The Labadie, Jones and Cockburn Banks *Nephrops* Grounds (FU2021) 2015 UWTV Survey Report and catch options for 2016

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Abstract

This report provides the main results of the 2015 underwater television survey on the 'Labadie, Jones and Cockburn Banks' ICES assessment area; Functional Unit 20-21. This was the second survey to achieve full coverage of the full area. The 2015 survey was multi-disciplinary in nature collecting UWTV, CTD and other ecosystem data. A total of 96 UWTV stations were completed at 6 nmi intervals over a randomised isometric grid design. The mean burrow density was 0.20 burrows/m^2 compared with 0.19 burrows/m^2 in 2014. The 2015 geostatistical abundance estimate was 2.0±0.02 billion a 2% decrease on the abundance for 2014 with a CV of 3% which is well below the upper limit of 20% recommended by SGNEPS 2012. Highest densities were general observed towards the north and southwest of the ground, and there were also high densities observed close to boundaries. Using the 2015 abundance estimate and updated stock data implies catch of 3045 tonnes and landings of 2225 tonnes. Only one species of sea pen *Virgilaria mirabilis* was recorded as present at the stations surveyed. Trawl marks were observed at 30% of the stations surveyed.

Key words: *Nephrops norvegicus,* Celtic Sea, stock assessment, geostatistics, underwater television (UWTV), CTD, 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. 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 this FU20-21, ~1,800 t were estimated to be worth in the region of €11.7 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 & 2012a). This is the third UWTV survey in the Celtic Sea FU20-21 grounds carried out by the Marine Institute, Ireland.

The survey was multi-disciplinary in nature and also covered FU19 and FU22 the results of which are presented in Lordan et. al 2015; the specific objectives are listed below:

1. To complete ~96 UWTV stations with 6.0 nautical mile (Nmi) spacing stations on the *Nephrops* ground.
2. To carry out ~12 UWTV stations in FU19 South and SW Ireland and 40 stations in FU22.
3. To obtain 2015 quality assured estimates of *Nephrops* burrow distribution and abundance on this ground and also for FU19 and 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.

This report details: the survey design, the final UWTV results of the 2015 survey and also documents other data collected during the survey. Operational survey details are available in form of a survey narrative from the scientist in charge (CL/JD). The 2015 abundance are used to generate catch options for 2016 in line with the recommendations and procedures outlined in the stock annex for FU20-21 (ICES, 2014).

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 (ICES, 2014) 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 96 stations with a 6.0 nautical mile spacing was planned for the 2015 survey (Figure 2). Stations depths varied from 103 m to 141 m and the completed stations ranged from 55 to 135 nautical miles (nmi) offshore. The 2015 survey took place in two legs due to engine breakdown on the Celtic Voyager: Leg 1 on RV Prince Madog between 9th to11th July and Leg 2 on RV Celtic Voyager between 23rd to 31st August. The survey legs also included UWTV operations in FU17, FU19 and FU22 reported elsewhere (http://oar.marine.ie/handle/10793/59).

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 2015 the USBL navigational data was used to calculate distance over ground for 80% of stations. For those stations where the USBL sensor was not operational, the amount of cable paid in/out on a minute by minute basis was recorded. This data was used to correct the SHIP position used to calculate distance travelled by the sled.

In line with SGNEPS recommendations all scientists were trained/re-familiarised using training material and reference footage from this area, prior to recounting at sea (ICES, 2009b). As the FU20-21 UWTV survey is in its infancy no FU specific reference footage counts were available. However, during this survey reference counts for this ground were generated using an average from 5 experienced counters. This is line with reference counts generated for other FUs (ICES, 2008). 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. Mean density was calculated by dividing the total number of burrow systems by the survey area observed. The USBL and corrected SHIP 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 2015 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 will be processed at a later stage.

For the 2013 and 2014 survey 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. The spatial structure of the density data was studied through variograms.

In 2015 the geostatistical analysis was carried out using RGeostats package (Renard D., *et al*, 2015) and is available as an R markdown document. The same steps were carried out as in previous years; construction of experimental variogram, a model variogram $\gamma(h)$, was produced with exponential model (see below), create krigged grid file using all data points as neighbours, same boundary used to estimate the domain area, mean density, total burrow abundance and then calculate survey precision.

Results

All 96 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 to 2015 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 2015 mean density of 0.20/m^2 was 23% higher than estimate of 0.16/m^2 in 2013 when the survey had incomplete coverage.

