Western Irish Sea *Nephrops* Grounds (FU15)

2012 UWTV Survey Report

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Abstract

This report provides the main results and findings of the tenth annual underwater television on the 'Irish sea west *Nephrops* grounds' ICES assessment area; Functional Unit 15. The survey was multi-disciplinary in nature collecting UWTV, CTD and other ecosystem data. An analysis of the precision, accuracy and sampling intensity trade-offs showed that sampling intensity could be reduced without significantly reducing the precision and accuracy of the survey. Consequently, sampling intensity was reduced this year from ~150 stations in a 3.5 nautical mile grid to 99 stations (4.5nmi grid). Full coverage of the grid was achieved. The krigged burrow abundance estimate for the Irish Sea ground increased slightly (+3% relative to 2011). Abundance estimates have been fairly very stable over the time series. The 2012 randomised isometric grid design resulted in a CV (or relative standard error) of 3% which is in line with CVs observed previously and well below the upper limit of 20% recommended by SGNEPS 2012.

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

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Introduction

The Norway lobster, *Nephrops norvegicus*, is exploited throughout its geographic range, from Icelandic waters to the Mediterranean and the Moroccan coast. The western Irish Sea stock (FU15) is by far the most productive of all the *Nephrops* stocks currently fished yielding landings of between 7,000-10,000 tonnes annually from a relatively small geographic area (ICES, 2012a). *Nephrops* spend a great deal of time in their burrows and their emergence behaviour is influenced many factors; time of year, light intensity and tidal strength. 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 tenth in a time series of UWTV surveys in the western Irish Sea carried out jointly by the Marine Institute, Ireland and the Agri-Food and Biosciences Institute (AFBI), Northern Ireland. The 2012 survey was multi disciplinary in nature; the specific objectives are listed below:

1. To complete randomised fixed isometric survey grid of ~99 UWTV with 4.5 nautical mile (Nmi) spacing stations on the western Irish Sea *Nephrops* ground (FU15).
2. To obtain 2012 quality assured estimates of *Nephrops* burrow distribution and abundance on the western Irish Sea *Nephrops* ground (FU15). These will be compared with those collected previously.
3. To collect ancillary information from the UWTV footage at each station such as the occurrence of sea-pens, other macro benthos and fish species and trawl marks on the seabed.
4. To collect oceanographic data using a sledge mounted CTD.
5. Technology, staff and protocol transfer between Marine Institute and AFBI.

This report details the final UWTV results of the 2012 survey and also documents other data collected during the survey.

SGNEPS (ICES, 2012b) recommended that a CV (or relative standard error) of < 20% is an acceptable precision level for UWTV surveys. SGNEPS also recommended that investigations into the precision of surveys be carried out and where possible survey effort should be extended to grounds not already covered with UWTV surveys (e.g. FU20-21). The results of a sensitivity analysis carried out in advance of the survey to investigate the consequences of reducing sampling intensity is also provided.

Material and methods

From 2003 to 2011 a randomised fixed grid for the western Irish Sea *Nephrops* ground has been used. The grid spacing was 3.5 nautical miles (6.5km) and an adaptive approach is taken whereby stations are continued past the known perimeter of the ground until the burrow densities are zero or very close to zero. The initial ground perimeter has been established using a combination of integrated logbook-VMS data (using the methods described in Gerritsen and Lordan, 2011), BGS & other sediment maps and previously collected UWTV data. The same boundary is used throughout the time serise.

Leg one of the survey took place on RV. Corystes between 2nd to 8th August 2012. This leg covers a proportion of the western Irish Sea (FU15) grid and also then complete coverage of the eastern Irish Sea (FU14). The remaining stations in FU15 were completed on leg two of the survey on the RV. Celtic Voyager between 8th to 10th August 2012. Survey timing was generally standardised to August/September each year and was also timed to take full advantage of the neap tides when visibility is normally better.

The protocols used were those presented and reviewed by WKNEPHTV 2007 (ICES, 2007) and are summarised as follows: At each station the UWTV sledge was deployed and once stable on the seabed a 10 minute tow was recorded onto DVD. Vessel position (DGPS) and position of sledge (using an Ixsea USBL transponder onboard RV Celtic Voyager and Scout USBL sensor onboard RV Corystes survey) were recorded every 1 to 2 seconds. The navigational data was quality controlled using an "r" script developed by the Marine Institute (ICES, 2009b). In 2012 the USBL navigational data was used to calculate distance over ground for 86% of stations whereas ship data was used for the remaining 14% of stations.

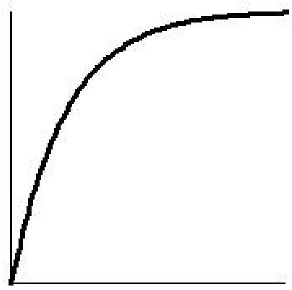
In addition CTD profile was logged for the duration of each tow using a Seabird SBE 19 for stations surveyed by RV. Celtic Voyager. This data will be processed at a later stage. No sediment sampling was carried out in 2012 as the Irish Sea is well sampled through various research programmes and good sediment maps exist for this area.

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 1 shows individual's counting performance in 2012 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 sea pens based SACFOR abundance scale (Table 2) 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. 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 2 and 3). Consistency and bias between individual counters was examined using a scatter plot matrix (not shown). There is some variability but no obvious bias problems between counters.

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. Either the USBL or estimated sledge lay-back 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 using lazers with the sledge was flat on the seabed (i.e. no sinking). Occasionally the lasers were not visible at the bottom of the screen due to sinking in very soft mud (this results in an underestimate of densities at stations where it 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 8.02. The spatial structure of the density data was studied through variograms. The mid-points of each UWTV transect were converted to UTMs. In addition to the survey stations various boundary positions were included in the analysis. The assumption at these boundary positions was that the *Nephrops* abundance was zero. These stations were outside the known distribution of *Nephrops* or suitable sediment and were approximately equidistant to the spacing within the main grid each year. An unweighted and unsmoothed omnidirectional variogram was constructed with a lag width of approximately 1417m and maximum lag distance of between 53-55 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. Then surface plots of the grids were made using a standardised scale. 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 are extremely close to the Surfer estimate in all years (+/- 0.1 billion burrows).

Results

Prior to this survey a study to investigate the impact of increasing station spacing to 7.0 and 10.5 nmi on accuracy and precision was carried out. This study subsetted the 2011 density observations. Figure 4 shows the various grid options of 7.0 and 10.5 nmi and also density data obtained in 2011. The same geo-statistical methods derive abundance estimates and CVs as outlined above were used. The resulting variograms, blanked krigged contour plot and posted point density data are shown in Figures 5 and 6. The 7.0nmi krigged contours correspond well to the observed data and depending on the density data the contours pick up the hot spots (Figure 6). However, the increased station spacing of 10.5 nmi does not pick up the varying density levels and the contour plot is more smooth (Figure 7).

The summary statistics from this geo-statistical analysis for the various grid options are given in Table 1. The estimates of abundance from the 7.0 nmi station spacing grid options are not significantly different from the estimate obtained using the 3.5 nmi grid. The CVs from the 7.0 nmi grids were in the range of 7 - 9%. The CV for the 10.5 nmi grid was 15%. To maintain a CV < 20%, to achieve good spatial coverage over the ground and to generate burrow surface that reflects the underlying abundance an intermediate spacing of 4.5nmi was used in 2012. This resulted in a randomised isometric grid of 99 stations.

The station positions are shown in Figure 8. Of these 65 were carried out on RV Corystes and 34 were carried out on RV Celtic Voyager. A histogram of the observed burrow densities from 2003 to 2012 on the western Irish Sea is presented in Figure 9. Over the time series available the density estimates observed are very similar with modal density of around $1/m^2$. Figure 10 and Figure 11 shows the variability in density between minutes and operators (counters) for each station. These quality control and consistency plots show that the burrow estimates were fairly consistent between minutes and counters. Variability is higher between minutes than counters. Stations close to the boundary tend to show higher minute by minute variability than those in the centre of the ground. Recent trawling activity also sometimes impacts on the between minute variability.

The geo-statistical structural analysis is shown in the form of variograms in Figure 12. There is a weak evidence of a sill in some years. The blanked and krigged contour plot and posted point density data are shown in Figure 13. The krigged contours correspond well to the observed data. These densities surfaces show a relatively dynamic situation. Some parts of the ground have consistently higher or lower densities. Densities are consistently lower close to the boundary which implies a well defined and discrete boundary. There tends to be a lower density towards the middle of the ground surrounded by an elongated ring of higher density stations with a SW-NE orientation. The burrow surface plot in 2005 shows quite an unusual pattern with very high observed densities in a band across the middle of the ground. The burrow surface in 2012 was quite consistent with the pattern observed in other years (except 2005) although the burrow densities were generally higher over the whole ground except the edges.

