The Labadie, Jones and Cockburn Banks *Nephrops* Grounds (FU2021) 2014 UWTV Survey Report and catch options for 2015

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Version 2 (Final) October, 2014

Abstract

This report provides the main results of the 2014 underwater television survey on the 'Labadie, Jones and Cockburn Banks' ICES assessment area; Functional Unit 20-21. Some exploratory UWTV stations were carried out in 2006 and 2012. In 2013 ~60% of the ground was surveyed. This was the first survey to achieve full coverage of the newly defined area. The 2014 survey was multi-disciplinary in nature collecting UWTV, CTD and other ecosystem data. A randomised isometric grid design was employed with 98 UWTV stations at 6.0 nmi intervals. The mean burrow density was 0.19 burrows/m^2 compared with 0.16 burrows/m^2 in 2013. The 2014 geostatistical abundance estimate was 2.1±0.1 billion a 26% increase on the extrapolated abundance for 2013. Highest densities were general observed towards the middle of the ground, but there were also high densities observed close to boundaries. Using the 2014 abundance and recent fisheries data it is possible to estimate harvest ratios consistent with various landings options. These can be used by ICES to provide catch options for 2015. The occurrence of sea-pens and trawl marks on the UWTV footage and processed CTD is also presented.

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

Suggested citation:
Doyle, J., Lordan, C., Hehir, I., Fitzgerald, R., O'Connor, S., Keith, M., and Sheridan, M. 2014. The Labadie, Jones and Cockburn Banks *Nephrops* Grounds (FU20-21) 2014 UWTV Survey Report and catch options for 2015. Marine Institute UWTV Survey report.

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. The *Nephrops* fishery in VII is extremely valuable with landings in 2013 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, 2014b). The 2013 reported landings from this FU20-21, ~€1,890, t were estimated to be worth in the region of €7 m at first sale. This ground has become increasingly important to the Irish demersal fleet which now account for over 60% of the FU20-21 *Nephrops* landings. 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 day, 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 third UWTV survey in the Celtic Sea FU20-21 grounds carried out by the Marine Institute, Ireland. The 2014 survey was multi-disciplinary in nature; the specific objectives are listed below:

1. To complete ~98 UWTV stations with 6.0 nautical mile (Nmi) spacing stations on the *Nephrops* ground.
2. To obtain 2014 quality assured estimates of *Nephrops* burrow distribution and abundance on this ground.
3. 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.
4. To collect oceanographic data using a sledge mounted CTD.

This report details: the survey design, the final UWTV results of the 2014 survey and also documents other data collected during the survey.

Material and methods

The knowledge about the distribution of suitable *Nephrops* habitat in this area has been developing. Information so far suggests that *Nephrops* are found in complex channels, which are probably the remnants of fluvial channels related to the deglaciation of the Irish ice sheet at the end of the last ice age. The ground area was revised by WKCELT 2014 (ICES, 2014a) to include both French and Irish integrated logbook VMS data(Gerritsen & Lordan, 2011) and is now calculated at 10 014 km² and this value is used for the survey. Within this area a randomised isometric grid of 98 stations with a 6.0 nautical mile spacing was planned for the 2014 survey (Figure 2). Stations depths varied from 95 m to 134 m and the completed stations ranged from 55 to 135 nautical miles (nmi) offshore. The 2014 Celtic Sea survey took place on RV Celtic Voyager between 25th June to 03rd July. The survey leg also included UWTV operations in FU17 reported elsewhere (Hehir, et. al 2014).

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 from a video camera with field of view or 'FOV' of 75 cm. Vessel position (DGPS) and position of sledge (using a USBL transponder) were recorded every 2 seconds. The navigational data was quality controlled using an "r" script developed by the Marine Institute (ICES, 2009b). The USBL navigational data was used to calculate distance over ground or 'DOG' for all of stations. In 2014 the USBL navigational data was used to calculate distance over ground for 94% of stations.

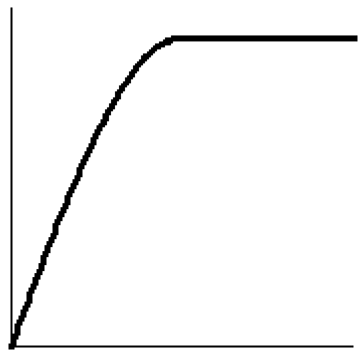
In line with SGNEPS recommendations all scientists were trained/re-familiarised using training material and footage from the 2013 Labadie survey, prior to recounting at sea (ICES, 2009a). As the FU20-21 UWTV survey is in its infancy there is no FU specific reference footage available. All recounts were 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. Abundance categories of sea-pen species were also recorded due to OSPAR Special Request (ICES 2011) using the scale provided in Table 1. 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. The "r" quality control tool allowed for individual station data to be analysed in terms of data quality for navigation, overall tow factors such as speed and visual clarity and consistency in counts (Figure 3). Consistency and bias between individual counters was examined using Figure 4. There is moderate variability between counters but no obvious bias or excessive deviations. The moderate variability between counters is because burrow counting in this area is particularly difficult (see discussion).

The recount data were screened for one minute intervals with any unusually large deviation between recounts. These minutes were re-verified by means of consensus counts. 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 during the 2014 survey using lasers. 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).

At each station CTD data was logged 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 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.

The empirical abundance estimates were calculated by estimating the mean and 2 standard errors of adjusted density and multiply these by the area of the ground (estimated to be 10,014 km^2). 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 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 2014 addition stations, with assumed zero density outside the known distribution of *Nephrops* or suitable sediment, were not included in the krigging process. An unweighted and unsmoothed omnidirectional variogram was constructed with a lag width of approximately 3.5km and maximum lag distance of between 66 km. A model variogram $\gamma(h)$, was produced with an spherical 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.



Spherical Model
Pannatier (1996, p. 48)

$$\gamma(h) = \begin{cases} C\left[1.5h - 0.5h^3\right] & h < 1 \\ C & h \geq 1 \end{cases}$$

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).