The blanked krigged contour plot and posted point density data from Surfer 10 are shown for 2013 and 2014 in Figure 7. Highest densities were towards the centre of the ground in both years. Some changes in the density surface have occurred between 2013 and 2014. Combined bubble and contour plot of the krigged density in 2015 shows high densities in the northern and southwestern area in Figure 8.

The summary empirical and geo-statistical results are given in Table 2. 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. The 2013 survey had partial coverage of the area (<60%) scaling the mean density to the total area (10,014 km^2) resulted in an abundance estimate of 1.6±0.3 billion. The 2015 geo-statistical abundance estimate is 2.0±0.02 billion which is 2% lower than in 2014. 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 2014 of 4.4%. The mean weight in the landings and the discards and the proportions of removal retained are also shown (Table 3). The mean weights are variable between 2012-2014 but are based on the only available sampling data (ICES, 2015). The basis to the catch options is given in Table 4. The catch options and the associated harvest rates and catch are presented in Table 5. Fishing at a precautionary rate of 5.7% in 2016 would result in total catches of 3045 t which implies; wanted catch of 2225 t and unwanted catch of 819 t (Table 5).

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 20% and occasionally present at 40% of total stations. Trawl marks were noted at 30% of the stations surveyed with trawl marks present for the entire transect for 2% of stations.

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 a new ground boundary was established (ICES, 2014).

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, 2014). 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.

The 2015 survey achieved full coverage of the stock area for the second time. The density estimates in 2013 - 2015 are relatively similar and would be considered low (mainly ~$0.2m^2$). 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.

The estimate harvest ratio in 2014 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 2016 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 a 5.7% harvest rate is used as the basis for the advice. This is well below the range of MSY harvest rates used for stocks with similar density i.e. FU7 Fladen 7.5% a (ICES, 2015). The lowest harvest rate applied to any *Nephrops* stock is 5%. This used for the Porcupine Bank where densities are half those estimated in this area.

Discard rates for this FU have been very high in the last three years (around 45% by number). Because harvest rates are calculated on the basis of numbers and 25% of the *Nephrops* in this area are assumed to survive 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 5 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 3045 t which implies; landings or in ICES terminology "wanted catch" of 2225 t and discards or "unwanted catch" of 819 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 (3431 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 (3865 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.

It is likely that the *Nephrops* populations in the Celtic Sea are linked in a meta-population sense (O'Sullivan et. al, 2015), 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.

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.

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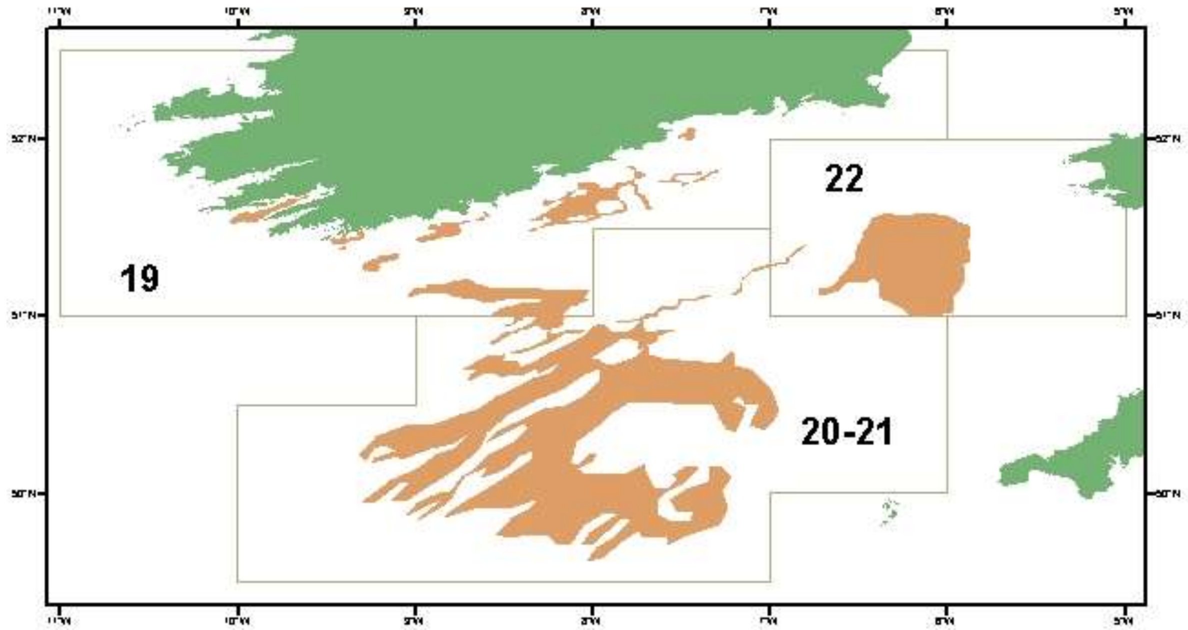


Figure 1:FU2021 grounds: *Nephrops* Functional Units (FUs) in the greater Celtic Sea and area polygons.