The summary statistics from this geo-statistical analysis are given in Table 2 and plotted in Figure 14. The 2012 final abundance estimate adjusted of 5.1 billion burrows is very close to that estimated in 2011 and just below the series average. The overall burrow abundance trend is fairly stable (<10% inter annual variation) although the abundance did decline by 17% between 2007 and 2008 (the lowest observed). The CV for 2012 was 3% indicating a very precise survey in line with CVs observed previously.

Sea-pen distribution across the western Irish Sea *Nephrops* grounds is mapped in Figure 13. All sea-pens were identified from the video footage as *Virgularia mirabilis*. Trawl marks were noted at 29% of the stations surveyed and trawl marks present for the entire video transect accounted for 4% of total stations.

Discussion

The western Irish Sea (FU 15) stock has accounted for >50% of the total landings reported to WGCSE for ICES Sub-area VII (ICES, 2012c) making it singly the most important FU in the TAC management area. This *Nephrops* fishing ground is particularly important to the Irish and Northern Irish *Nephrops* métiers. In the last decade it has become by far the most economically important fishery in the Irish Sea. The Western Irish Sea *Nephrops* stock relatively well studied with size information on catches extending back to the 1970s, a trawl survey series since 1994 and larval production surveys in a few years.

Since the benchmark assessment by ICES in 2009 this UWTV survey has become the main input for assessment and calculation of catch options for this stock. Concerns about the accuracy of catch data and unknown and variable growth rates have hampered the development of analytical assessments prior to the benchmark (ICES, 2009a). The survey information up to 2011 was used as the main basis for the ICES assessment and 2013 management advice (ICES, 2012a&c). ICES concluded that the *Nephrops* in FU15 was fished at a sustainable rate (ICES, 2012c).

SGNEPS 2012 recommended that a review of survey sampling intensity (ICES, 2012b). Resulting from that review (presented here) the intra-station spacing was increased from 3.5 to 4.5 nautical miles. This resulted in a 40% reduction in stations and an estimated 30% reduction in time. Reducing the number of stations is not expected to have affected the accuracy of the survey estimate and the observed CV of 3% remained in line with previous estimates well below the SGNEPS 2012 recommendation of 20%. Also in line with SGNEPS recommendations the vessel time saved was used to extend survey coverage to other areas within Irish waters such as FU19 and FU20-21 within the exiting survey schedule. The results of these other surveys are presented in separate reports.

The 2012 burrow abundance estimates presented here are not significantly different than last year and will not change the ICES conclusions made in June 2012. Previously ICES have revisited the catch advice for some *Nephrops* stocks where the UWTV survey abundance has changed by more than 15% which is not the case here. The stock remains in a very healthy condition. The abundance observed throughout the short series is well above the MSY B_{trig} (biomass trigger) proposed by ICES of 3.0 billon burrows which was derived from a longer time series of trawl survey data.

Burrow identification in the western Irish Sea is notoriously difficult due to the high underlying burrow densities and sometimes poor visibility. The burrows of *Calocaris macandrae* (a mud burrowing shrimp species) are abundant particularly in the softer muds in the middle of the western Irish Sea grounds. This can lead to confusion with *Nephrops* burrows. However, such allocation errors are minimised due to the training procedures employed during the survey. These include refresher training on classical *Nephrops* burrow signatures and consistency verification with reference count analyses (ICES, 2008 & 2009b). The counting performance of the 2012 counters was generally very high with Linn's CCC scores >0.8 for all stations.

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, 2009a). The CTD data collected will be processed at a later stage. This information is relatively easy to collect and over time will provide a useful data series on oceanographic regime in this region.

The impact of trawling activity on the sea-bed communities' structure and functioning has been raised a potential ecosystem concern (OSPAR, 2010). Sea-pens in particular have been identified as a potential indicator species for benthic habitat health status. OSPAR have sought advice from ICES on the utility of UWTV surveys for collecting data on sea pen status and distributions (ICES, 2011). The occurrence of sea pens has been noted on this survey since the outset. This is the second year that a systematic quantification and identification of sea-pens to species level was undertaken. Only *Virgilaria mirabilis* was positively identified on the 2012 footage although *Pennatula phosphorea* has been observed in previous years.

The main objectives of the survey were successfully met for the tenth successive year. The UWTV coverage and footage quality was excellent on the western Irish Sea grounds due to survey timing, favourable weather conditions and minimal technical difficulties. The multi-disciplinary nature of the survey means that the information collected is highly relevant for a number of research and advisory applications.

Acknowledgments

We would like to express our thanks and gratitude to the Captains and crews of both vessels: RV. Celtic Voyager and Corystes for their good will and professionalism during the survey. Also thanks to Antony English P&O Maritime IT & Instrumentation Technician**,** for handling all onboard technical difficulties on RV.Celtic Voyager and to William Clarke, AFBI who provided technical expertise in system set-up onboard RV.Corystes. Aodhan Fitzgerald of RV Operations at the Marine Institute greatly assisted in organising survey logistics. Finally, thanks to the Marine Institute, AFBI and CEFAS staff onboard for their hard work and enthusiasm in making this survey a success.

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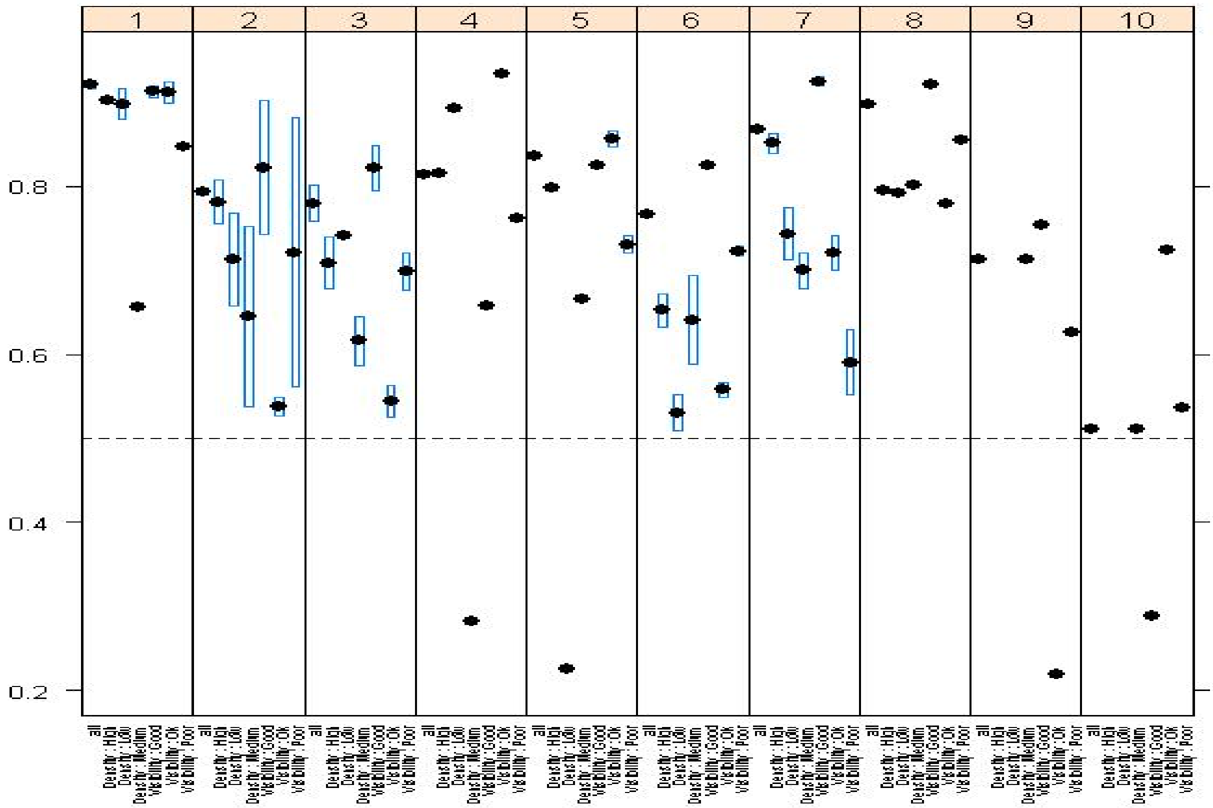

Figure 1: FU15 western Irish Sea grounds: 2012 Counting performance against the reference counts as measured by Linn's CCC for FU15 reference set. Each panel represents an individual. The x-axis (from left to right), all stations pooled, high density, low density, medium density and visibility good.