Results

All 98 stations were completed successfully on the FU20-21 *Nephrops* grounds (Figure 2). 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. The variability is slightly higher between minutes then between counters.

The adjusted burrow densities in 2013 and 2014 are shown in Figure 6 as a combined violin and box plot. These show that density appears to have a bimodal distribution, with the second mode being highly skewed. The 2014 mean density of $0.19/m^2$ was 20% higher than estimate of $0.16/m^2$ in 2013 when the survey had incomplete coverage.

The geo-statistical structural analysis is shown in the form of variograms in Figure 7. There is evidence of a sill at around 25km. The blanked krigged contour plot and posted point density data are shown for 2013 and 2014 in Figure 8. The 2013 surface is truncated to the observed domain area. The spherical model used is fairly flexible so the krigged contours correspond well to the observed data. Highest densities were towards the centre of the ground in both years. Some changes in the density surface have occurred between 2013 and 2014.

The summary empirical and geo-statistical results are given in Table 3. There were some stations were carried out in 2006 and in 2012 these should be viewed as exploratory surveys and have not been used to extrapolate total abundance. In 2013 the survey had partial coverage of the area (<60%). Scaling the mean density to the total area (10,014 km^2) would result in an abundance estimate of 1.6±0.3 billion in 2013. The estimate increased in 2014 to 1.9±0.3 billion. The geo-statistical estimate of abundance in 2013 was 0.94 billion for a domain area of 5,701km^2. Scaling that up to the domain area estimated in 2014 of 9,835 km^2 would result in an estimate of 1.6±0.1 billion. The 2014 geo-statistical abundance estimate is 2.1±0.1 billion which is 26% higher than in 2013. The empirical CVs for 2013 and 2014 were less than 10% and the geo-statistical CVs were 3%. These are well below the upper limit recommended of <20% (ICES, 2012). The UWTV abundance data together with data from the fishery; landings, discards and removals in number are used to calculate the harvest ratio in 2013 of 3.1%. The mean weight in the landings and the discards and the proportions of removal retained are also show. This are variable between 2012-2013 but are based on the only available sampling data (ICES, 2014). The mean weights in the landings in 2013 are slightly different than those presented at WGCSE (ICES, 2014).

Sea-pen distribution across the *Nephrops* grounds is mapped in Figure 9. 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 30% and occasionally present at 55% of total stations. Trawl marks were noted at 16% of the stations surveyed with trawl marks present for the entire transect for 3% of stations.

A summary of the CTD data collected during the survey is shown as bottom temperature and salinity in Figure 10. Bottom sea temperatures varied by only 1^oC

across the *Nephrops* ground surveyed. Highest temperatures were observed towards the south east of the area with the lowest observed in the most northern stations. Salinity varies by only 0.18 psu. The salinity is highest in the south and lowest in the north.

Discussion

In response to the WKNEPH 2012 recommendations the Marine Institute has reduced survey effort in FU15, 17 and 22 and increased survey effort to FU16, 19 and 20-21 (ICES, 2012). The main aim was to achieve some UWTV survey coverage for all the main *Nephrops* grounds fished in ICES sub-area VII whilst maintaining the accuracy and acceptable precision for existing survey time series. As is clear from Figure 1 and 2 the area of *Nephrops* ground in FU20-21 is both geographically extensive and complex in structure. Scientific knowledge of the heterogeneous habitat and spatial distribution of the *Nephrops* population in this area has been developing. In 2014 a benchmark of the available information was carried out by ICES and an estimate area for the ground was established (ICES, 2014a).

Developing an UWTV survey for FU20-21 has been particularly challenging. During the exploratory surveys of FU20-21 in 2006 and 2012 stations were chosen based on areas heavily fished by vessels (Doyle et al, 2013). These are likely to be biased estimate of density and cannot be extrapolated to estimate density for the whole area (ICES, 2014a). Since 2013 a randomised isometric grid design has been used. This survey design is used for several other grounds. It has the advantage of random and less prone to bias as might be the case with fixed grid designs but all allows burrow surfaces to be estimated for the full area thus taking advantage of the spatial auto-correlation between stations to reduce estimation variance. Due to a combination of poor weather and some technical down time in 2013 only ~60% coverage limited to the northern part of the survey grid was achieved (Doyle et al., 2013). In February 2014 WKCELT concluded that full survey coverage was needed before this stock could be moved into a full UWTV survey category for assessment and advice (ICES, 2014a).

The 2014 survey achieved full coverage of the stock area defined at WKCELT using VMS linked logbook information for Ireland and France (ICES, 2014a). The density estimates in 2013 and 2014 are relatively similar and would be considered low (mainly ~0.2/m^2). Similar densities have been observed on the Fladen (FU7), Devil's Hole FU34, Galley Grounds 4 (in FU19) and the Moray Firth (FU9). Despite the fairly complex spatial structure of the ground some general patterns in density distribution are apparent. The densities appear to be higher towards the centre of the ground. There are some quite high densities close to the boundaries. This implies that there will be some uncertainty associated with the accuracy of the boundary definition. Given that the densities observed in the southern part of the ground were not significantly different than the northern part surveyed in 2013 it would seem appropriate to extrapolate the 2013 survey abundance up to the entire area.

The estimate harvest ratio in 2013 confirms that the stock is currently relatively lightly exploited as was suggested by previous ICES assessments (ICES, 2012). In order to provide landings and catch advice for 2015 consistent with the ICES MSY approach a stock specific F_{msy} proxy is required. Fishing mortality reference points derived using length-based yield-per-recruit analysis have not yet been estimated for this stock. It may be possible to estimate these in the near future with a longer series of reliable sampling data. In the interim various landings options and the associated harvest rates and catch are presented in Table 5. Maintaining the same advice as given previously by ICES of landings less than 2,500 t would result in a harvest rate of 5.5% from this stock. Assuming that discard rates do not change from the average of the last two years (2012-2013) the resulting catch would be no more than 3366 t. The 5.5% harvest rate is well below the range of MSY harvest rates used for stocks with similar density i.e. FU7 Fladen 10.3% and FU9 the Moray Firth 11.8% (ICES, 2014). The lowest harvest rate applied to any *Nephrops* stock is 5% which used for the Porcupine Bank, with densities are half those estimated in this area. The 5% harvest rate would imply landings of around 2,300 t and catches of 3,100 t in 2015.