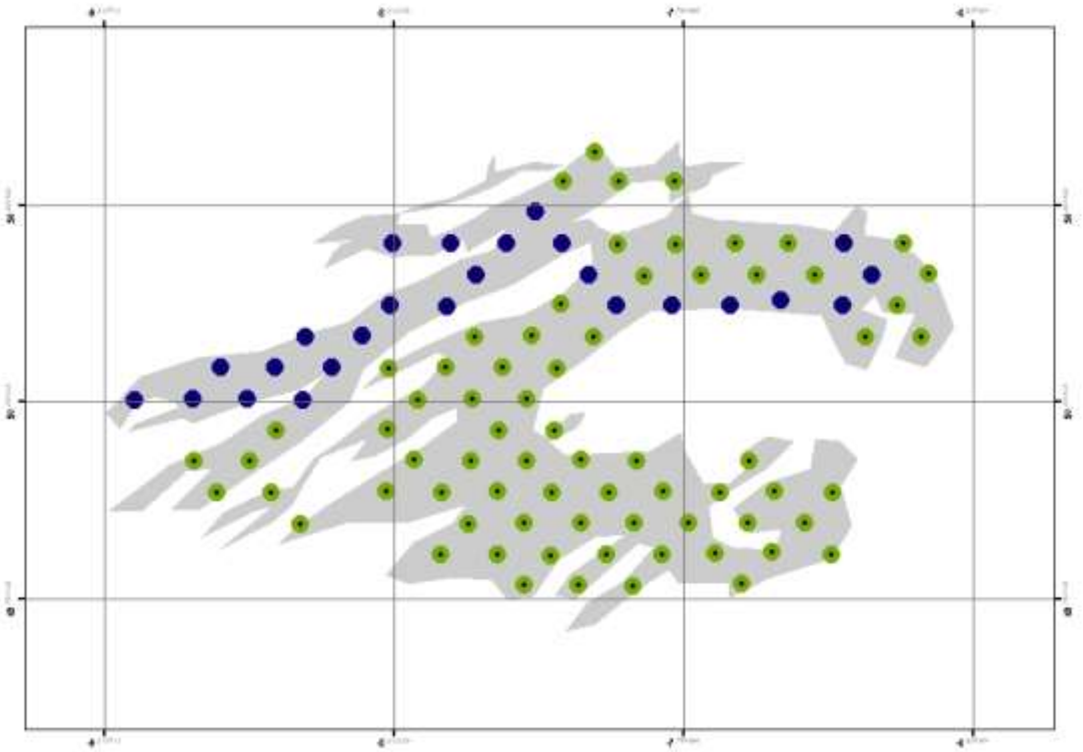


Figure 2: FU2021 grounds: TV stations completed on the 2015 survey.Blue circles indicate stations completed by RV Prince Madog and green circles stations by RV Celtic Voyager.