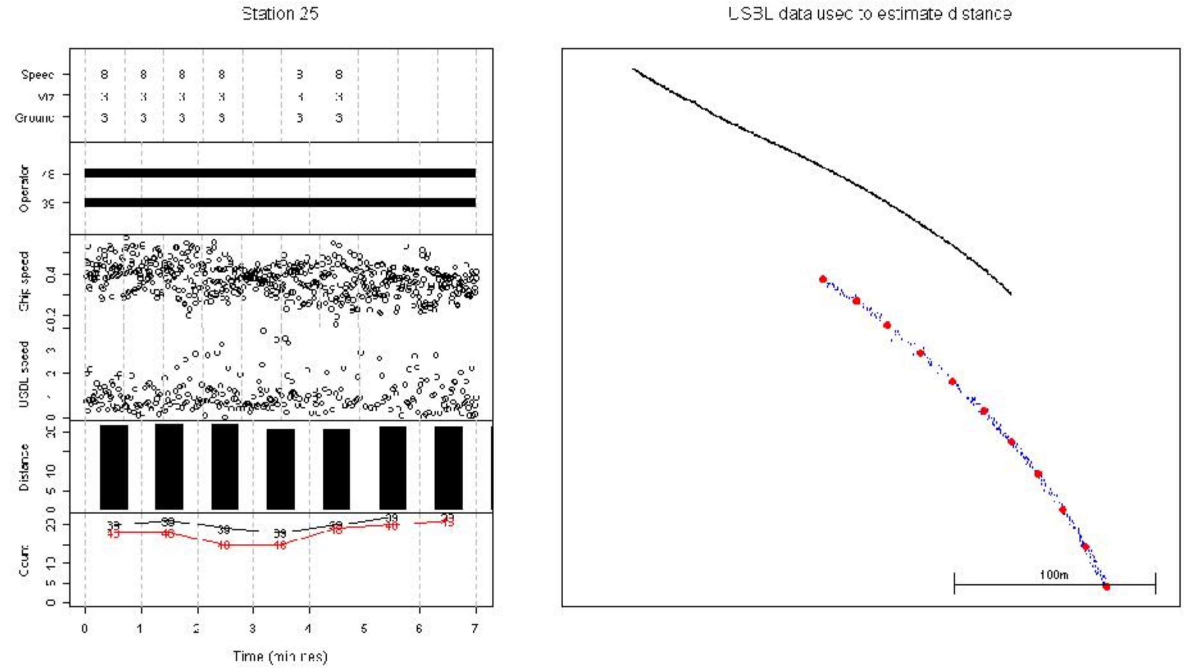

Figure 2: FU15 western Irish Sea grounds: r - tool quality control plot for station 25 of the 2012 survey – RV. Corystes leg.

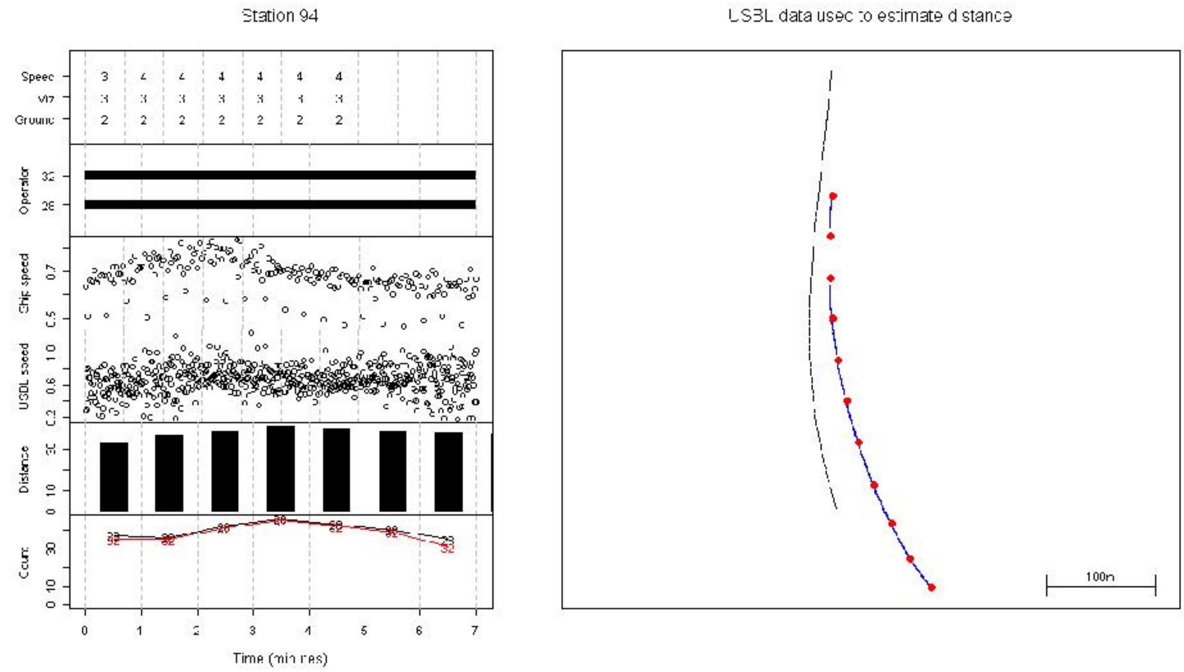

Figure 3 : FU15 western Irish Sea grounds: r - tool quality control plot for station 94 of the 2012 survey - RV. Celtic Voyager leg.

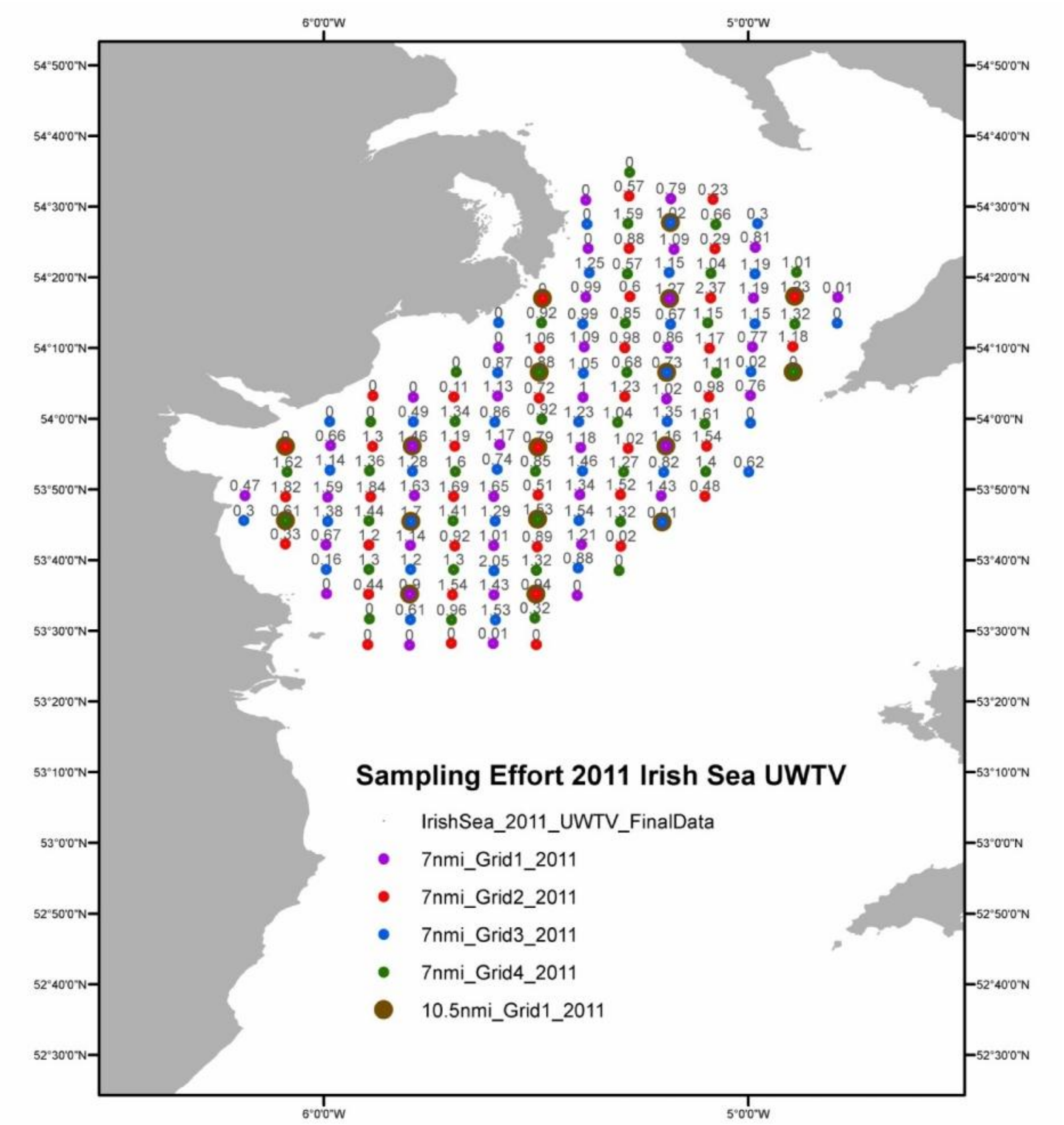

Figure 4: FU15 western Irish Sea grounds: Grid options for station spacing of 3.5, 7 and 10.5nmi and density data obtained in 2011