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 collected during UWTV surveys will over time prove to be a data asset in monitoring changes to the environment on *Nephrops* grounds.

Acknowledgments

We would like to express our thanks and gratitude to Colin McBrearty (Master) and crew of the RV. Celtic Voyager; Jason White, Tommy Greely, Adam Rahilly, Finbar Goggin, Lar Kirwan, and Tommy Barry for their good will and professionalism throughout the survey. Thanks also to Antony English P&O Maritime IT & Instrumentation Technician**,** for handling all onboard technical difficulties. Thanks to Aodhan Fitzgerald RVOPs and Rob Bunn FEAS at the Marine Institute for organising survey logistics. Thanks to Gordon Furey, Barry Kavanagh and Tom O'Leary P&O Maritime for shore side support. Kieran Lyons and Alan Berry processed the CTD data.

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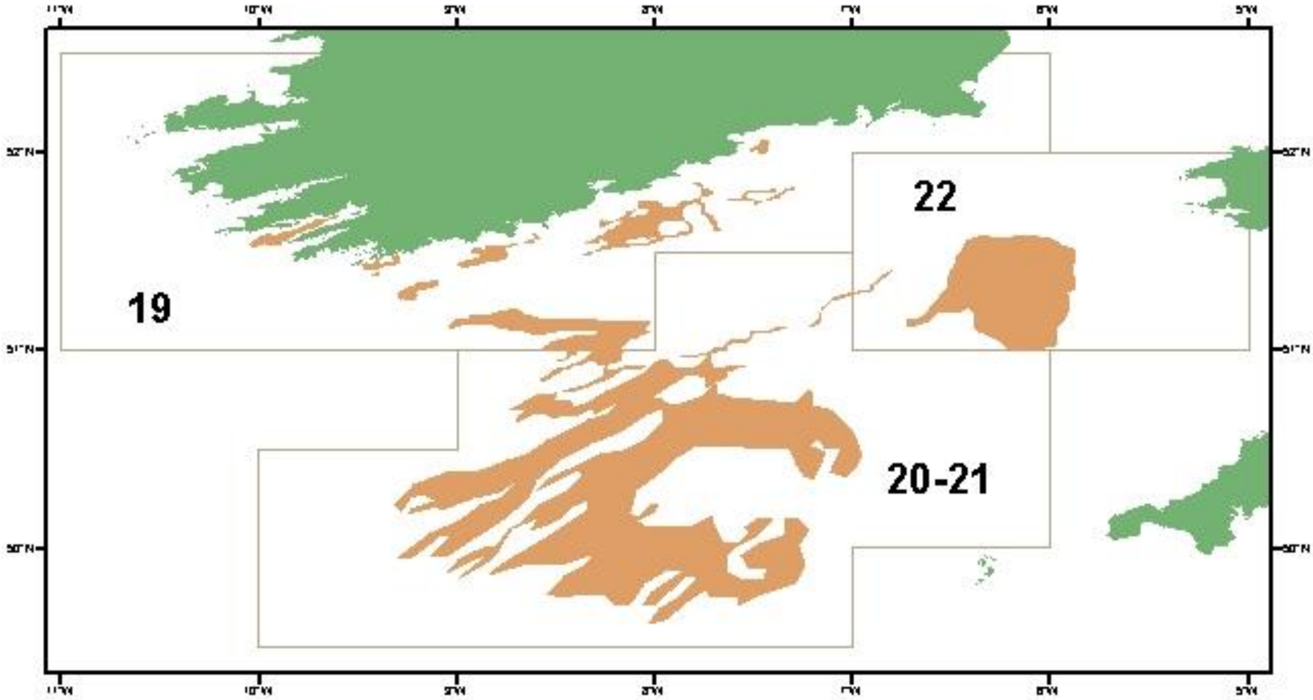

Figure 1:FU2021 grounds: *Nephrops* Functional Units (FUs) in the greater Celtic Sea and area polygons.