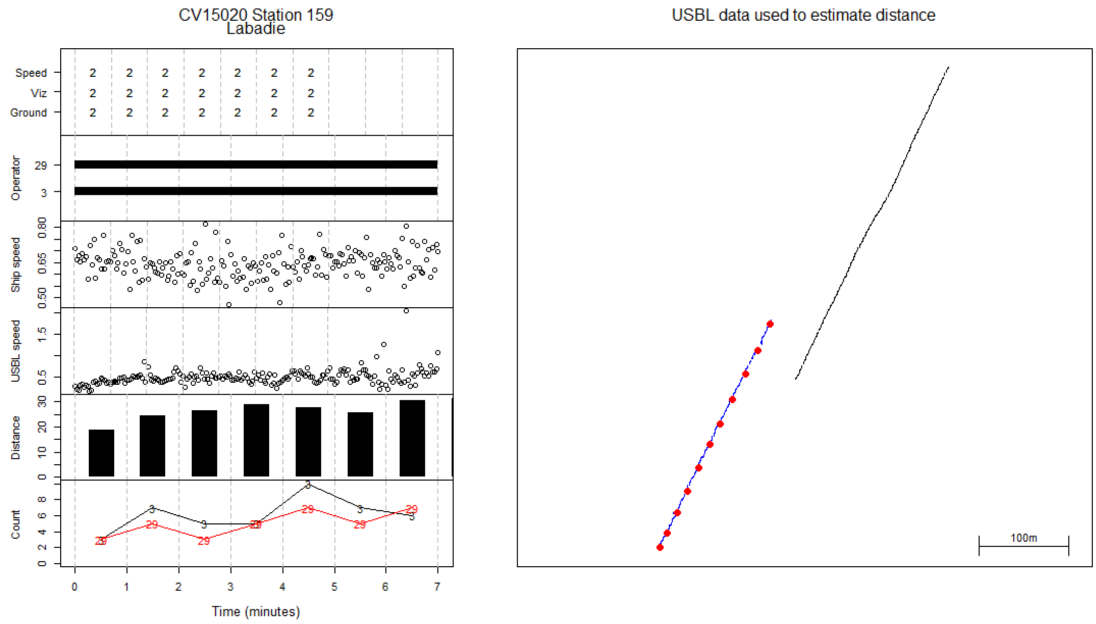


Figure 3: FU2021 grounds: r - tool quality control plot for station 159 of the 2015 survey.

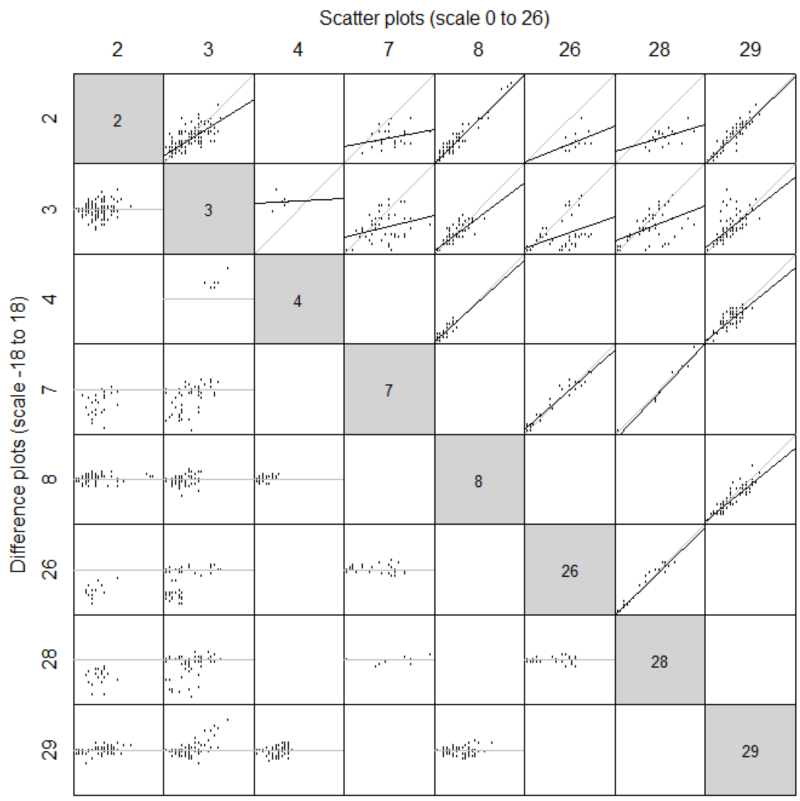
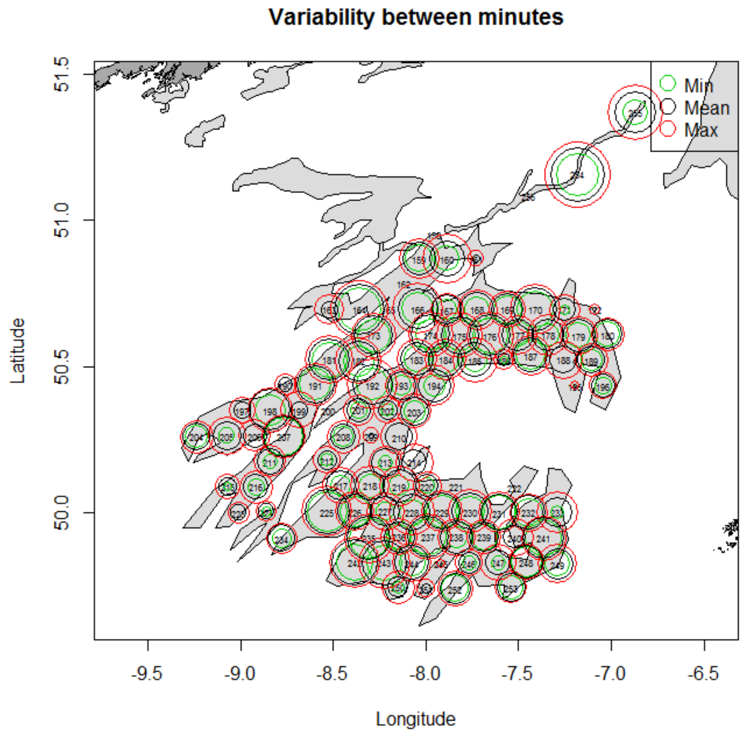