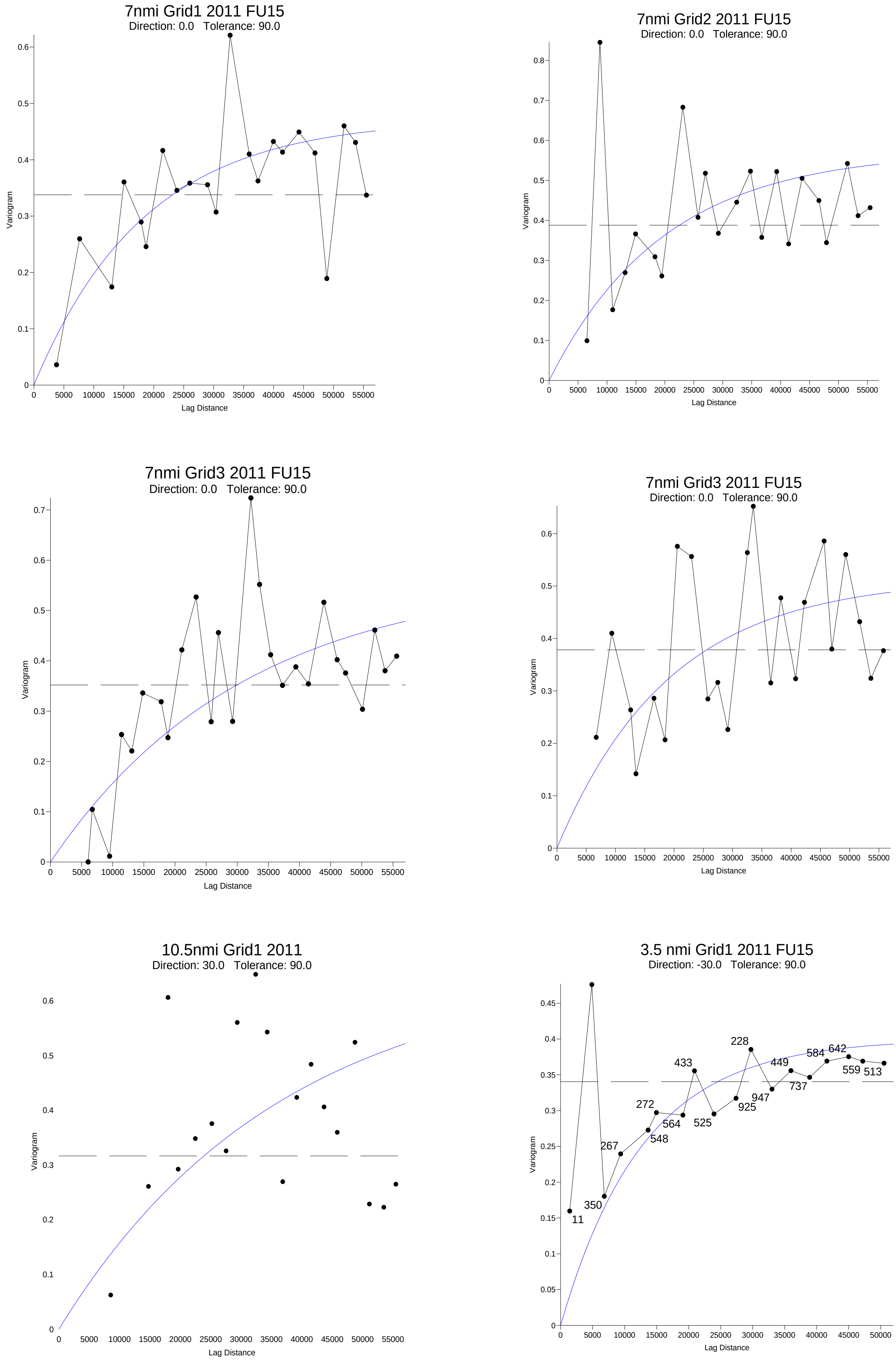

Figure 5: FU15 western Irish Sea grounds: Omnidirectional mean variograms of station spacing of 3.5, 7 and 10.5 nmi grids from the 2011 UWTV survey.

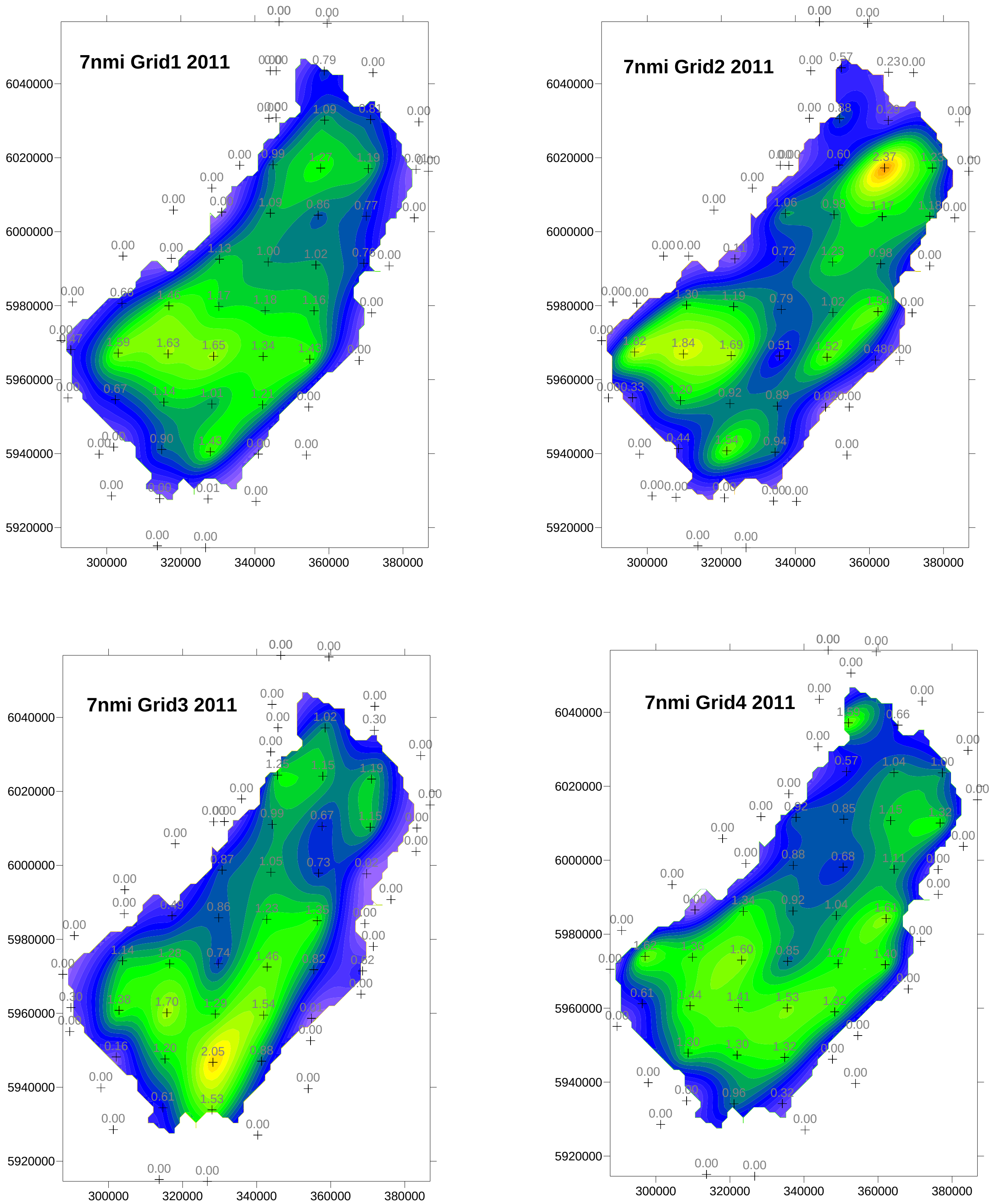

Figure 6 FU15 western Irish Sea grounds: Contour plots of the krigged density estimates 7.0 nmi grid options from the 2011 UWTV survey.