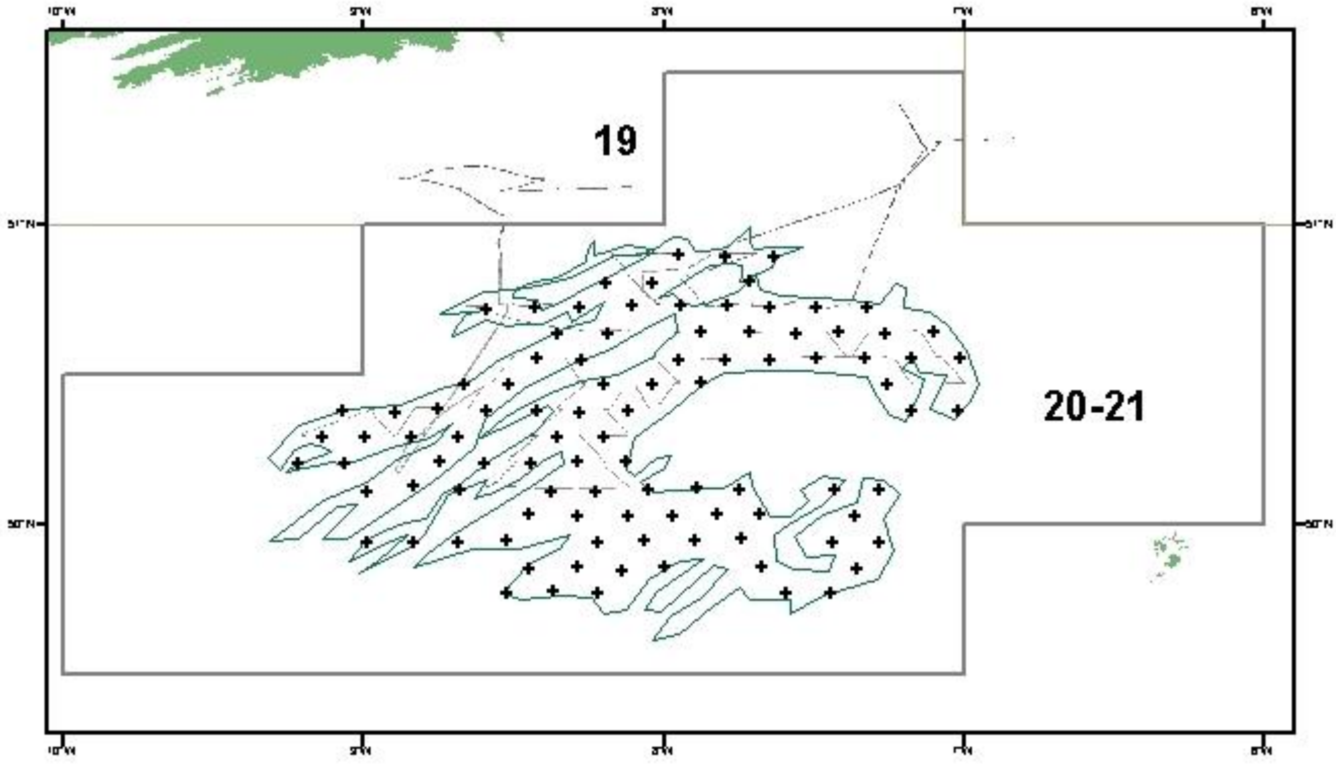

Figure 2: FU2021 grounds: TV stations completed on the 2014 survey and 2013 processed multibeam backscatter tracks.

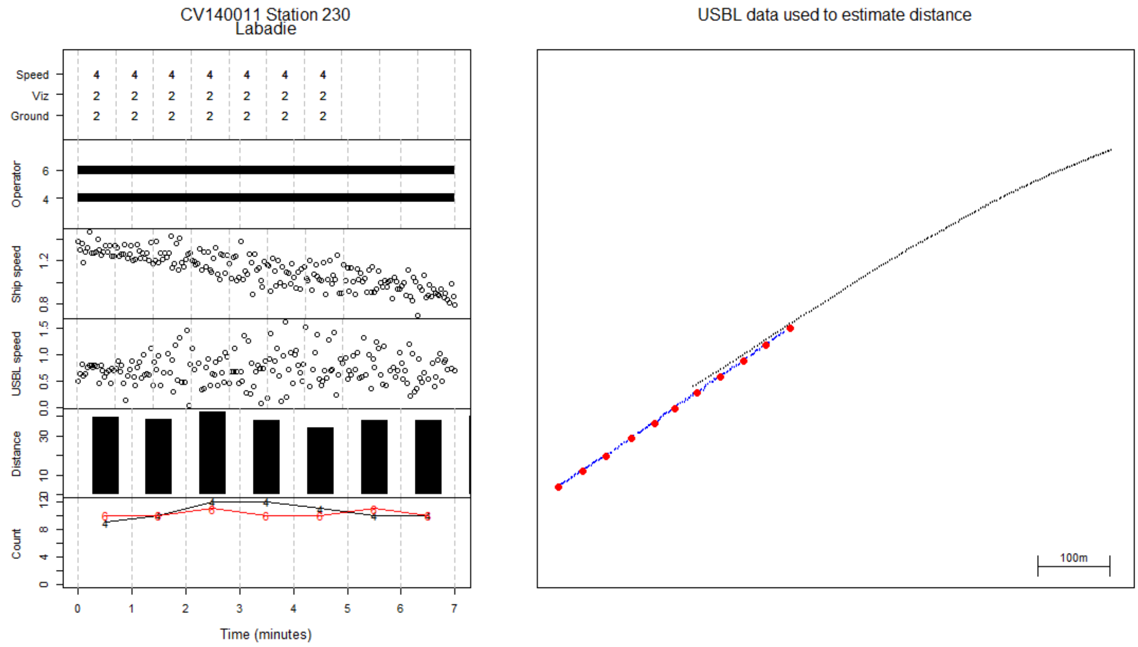

Figure 3: FU2021 grounds: r - tool quality control plot for station 230 of the 2014 survey.

