Western Irish Sea *Nephrops* Grounds (FU15) 2013 UWTV Survey Report and catch options for 2014

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Abstract

This report provides the main results and findings of the eleventh annual underwater television survey on the ‘Irish sea west *Nephrops* grounds’ ICES assessment area, Functional Unit 15. The survey was multi-disciplinary in nature collecting UWTV and other ecosystem data. The 2013 design consisted of a randomised isometric grid of 80 stations at 5 nautical mile intervals out over the full known extent the stock. The resulting krigged burrow abundance estimate was 4.3 billion burrows. This was a 16% decrease relative to 2012. The spatial distribution shows higher abundance in the south of the area and a larger decline in abundance is apparent in the North. Overall densities remain high and abundance remains relatively stable, well above MSY $B_{trigger}$. Reducing the number of stations in 2013 is not expected to have significantly affected the accuracy of the survey estimate. The CV (or relative standard error) of 3% is in line with previous estimates and 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 9,914 tonnes which results in landings of no more than 8,244 tonnes. The only sea-pen species observed in 2013 was *Virgularia mirabilis* and the frequency of occurrence was lower than in 2012. Trawl marks were noted at 43% of the UWTV stations,

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

Suggested citation:
Doyle J., Lordan C., Ligas A., Brown V., Leocadio A., McCausland I., McCorriston P., Service M., Stewart P., and Schön P.-J. 2013. Western Irish Sea *Nephrops* Grounds (FU15) 2013 UWTV Survey Report and catch options for 2014. Marine Institute and AFBI UWTV Survey report.

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 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 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 eleventh in a time series of UWTV surveys in the western Irish Sea carried out jointly by the Agri-Food and Biosciences Institute (AFBI), Northern Ireland, and 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 ~80 UWTV with 5.0 nautical mile (Nmi) spacing stations on the western Irish Sea *Nephrops* ground (FU15).
2. To obtain 2013 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. Technology, staff and protocol transfer between Marine Institute and AFBI.

This report details the final UWTV results of the 2013 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 (including FU16, FU19 and FU20-21).

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), British Geological Survey (BGS), and other sediment maps and previously collected UWTV data. The same ground boundaries have been used throughout the time series.

The survey took place on RV Corystes between 11th and 18th August 2013. The survey covered the western Irish Sea (FU15) grid and the eastern Irish Sea (FU14). The results for FU14 will be presented in a separate report. Survey timing for FU15 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 USBL transponder onboard RV Corystes) were recorded every 1 to 2 seconds. The navigational data were quality controlled using an "R" script developed by the Marine Institute (ICES, 2009b). In 2013 the USBL navigational data were used to calculate distance over ground for 65% of stations whereas ship data were used for the remaining 35% of stations (due to a technical malfunction of the USBL system in the latter part of the survey).

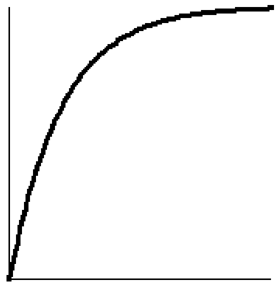
No sediment sampling was carried out in 2013 as the Irish Sea is well sampled through various research programmes and good sediment maps exist for this area.

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 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 and recorded by each scientist for each one-minute interval. Following the recommendation of SGNEPS 7 minutes of recount should be carried out for each station (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 on 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), the duration was also recorded 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 (examples are given with and without USBL data in Figures 2 and 3). Consistency and bias between individual counters were 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. 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. 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 lasers with the sledge 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 would result in an underestimate of density 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 10.7.972. The spatial structure of the density data were 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 additional stations, with assumed zero density outside the known distribution of *Nephrops* or suitable sediment, in the krigging process. An un-weighed and un-smoothed omni-directional variogram was constructed with a lag width of approximately 1417m and maximum lag distance of 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

The station positions are shown in Figure 4. A histogram of the observed burrow densities from 2003 to 2013 on the western Irish Sea is presented in Figure 5. Over the time series available the density estimates observed are very similar with modal density of around 1 burrow/m^2. Figure 6 and Figure 7 show the variability in density between minutes and operators (counters) for each station, respectively. 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. Also recent trawling activity sometimes impacts on the between minute variability.