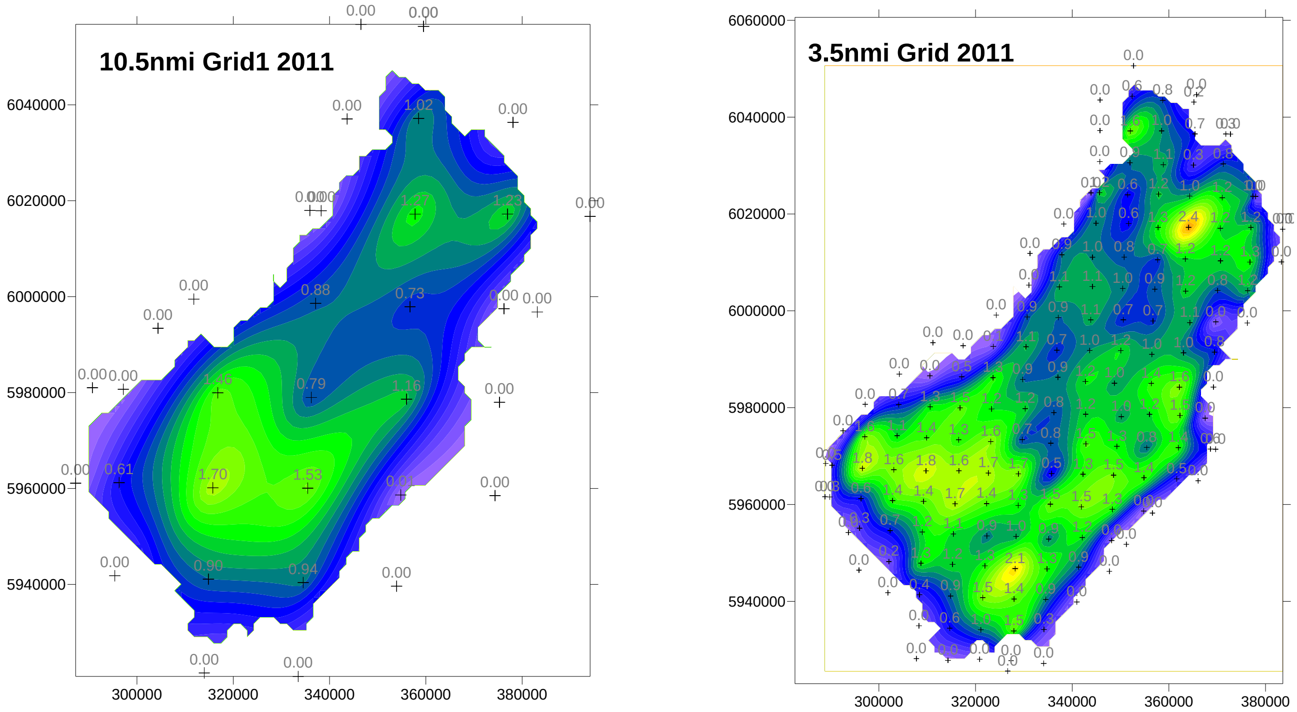

Figure 7 FU15 western Irish Sea grounds: Contour plots of the krigged density estimates 3.5 and 10.5 nmi grid options from the 2011 UWTV survey.

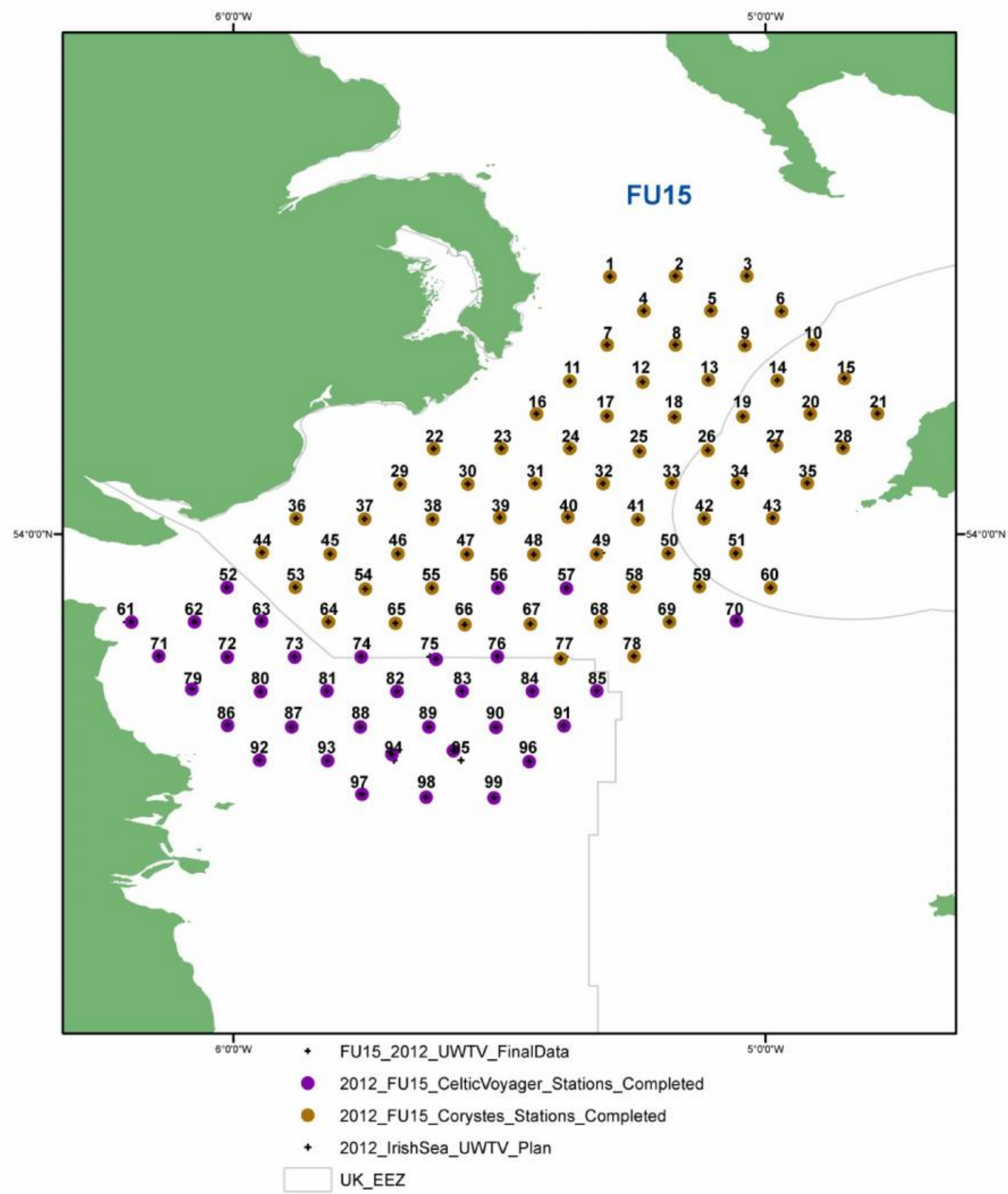

Figure 8: FU15 western Irish Sea grounds: Stations completed on the 2012 UWTV Survey.