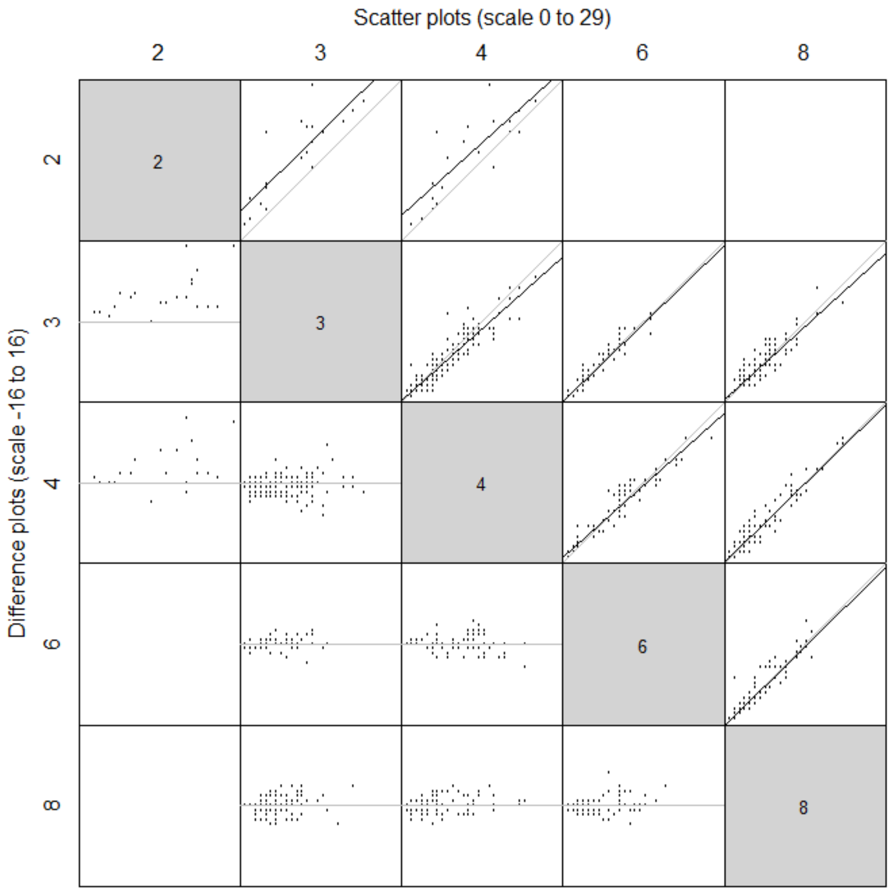

Figure 4: FU2021 grounds: Scatter plot analysis of counter correlations for the 2014 survey.

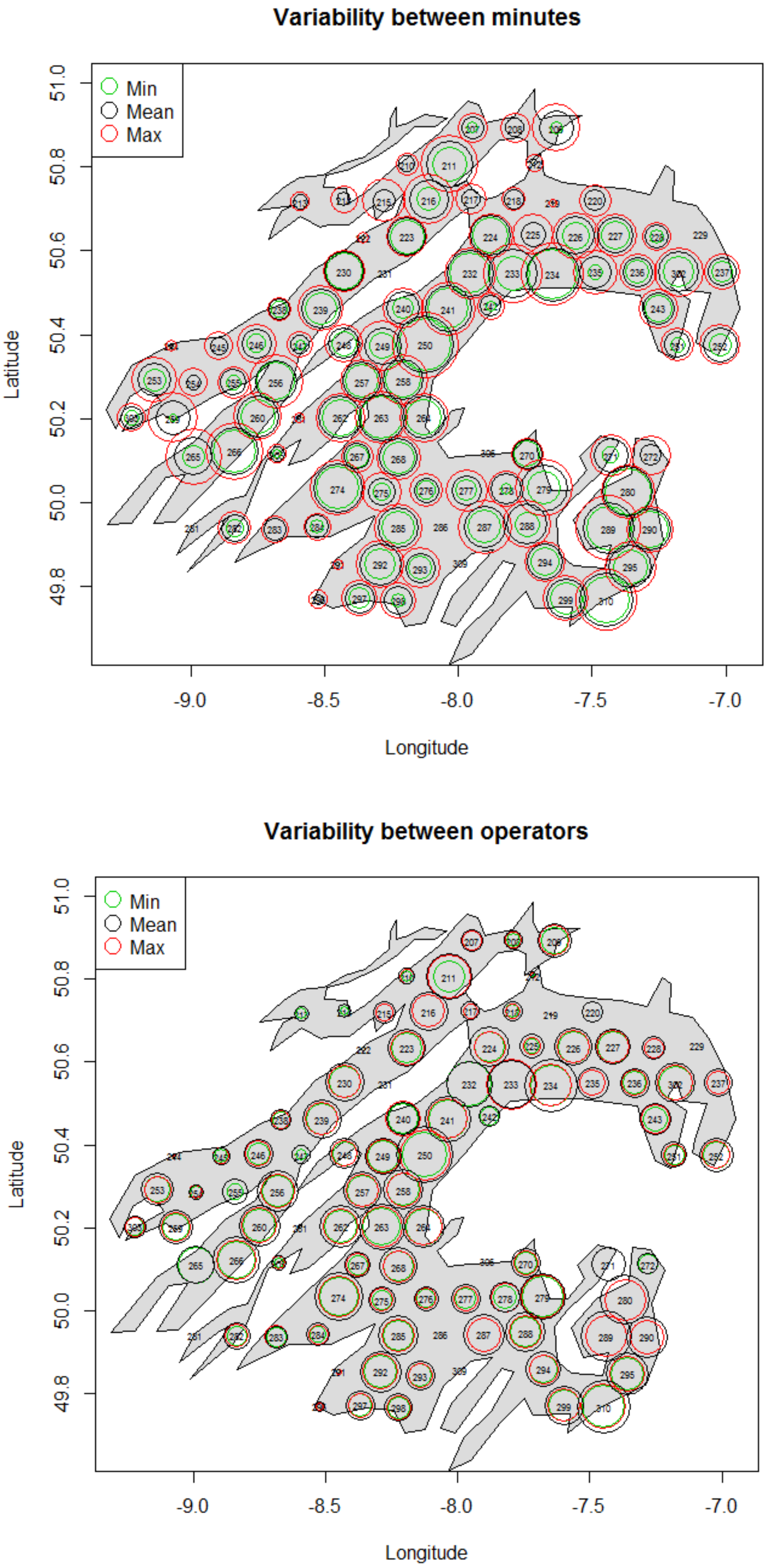

Figure 5: FU2021 grounds: Plot of the variability in density between minutes (top panel) and between operators (counters) (bottom panel) for each station in 2014.