Figure 4: FU2021 grounds: Scatter plot analysis of counter correlations for the 2015 survey.



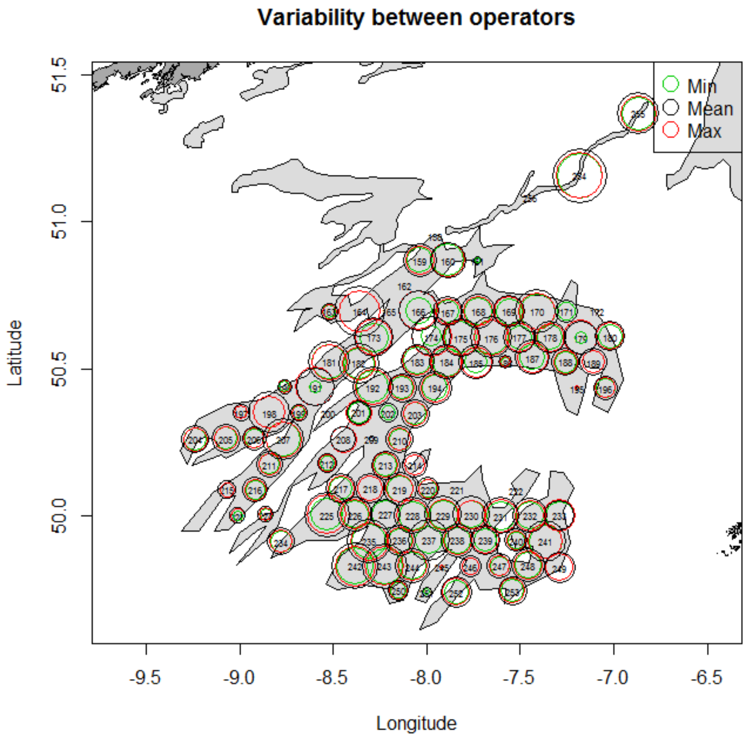


Figure 5: FU2021 grounds: Plot of the variability in density between minutes (top panel) and between operators (counters) (bottom panel) for each station in 2015.

