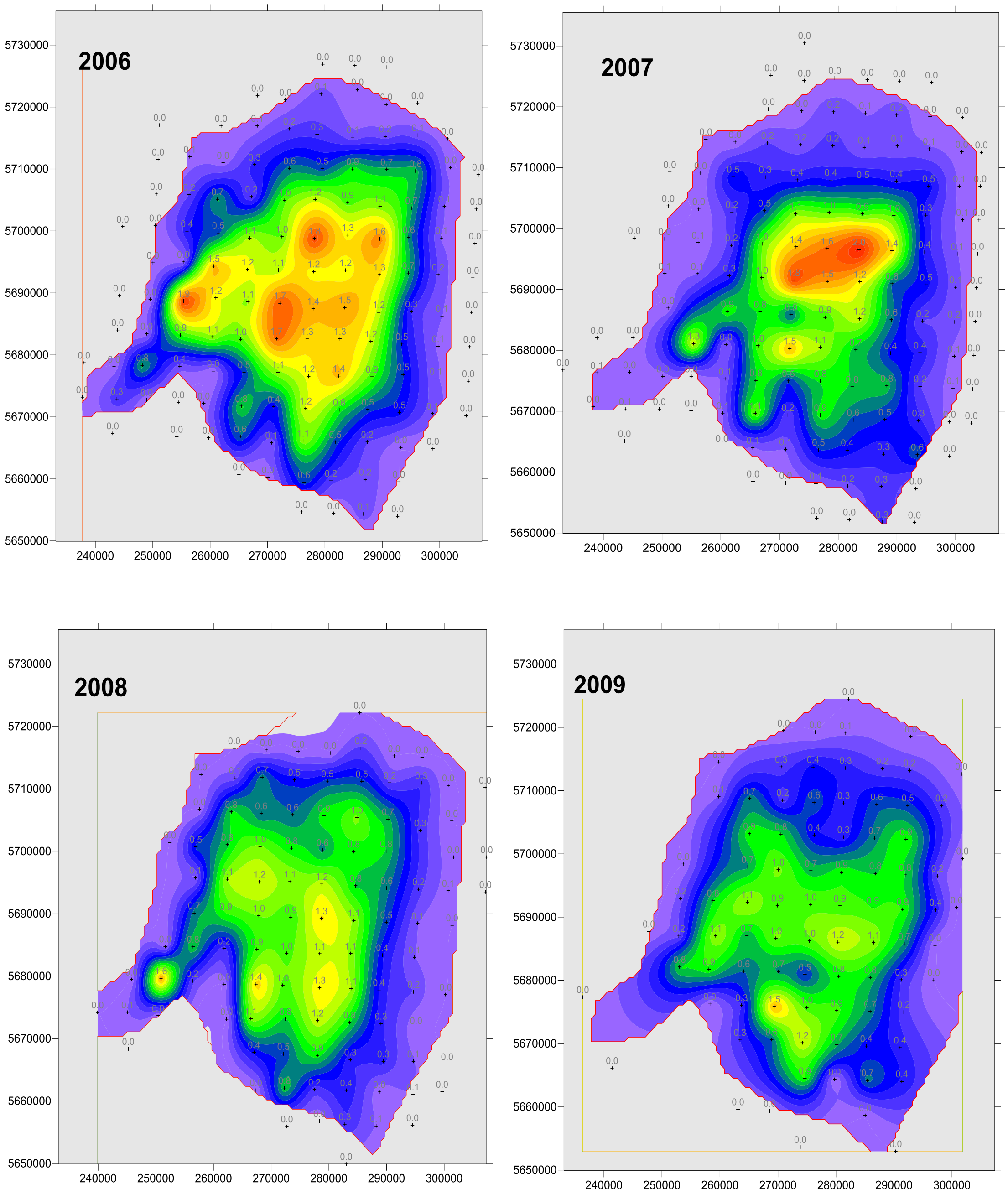

Figure 9: FU22 Smalls grounds: Contour plots of the krigged density estimates by year from 2006-2009.