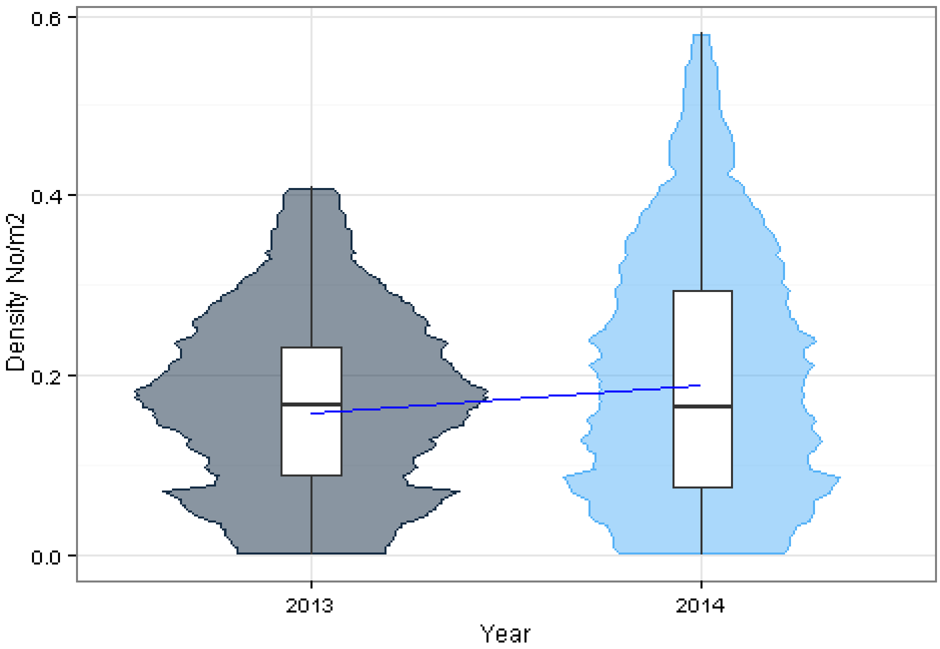

Figure 6 : Violin and box plot a of adjusted burrow density distributions by year from 2013-2014. The blue line indicates the mean density over time.

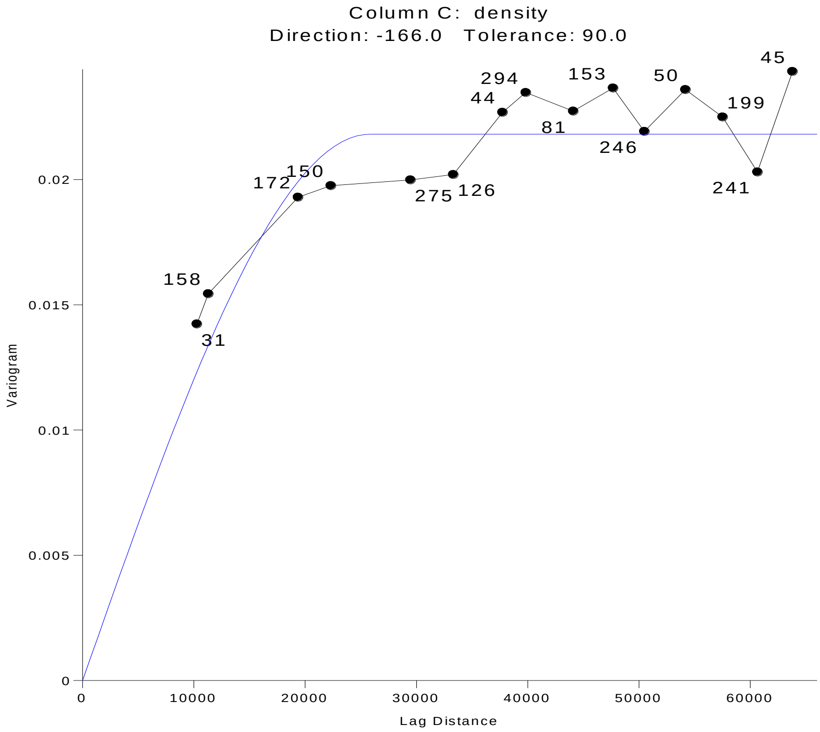

Figure 7: FU2021 grounds: Omnidirectional mean variogram for 2014.