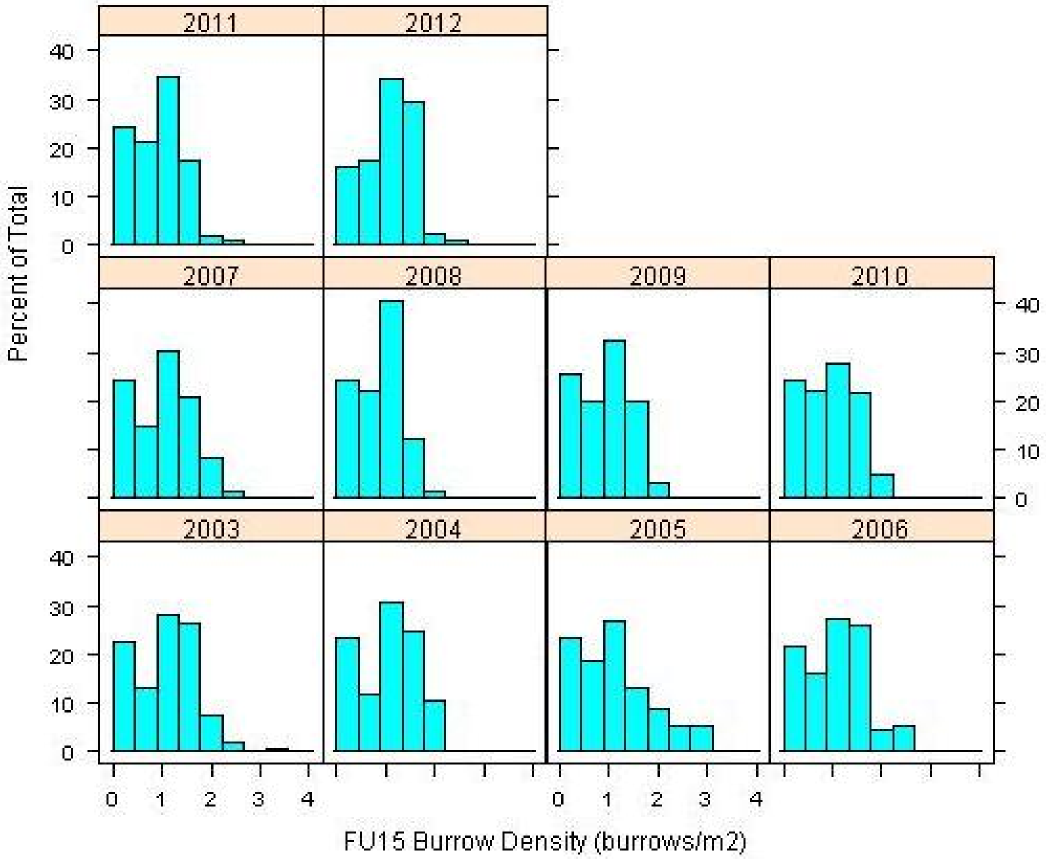

Figure 9: FU15 western Irish Sea grounds: Histogram of burrow density distributions by year from 2003-2012.

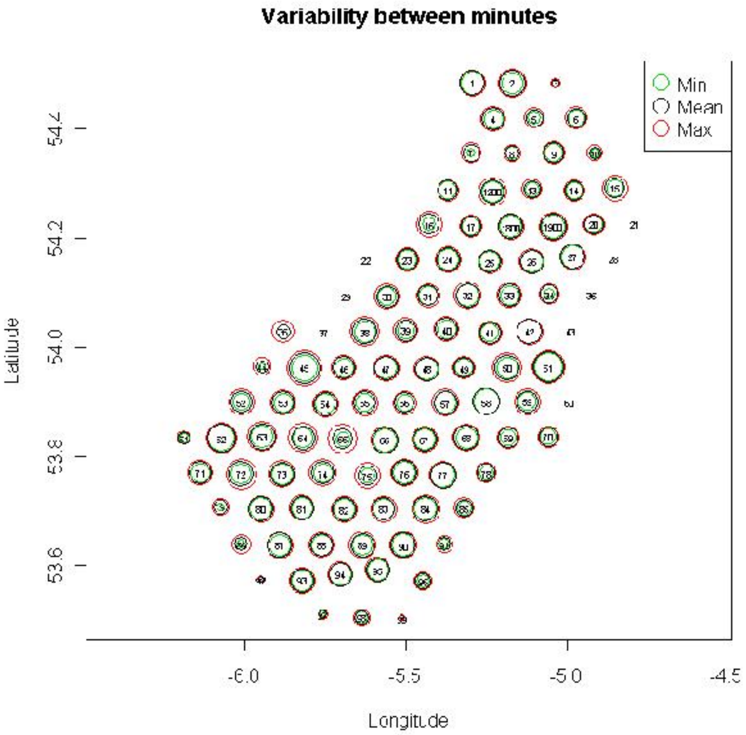

Figure 10: FU15 western Irish Sea grounds: Plot of the variability in density between minutes for each station in 2012.

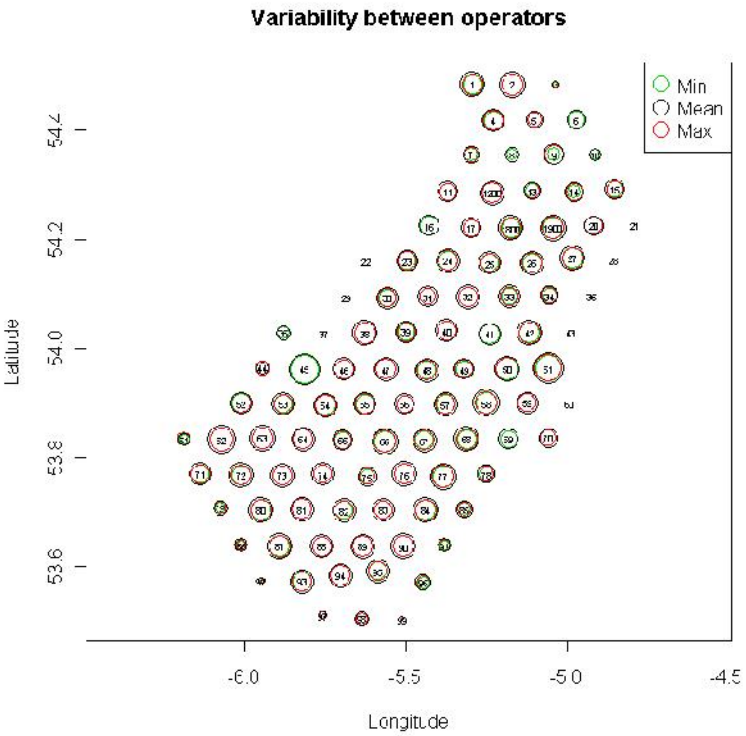

Figure 11: FU15 western Irish Sea grounds: Plot of the variability in density between operators (counters) for each station in 2012.

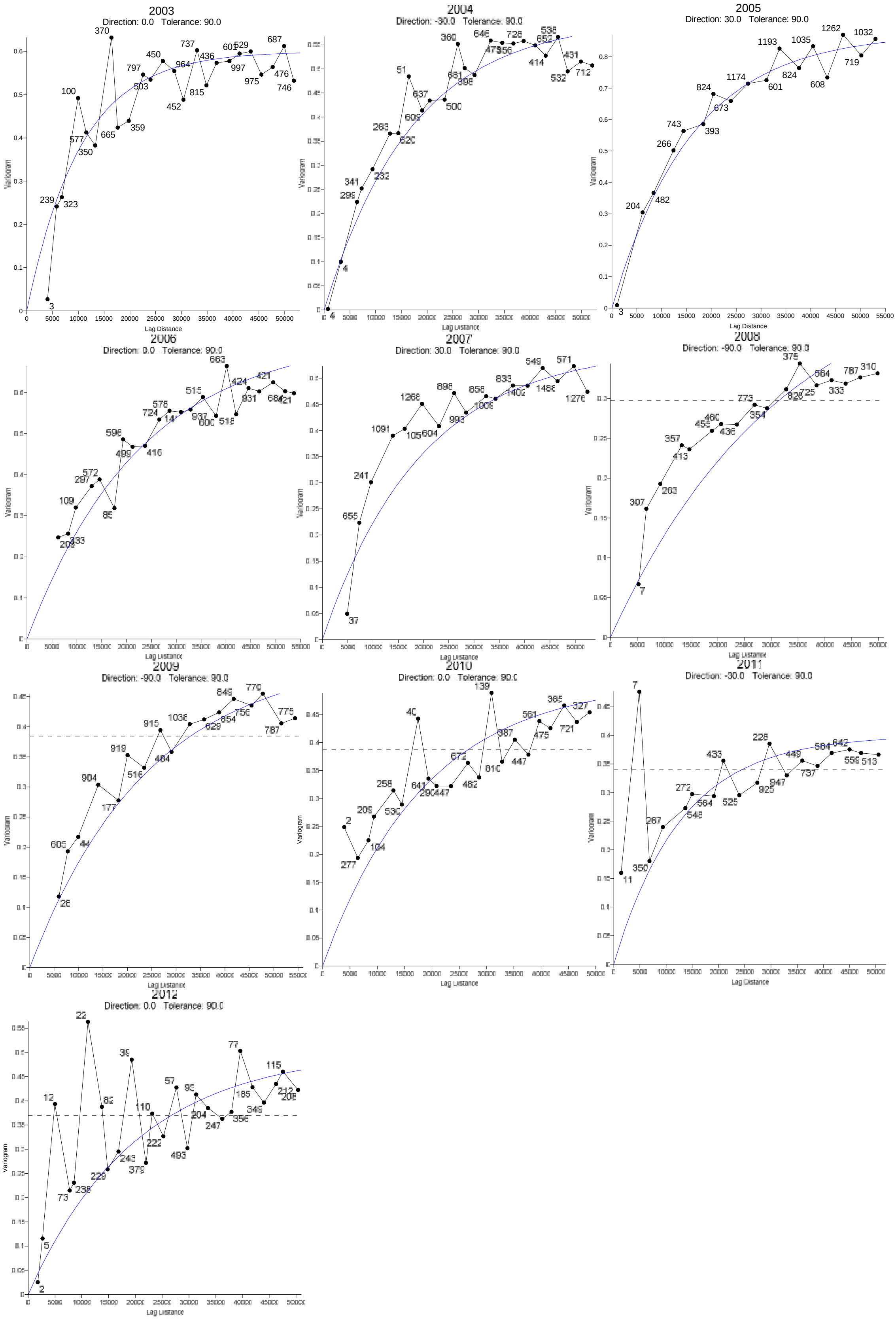

Figure 12 : FU15 western Irish Sea grounds: Omnidirectional mean variograms by year from 2003-2012.