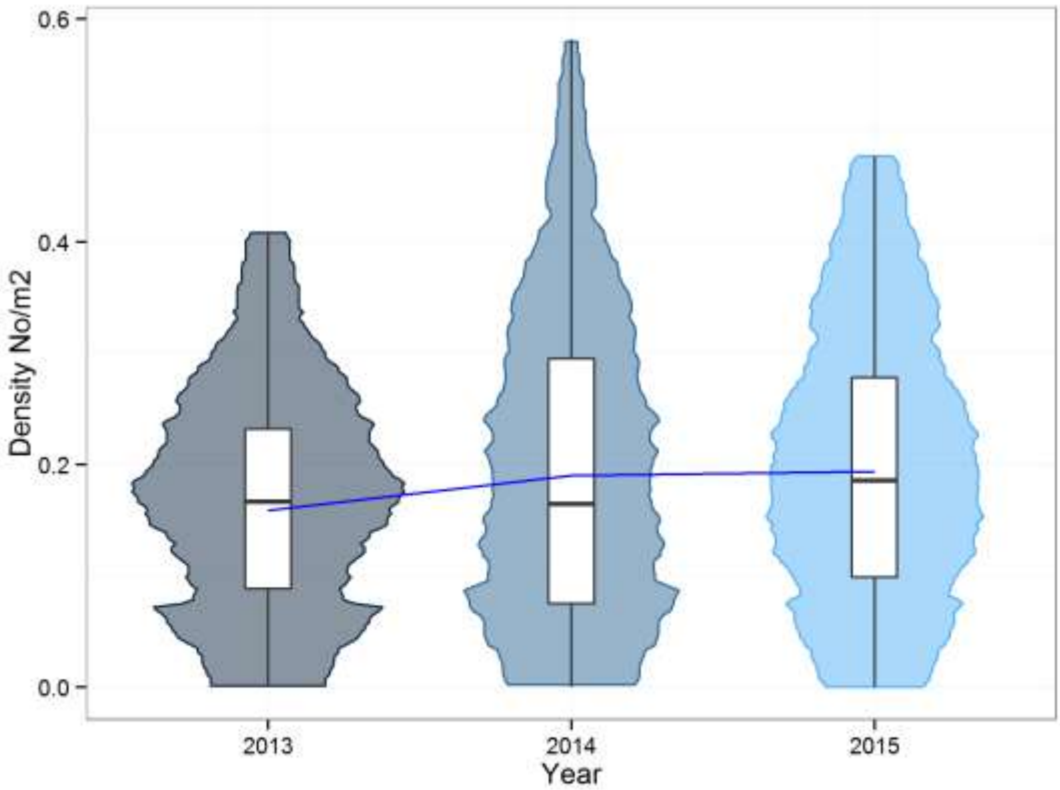


Figure 6 : Violin and box plot a of adjusted burrow density distributions by year from 2013-2015. The blue line indicates the mean density over time.