A comparison between USBL and Ship derived distance over ground (DOG) for the 65% of stations where both were available was carried out to assess whether a bias or increased uncertainty was introduced for the 35% of stations without USBL data. There is no bias with the average ratio (ship/usbl) = 0.9957. However there is some variability around this average with the majority (91%) of ship DOG estimates +/5% of the USBL estimate. The impact will be slightly increased uncertainty in the individual density estimates. Since these are krigged later in the process it is unlikely to significantly impact on the overall survey estimate or its uncertainty.

The geo-statistical structural analysis is shown in the form of variograms in Figure 8. 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 Figures 9 and 10. 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 spatial pattern of burrow density in 2013 was also quite different from the pattern observed in previous years. The high density areas observed in the north-eastern part of FU15 in the past have almost disappeared; only the south-western area of the FU15 seems to maintain a rather high density similar to that observed in the past. As a matter of fact, the total burrow density was generally lower (~ -16%) over the whole ground than that observed in 2012.

The summary statistics from this geo-statistical analysis are given in Table 3 and plotted in Figure 11. The 2013 final abundance estimate adjusted of 4.3 billion burrows is very close to that estimated in 2008, which was the lowest observed estimate in the time series. The overall burrow abundance trend is fairly stable although the abundance did decline between 2007 and 2008. The CV for 2013 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 12. All sea-pens were identified from the video footage as *Virgularia mirabilis*. The frequency of identification of *V. mirabilis* on the footage was significantly lower than in

2012. Trawl marks were noted at 43% of the stations surveyed and persistent trawl marks for the entire video transect occurred in 6% of 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. The burrow densities typically observed in FU15 are amongst the highest observed of all *Nephrops* stocks but the mean sizes of individuals in the catches are relatively small. It appears that growth is suppressed due to competition and/or recruitment effects (Johnson, et. al, 2012). Despite the smaller size of individuals the fishery 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 is 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. The survey information up to 2012 was used as the main basis for the ICES assessment of status and exploitation rare up to 2012. ICES concluded that this stock abundance is stable and is above MSY $B_{trigger}$ (ICES, 2013). The 2013 burrow abundance estimate is significantly lower than 2012 (-16%); a similar scale reduction in abundance was observed in 2008 from which the abundance increased again in 2009. The 2013 abundance estimate remains well above the MSY $B_{trigger}$ (biomass trigger) proposed by ICES of 3.0 billion burrows which was derived from a longer time series of trawl survey data. All other stock status indicators suggest that the stock remains at a stable healthy condition (ICES, 2013). Table 4 is an updated management option table giving total catch and landings options at various levels of fishing mortality for 2014. Using the 2013 estimate of abundance would imply a total catch option at F_{msy} ($=F_{max}$) of 9,914 tonnes which results in landings of no more than 8,244 tonnes.

SGNEPS 2012 recommended a review of survey sampling intensity (ICES, 2012b). Following a review (Doyle et al., 2013) the grid design was changed from a 3.5 nautical mile square grid prior to 2012 to 4.5 nautical mile isometric grid in 2012. In 2013 the grid spacing was increased further to 5.0 nautical mile isometric grid. The main motivation to do this was to achieve full spatial coverage of FU15 whilst giving the option to reallocate ship time to increase coverage in other Functional Units (FU16, FU20-21 and FU19); also in line with SGNEPS recommendations (ICES, 2012b). Reducing the number of stations is not expected to have significantly affected the accuracy of the survey estimate given the apparent spatial autocorrelation in density across the area. Increasing the station spacing to 7 nautical miles did not affect the accuracy of the result in the removal analysis carried out by Doyle et al. (2013). The precision do not appear to have been significantly reduced either with as CV of 3% which was in line with previous estimates well below the SGNEPS 2012 recommendation of 20%.

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 macandreae* (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 2013 counters was generally very high with Linn's CCC scores >0.5 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 can 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 third year that a systematic quantification and identification of sea-pens to species level was undertaken. Only *Virgularia mirabilis* was positively identified on the 2013 footage although *Pennatula phosphorea* has been observed in previous years.