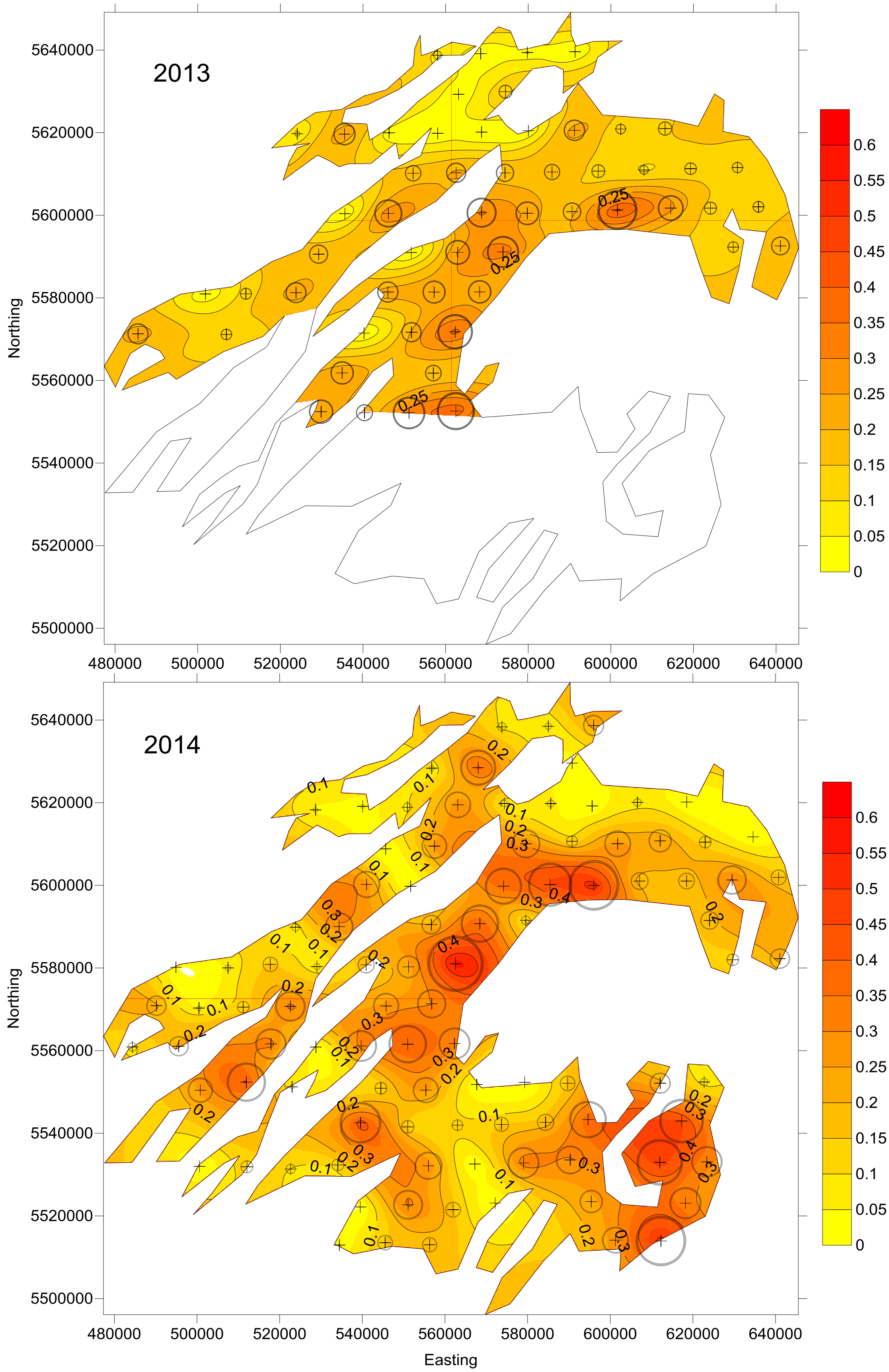

Figure 8: Combined bubble and contour plot of the krigged density in 2013 & 2014.

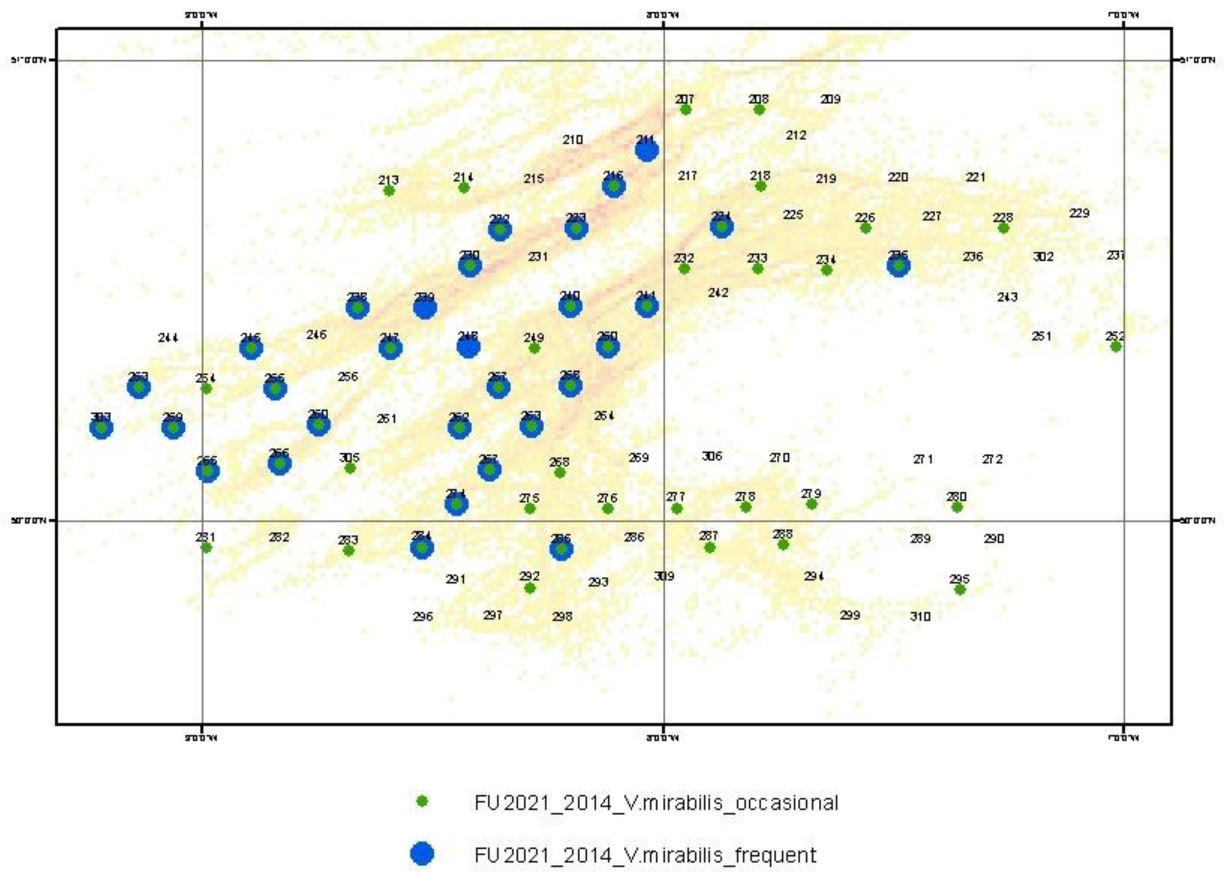

Figure 9: FU2021 grounds: Stations where *Virgilaria mirabilis* was identified during the 2014 survey overlaid on a heat map *Nephrops* directed fishing activity.