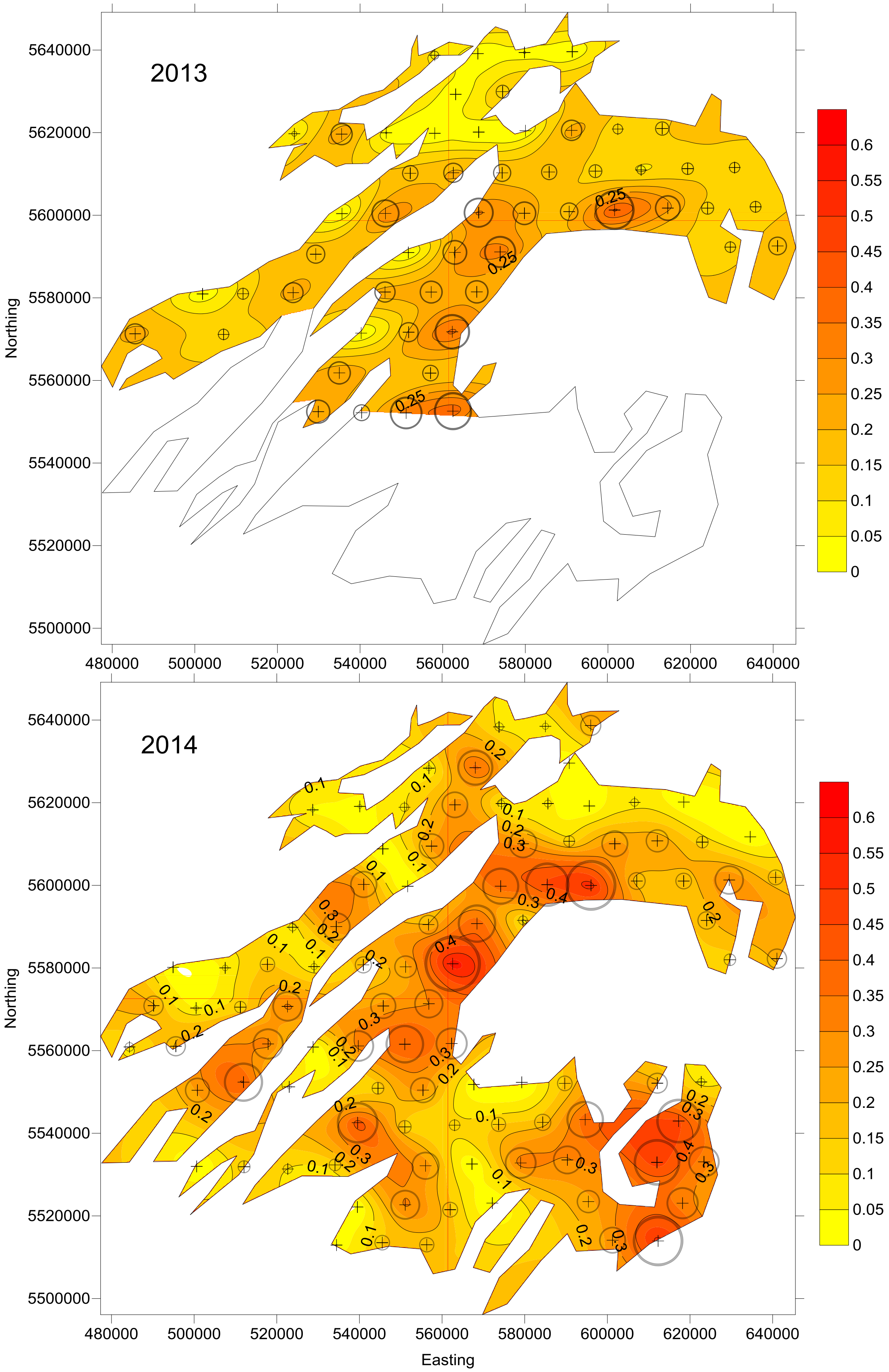


Figure 7: Combined bubble and contour plot of the krigged density in 2013 & 2014.Surfer 10 graphical output.

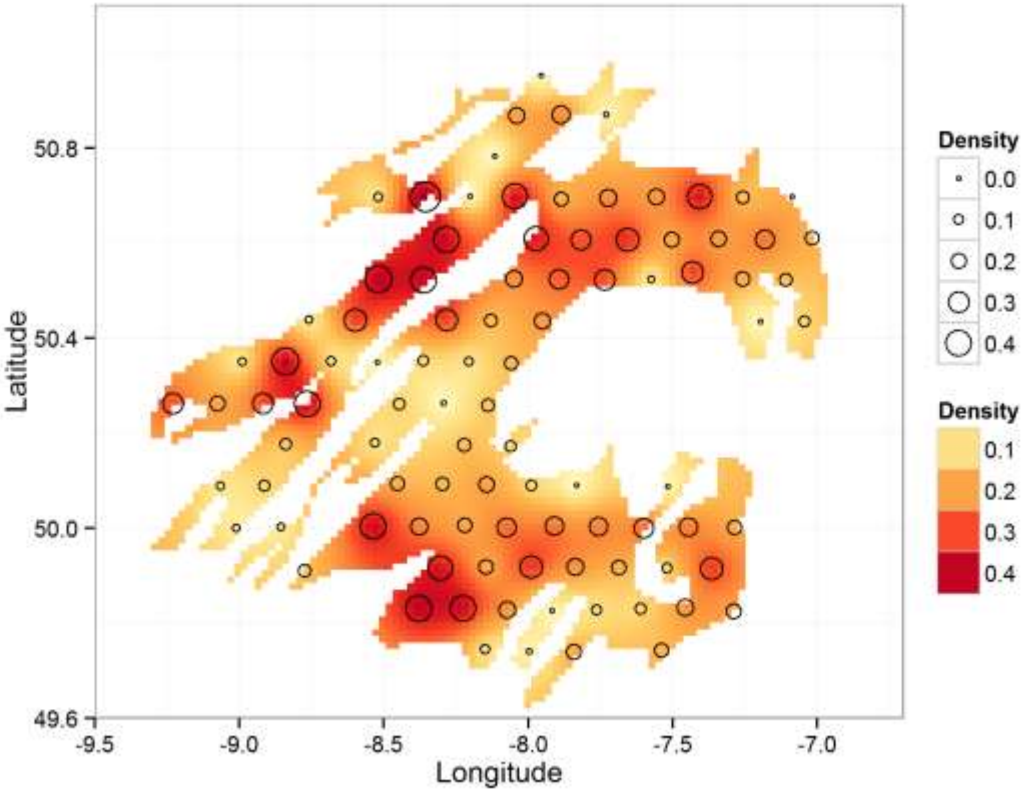


Figure 8: Combined bubble and contour plot of the krigged density in 2015.RGeostats graphical output.