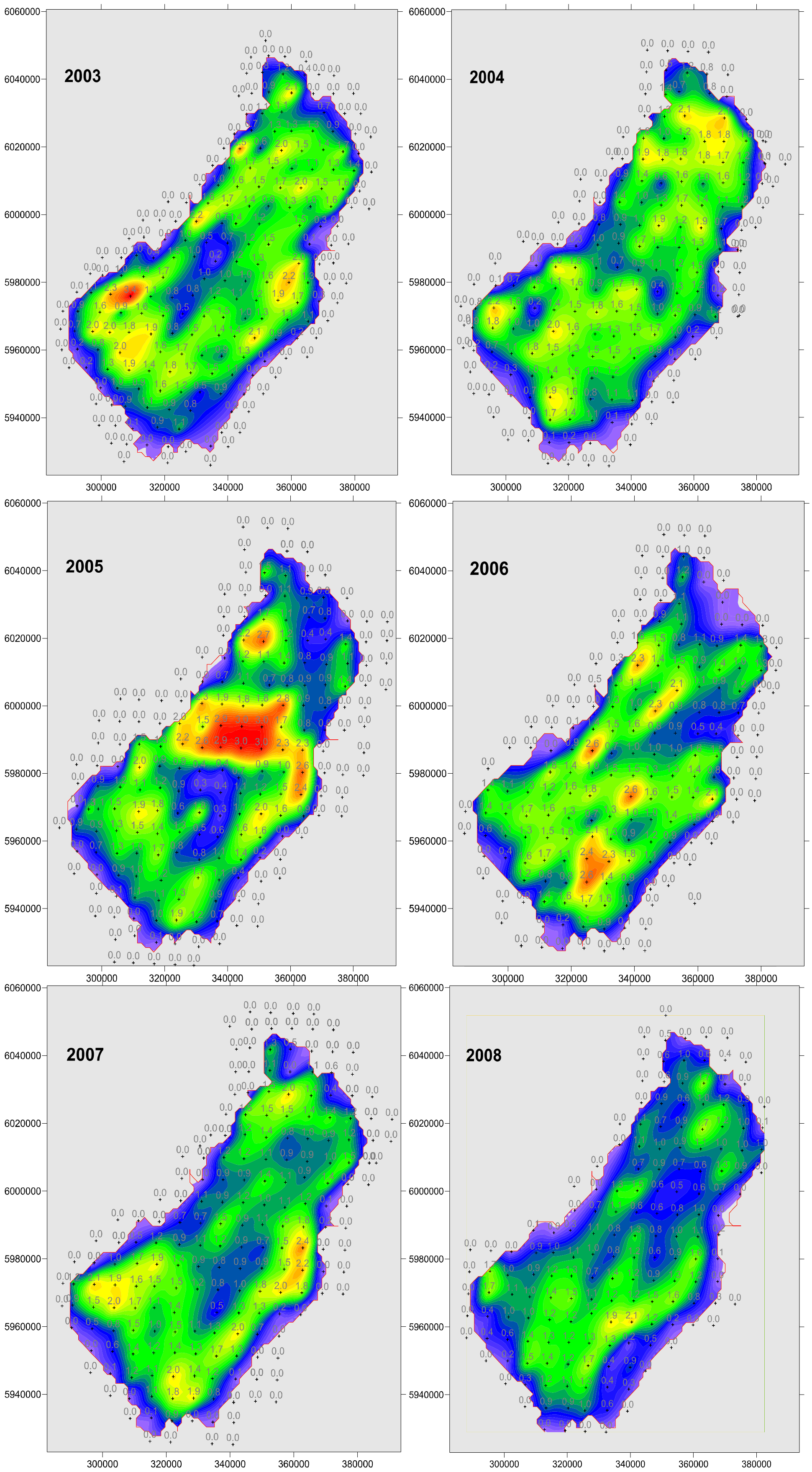

Figure 13: FU15 western Irish Sea grounds: Contour plots of the krigged density estimates by year from 2003 -2008.

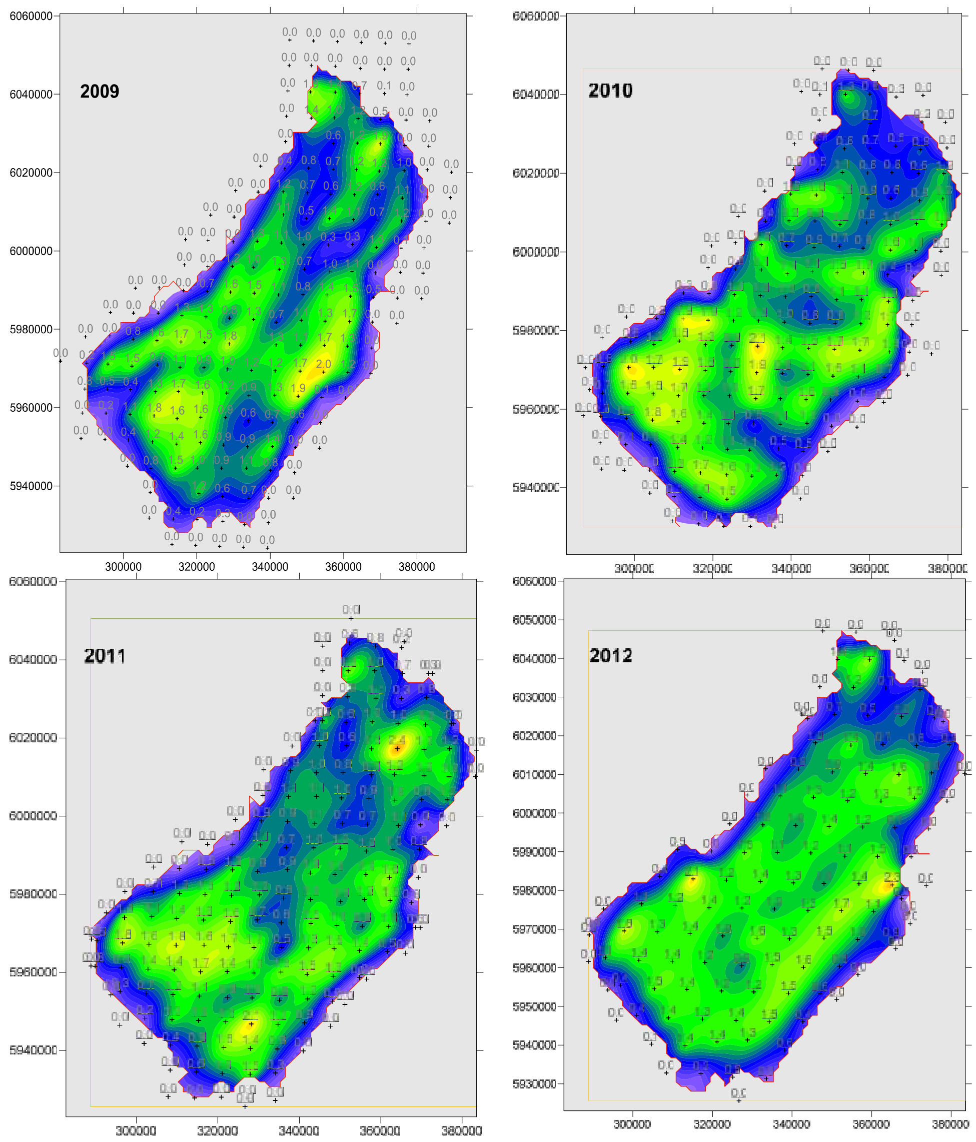

Figure 13: FU15 western Irish Sea grounds: Contour plots of the krigged density estimates by year from 2009 -2012.