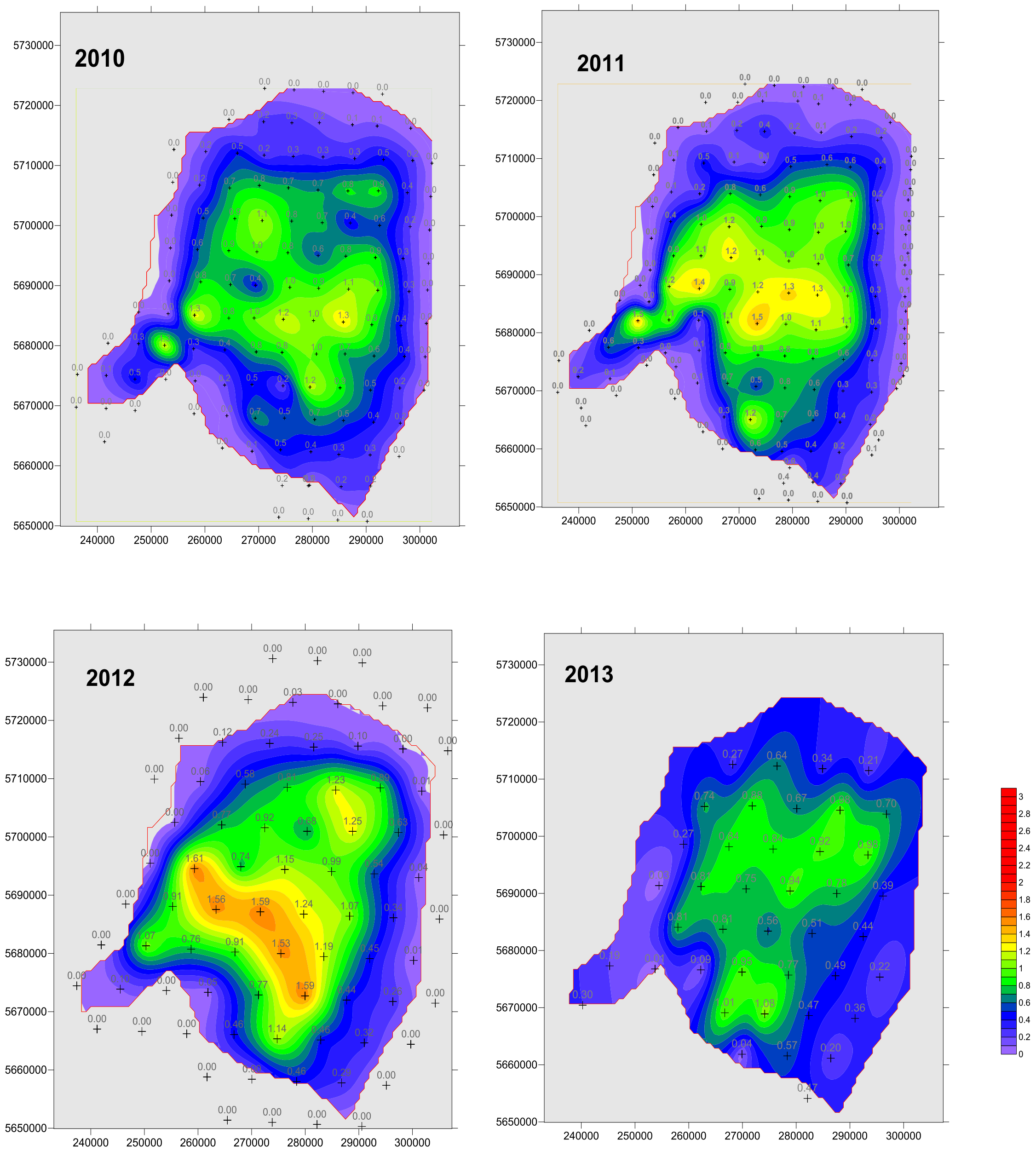

Figure 10: FU22 Smalls grounds: Contour plots of the krigged density estimates by year from 2010-2013.