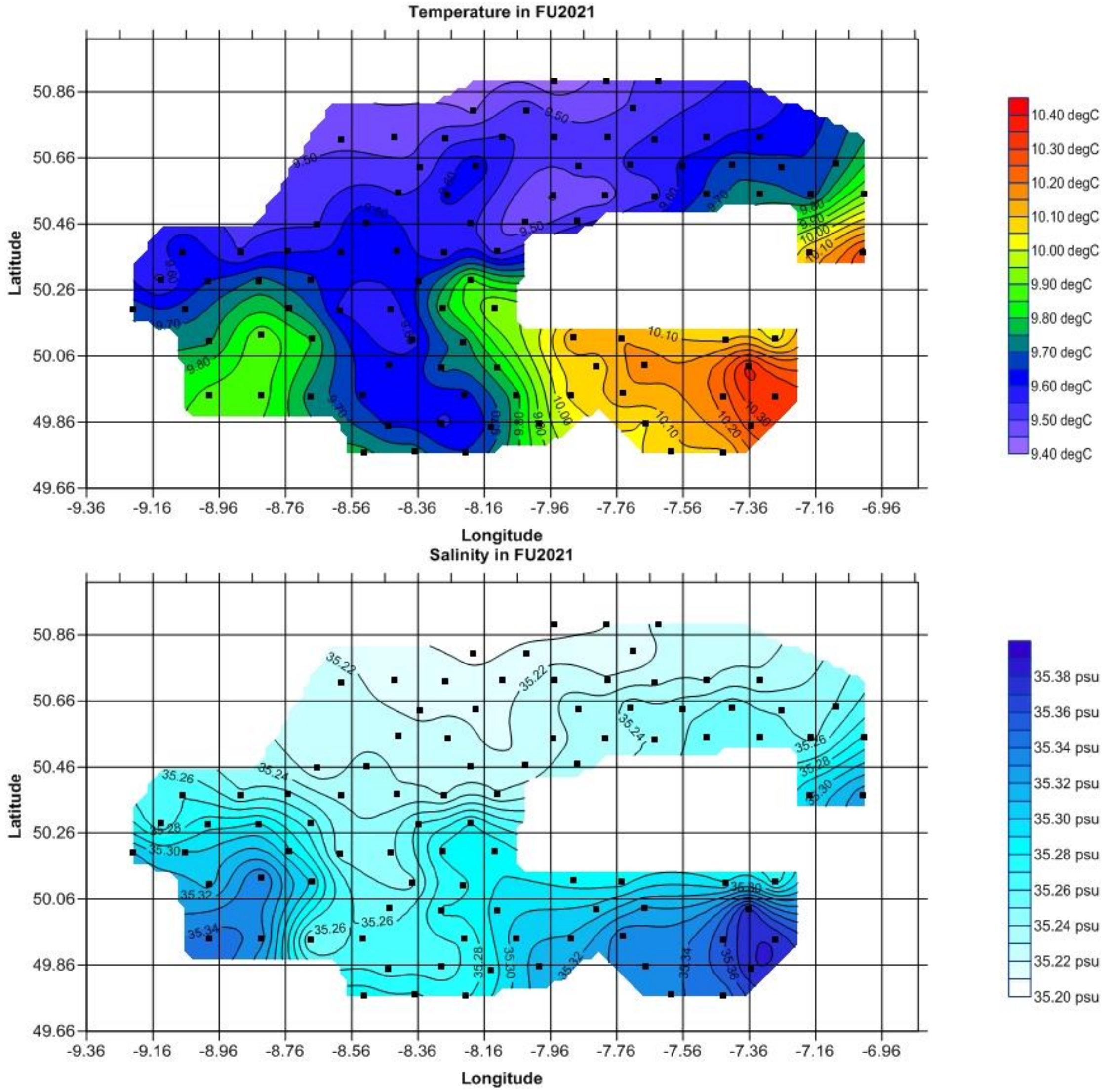

Figure 10: Bottom temperature and salinity observed using a sledge mounted CTD in the Celtic Sea in July 2014. Station positions shown as black dots.

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

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)	FU3-4	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	FU20-21	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: Summary of UWTV results; number of stations, mean density observed, standard deviation, absolute abundance estimates with 95% confidence intervals, estimated area of the stock and coefficient of variation on the abundance.

Year	Number of stations	Mean Density adjusted (burrows m^{-2})	Standard Deviation (burrows m^{-2})	Absolute abundance estimate (million burrows)	95%CI on Abundance (million burrows)	Domain area (km^2)	CVs
2006	9	0.44	0.31	nr			
2012	54	0.57	0.25	nr			
2013	55	0.16	0.11	942	60	5701	3%
2013*				1624	103	9835	
2014	98	0.19	0.14	2051	131	9835	3%

* the 2013 survey achieved partial coverage ~60% of the total area. The abundance has been scaled up to the entire area since densities in the unsurveyed part of the ground were not significantly different in 2014.
nr= no reliable abundance estimate could be calculated because survey coverage was partial.

Table 4: Landings, discards, and removals in number, UWTV survey abundance estimates, 95% confidence intervals, harvest ratio, and total weight and mean weights of landings and discards.

Year	Landings in Number (millions)	Discards in Number (millions)	Removals in Number (millions) 25% discard survival	Prop Removals Retained	Adjusted Survey (millions)	95% Conf. intervals (millions)	Harvest Ratio	FU 20-21 Landings (t)	FU 20-21 Discards (t)	Mean Weight in landings (gr)	Mean Weight in discards (gr)
2012	38.8	37.1	66.7	0.58				1,189	566	30.6	15.2
2013	35.8	20.1	50.9	0.70	1624	103	3.1%	1,387	347	38.8	17.2
2014					2051	131					
			Average 2011-13	**0.643**					Avg 2012-13	**34.69**	**16.24**

Table 5: Catch option table for 2015

Basis: Absolute survey abundance index (2015) = 2051 million (2014 index); Mean individual weight in landings (2011–2013) = 34.69g; Dead discard rate (by number, 2012-2013) = 35.7%; Mean individual weight in discards (2012–2013) = 16.24 g.

Basis	Total Catches*	Landings	Dead Discards**	Surviving Discards**	Harvest Rate
	L+DD+SD	L	DD	SD	for L+DD
Same advice as for 2013-2014	3366	2500	650	217	5.5%
F_{2013}	1929	1432	372	124	3.1%
F 10 year ave. landings	2907	2159	561	187	4.7%
Lowest harvest ratio in Subarea VII (FU16)	3080	2287	594	198	5.0%

* Total catches are the landings including dead and surviving discards
** Total discard rate is assumed to be 43.4% of the catches (in number, last 2 years average, 2012-2013), discard survival is assumed 25%