The main objectives of the survey were successfully met for the eleventh successive year. The UWTV coverage and footage quality were generally good 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 Captain and crew of RV Corystes for their good will and professionalism during the survey. Also thanks to William Clarke and Matthew Service, AFBI, who provided technical expertise in system set-up onboard RV Corystes. Finally, thanks to the AFBI, Marine Institute, and CEFAS staff onboard for their hard work and enthusiasm in making this survey a success.

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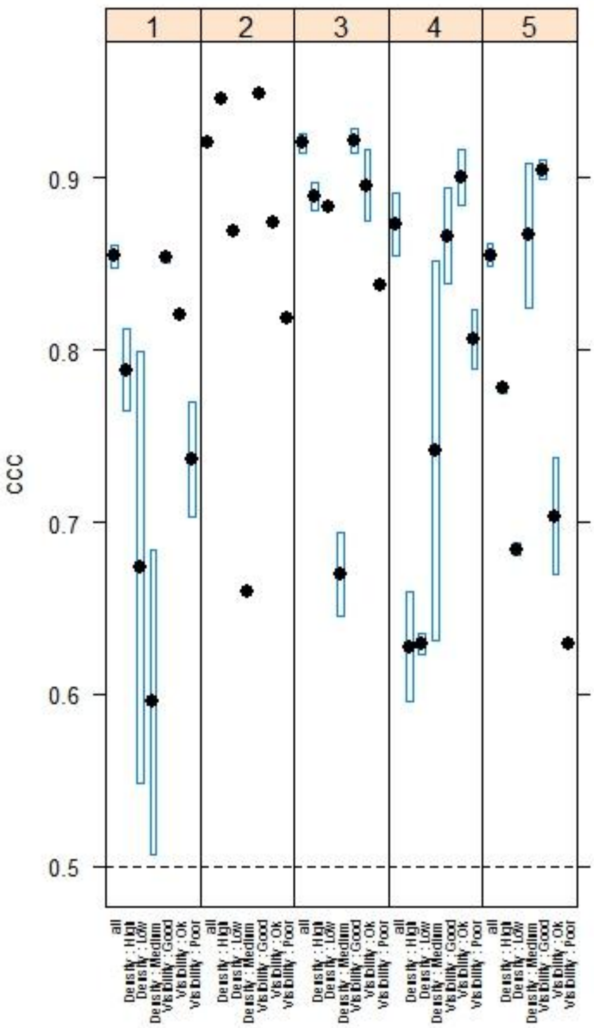

Figure 1: FU15 western Irish Sea grounds: 2013 count performance against the reference counts as measured by Linn’s CCC for FU15 reference set. Each panel represents an individual. The x-axis (from left to right) shows all stations pooled, high density, low density, medium density and visibility good.