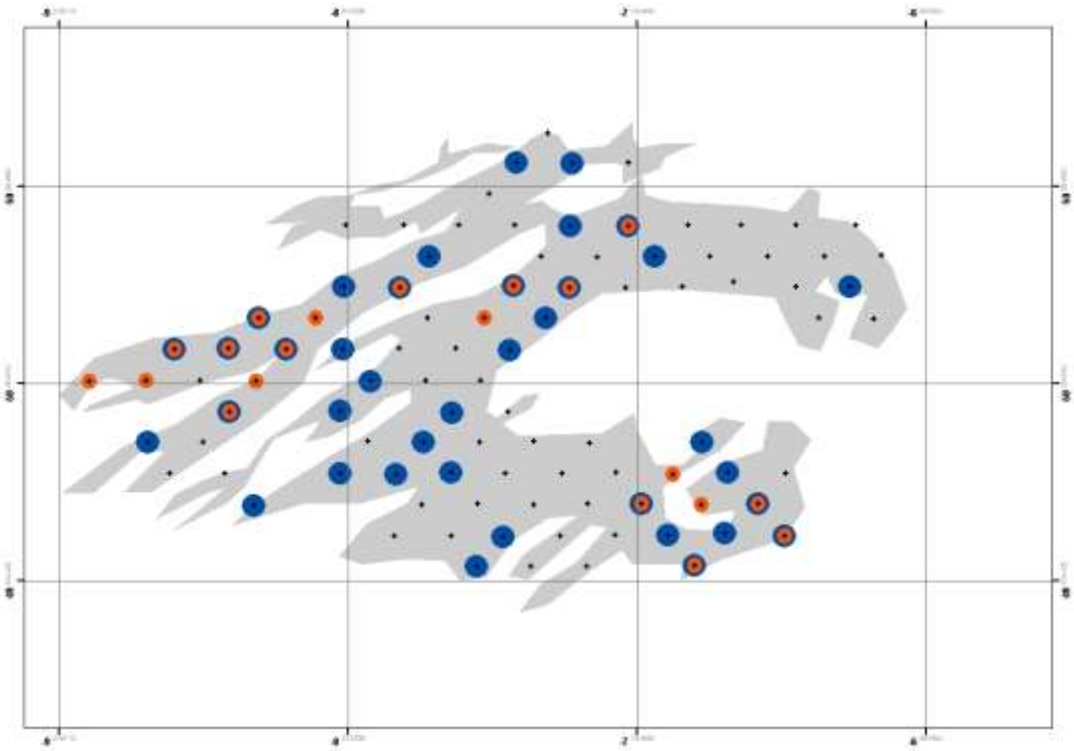


Figure 9: FU2021 grounds: Stations where *Virgilaria mirabilis* was identified during the 2015 survey.

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: 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 (burrow /m²)	Standard Deviation	Absolute abundance estimate (million burrows)	95% CI on Abundance	Domain area	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%
2015	96	0.20	0.02	2003	25	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 3: Inputs to short-term catch option table.

Year	Landings in number	Total discards in number	Removals in number; 25% discard survival	Proportion removals retained	Adjusted survey	95% Conf. intervals	Harvest rate	Landings	Total discards	Mean weight in landings	Mean weight in discards
	millions	millions	millions		million	millions	%	tonnes	tonnes	grs	grs
2012	37.3	35.2	63.7	0.59				1,189	529	31.1	15
2013	33.2	18.2	46.9	0.71	1624	103	2.89%	1,387	312	39.9	17.1
2014	49.8	54.7	90.9	0.55	2051	131	4.43%	1,837	821	36.6	15
Average 2012–14				0.62						35.5	15.7

Table 4: The basis for the catch options for 2016.

Variable	Value	Source	Notes
Stock abundance	2003 million individuals	ICES (2015)	UWTV survey 2015
Mean weight in landings	35.5 g	ICES (2015)	Average 2012–2014
Mean weight in discards	15.7 g	ICES (2015)	Average 2012–2014
Discard proportion	45.4%	ICES (2015)	Average (proportion by number) 2012–2014
Discard survival rate	25%	ICES (2015)	Only applies in scenarios where discarding is allowed.
Dead discard rate	38.3%	ICES (2015)	Average 2012–2014 (proportion by number). Calculated as dead discards divided by dead removals (landings + dead discards). Only applies in scenarios where discarding is allowed.

Table 5: Catch options for 2016 using 2015 UWTV estimate.

Landing obligation

Basis	Total catches	Wanted catches	Unwanted catches	Harvest rate
Precautionary approach	3045	2225	819	5.7%
F_{2014}	2353	1720	633	4.4%
F (10-year average landings)	2882	2100	782	5.4%
Lowest harvest rate in Subarea VII (FU 16)	2654	1940	714	5.0%

Discarding allowed

Basis	Total catches	Dead removals	Landings	Dead discards	Surviving discards	Harvest rate
	L+DD+SD	L+DD	L	DD	SD	for L+DD
Precautionary approach assuming recent discard rates	3431	3198	2500	698	233	5.7%
Precautionary approach assuming 7% discard rate in weight	3865	3797	3594	203	68	5.70%