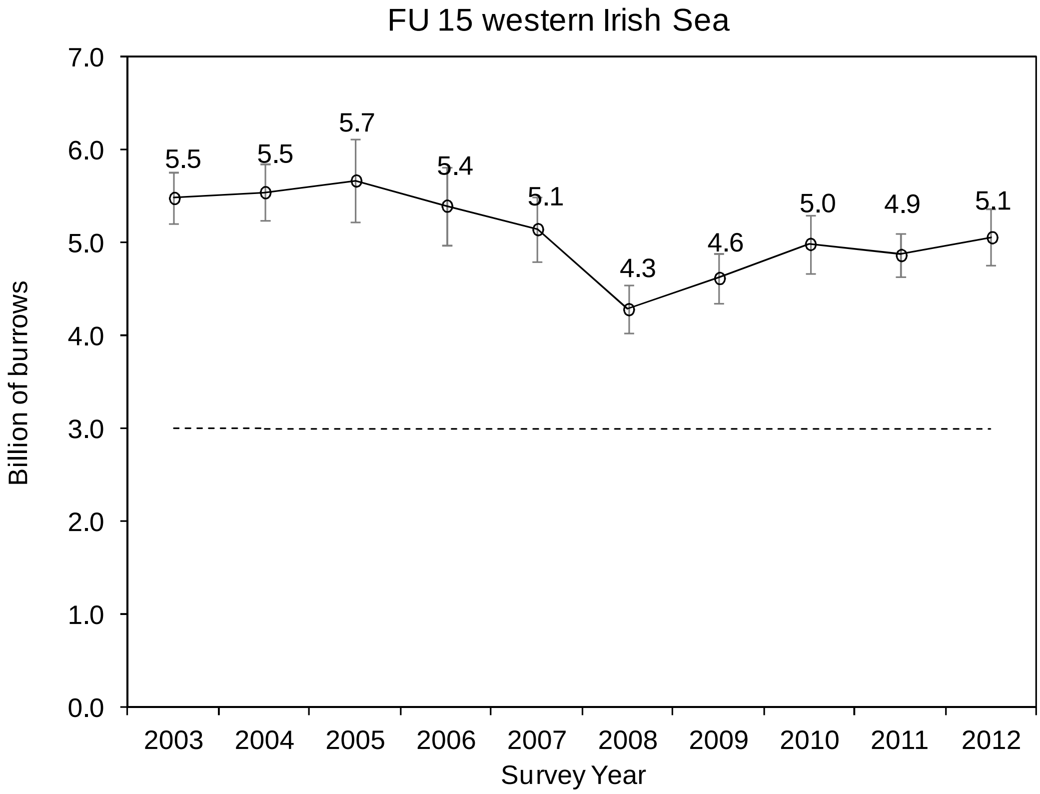

Figure 14: FU15 western Irish Sea grounds: Time series of geo-statistical adjusted abundance estimates (in billions of burrows) from 2003 -2012. Error bars correspond to the 95% confidence intervals. Dashed line is Btrigger of 3.0 billion burrows.

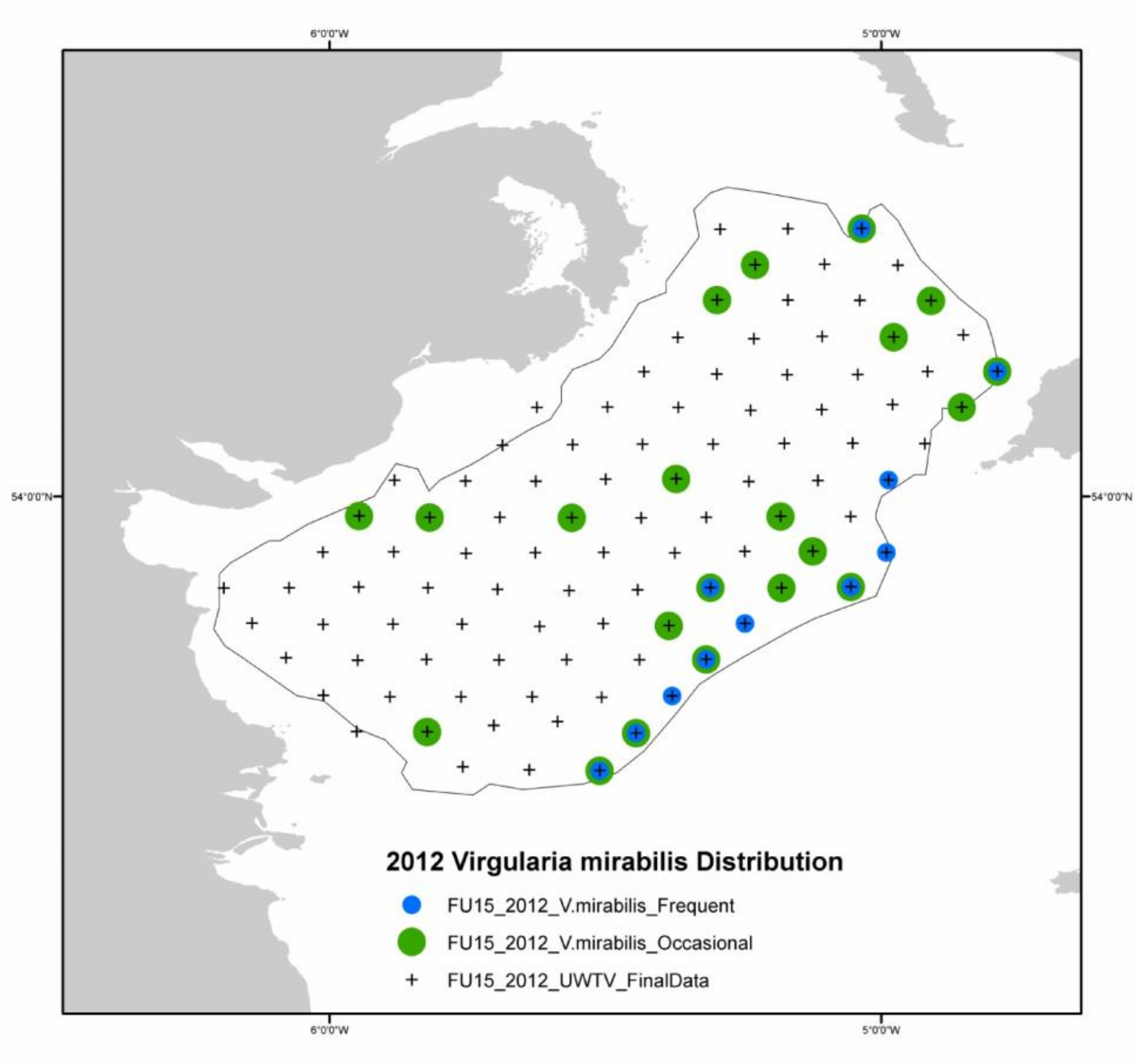

Figure 13: FU15 western Irish Sea grounds:Stations where *Virgilaria mirabilis* was identified during 2012.

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.

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

Table 3: FU15 western Irish Sea grounds: Overview of geostatistical results for the various 2011 grid options.

FU15	Year	Number of stations	Mean Density (burrows./m²)	Domain Area (km²)	Geostatistical abundance estimate (billion burrows)	CV on Burrow estimate
3.5 grid	2011	156	1.00	5289	5.6	2%
7.0 grid1	2011	39	0.94	5264	5.2	8%
7.0 grid2	2011	40	0.93	5264	5.2	9%
7.0 grid3	2011	39	0.93	5264	5.2	8%
7.0 grid4	2011	38	0.99	5260	5.5	7%
10.5grid1	2011	17	0.86	5287	4.8	15%

Table 4: FU15 western Irish Sea grounds: Overview of geostatistical results from 2003-2012.

FU 15	Year	Number of stations	Mean Density adjusted (burrows./m²)	Domain Area (km²)	Geostatistical abundance estimate adjusted (billion burrows)	CV on Burrow estimate
Western Irish Sea	2003	160	0.99	5295	5.5	3%
	2004	147	1.00	5310	5.5	3%
	2005	141	1.02	5281	5.7	4%
	2006	138	0.97	5194	5.4	4%
	2007	148	0.93	5285	5.1	3%
	2008	141	0.77	5287	4.3	3%
	2009	142	0.83	5267	4.6	3%
	2010	149	0.90	5307	5.0	3%
	2011	156	0.88	5289	4.9	2%
	*2012	99	0.91	5291	5.1	3%

*reduced isometric grid