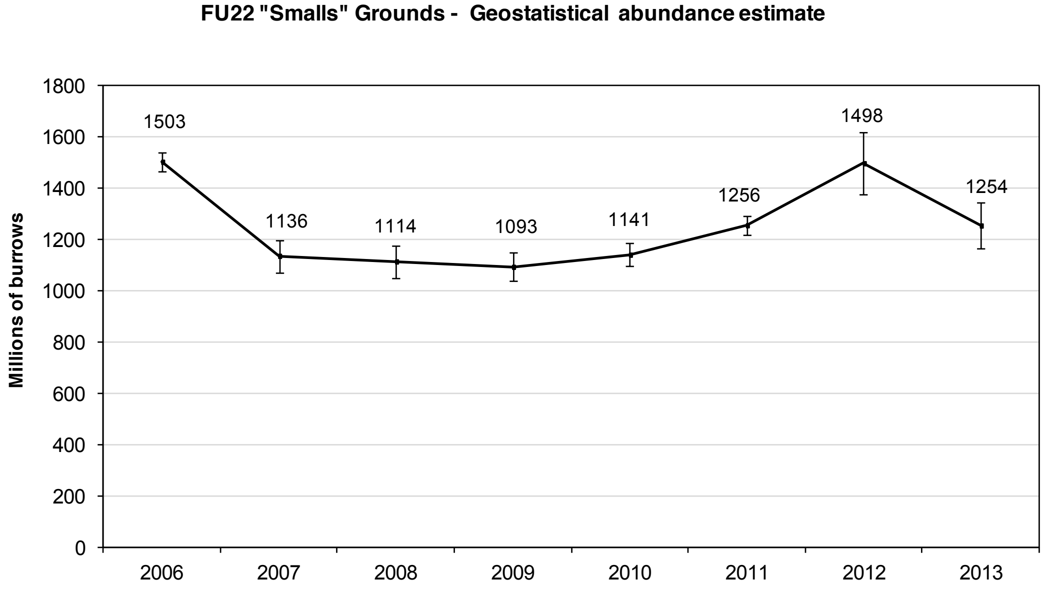

Figure 11: FU22 Smalls grounds: Time series of geo-statistical adjusted abundance estimates (in millions of burrows) from 2006-2013.

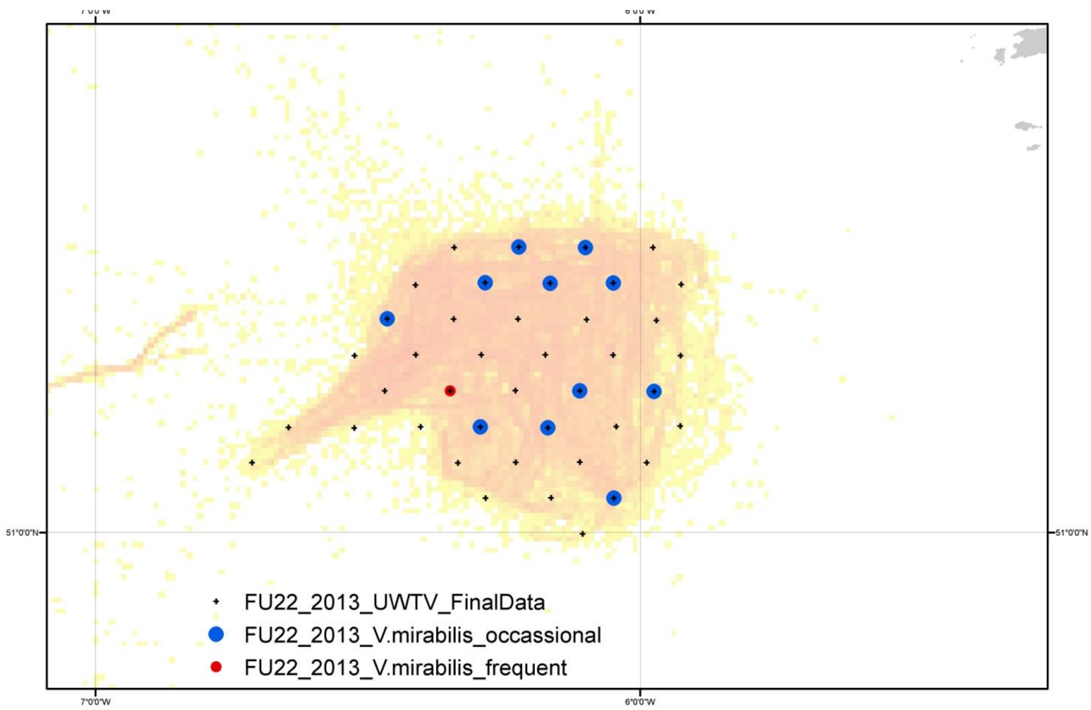

Figure 12: FU22 Smalls grounds: Stations where *Virgilaria mirabilis* was identified during the 2013 survey overlaid on a heat map *Nephrops* directed fishing activity.

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 2006-2013.

FU	Ground	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%
22	Smalls	*2013	41	0.41	2975	1254	7%

*reduced randomised isometric grid

Table 4 :. FU22 Smalls grounds: Short-term forecast management option table giving total catches and landings options for 2014 using 2013 UWTV estimate.

Basis	Total catches*	Landings	Dead discards**	Surviving discards**	Harvest rate
	L+DD+SD	L	DD	SD	for L+DD
F_{MSY} proxy	2937	2674	197	66	10.9%
F_{2013}	2551	2323	171	57	9.5%
$F_{0.1\ Combined}$	2021	1840	136	45	7.5%
F_{max}	3314	3018	222	74	12.3%

Weights in tonnes.
* Total catches are the landings plus dead and surviving discards.
** Total discard rate is assumed to be 14.7% of the catches (in number, average of the last three years, 2010–2012), discard survival is assumed to be 25%.