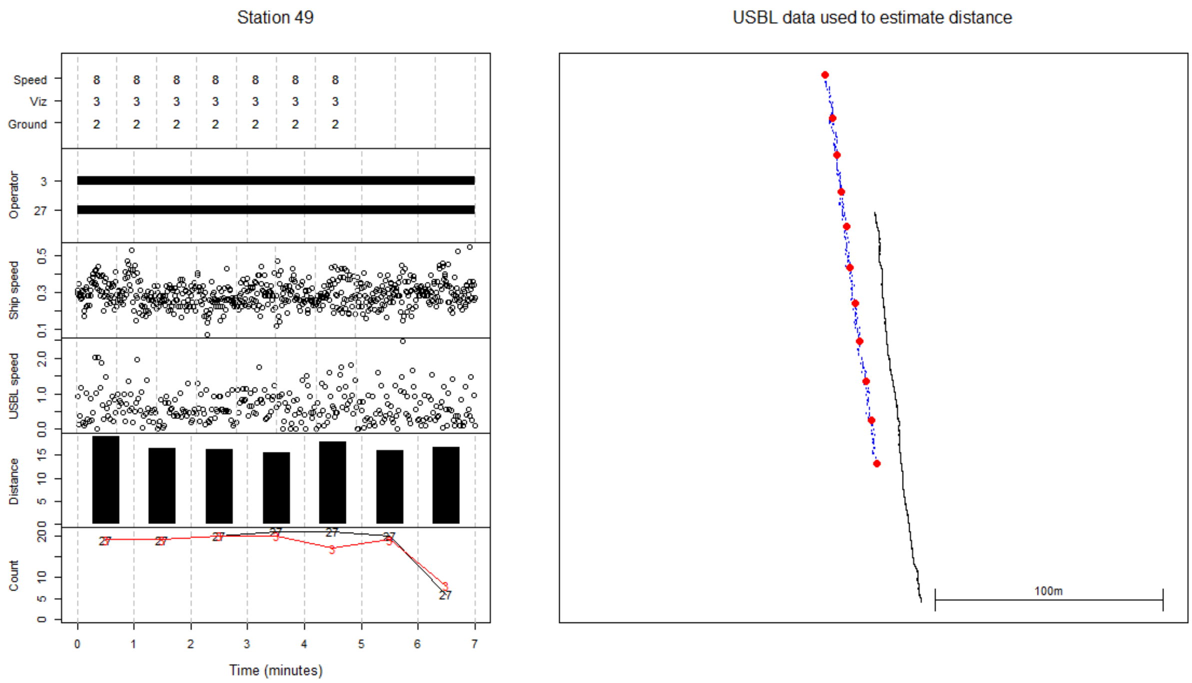

Figure 2: FU15 western Irish Sea grounds: R - tool quality control plot for station 49 of the 2013 survey.

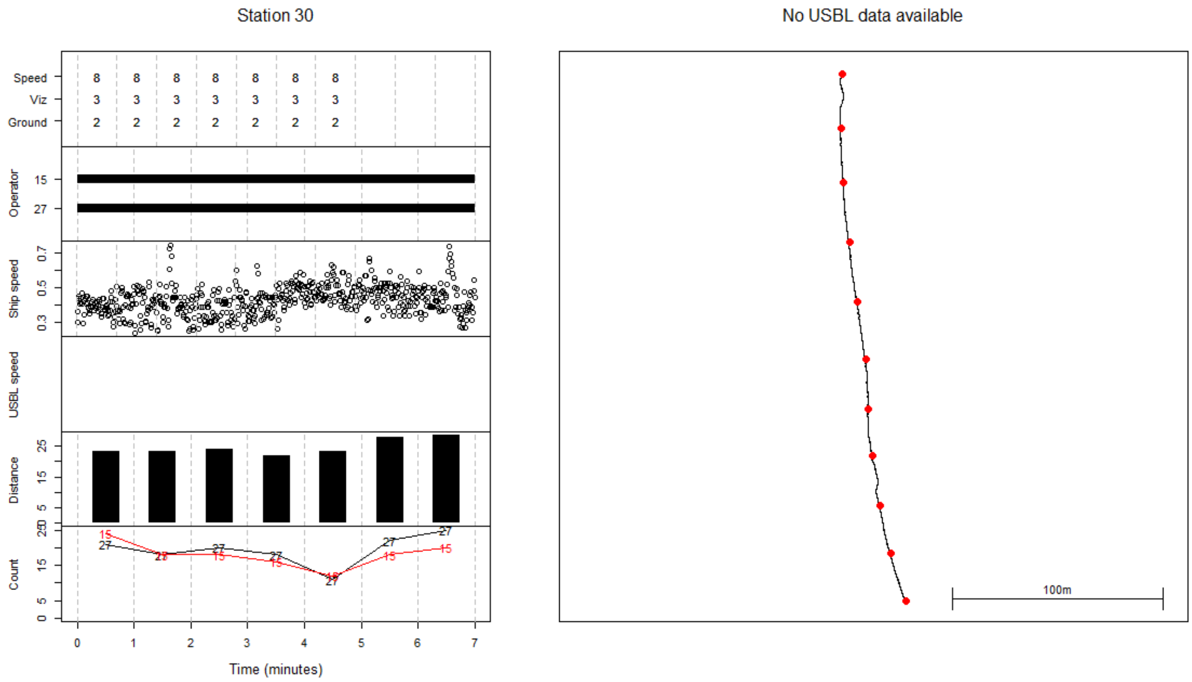

Figure 3: FU15 western Irish Sea grounds: R - tool quality control plot for station 30 (no USBL data available) of the 2013 survey.

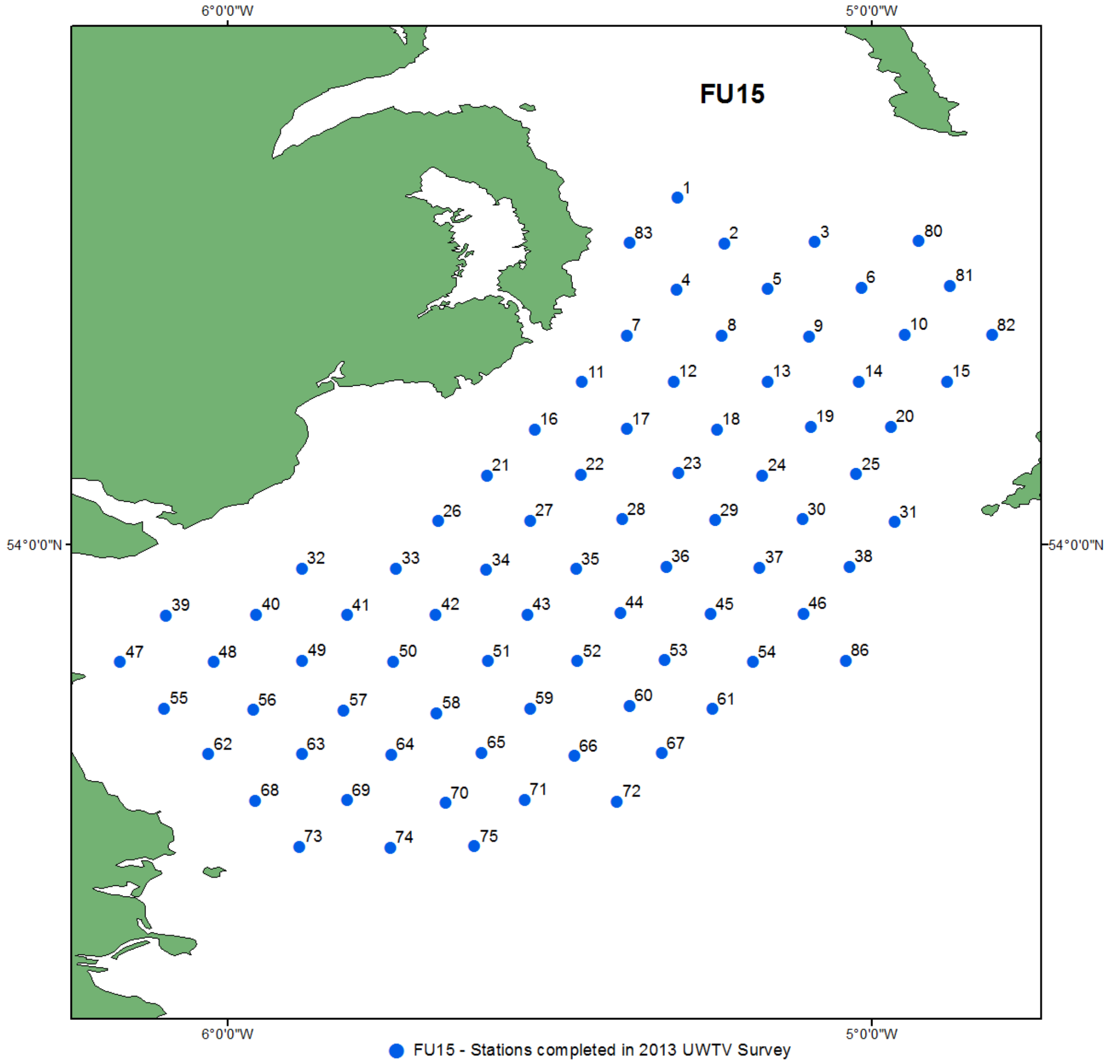

Figure 4: FU15 western Irish Sea grounds: Stations completed on the 2013 UWTV Survey.

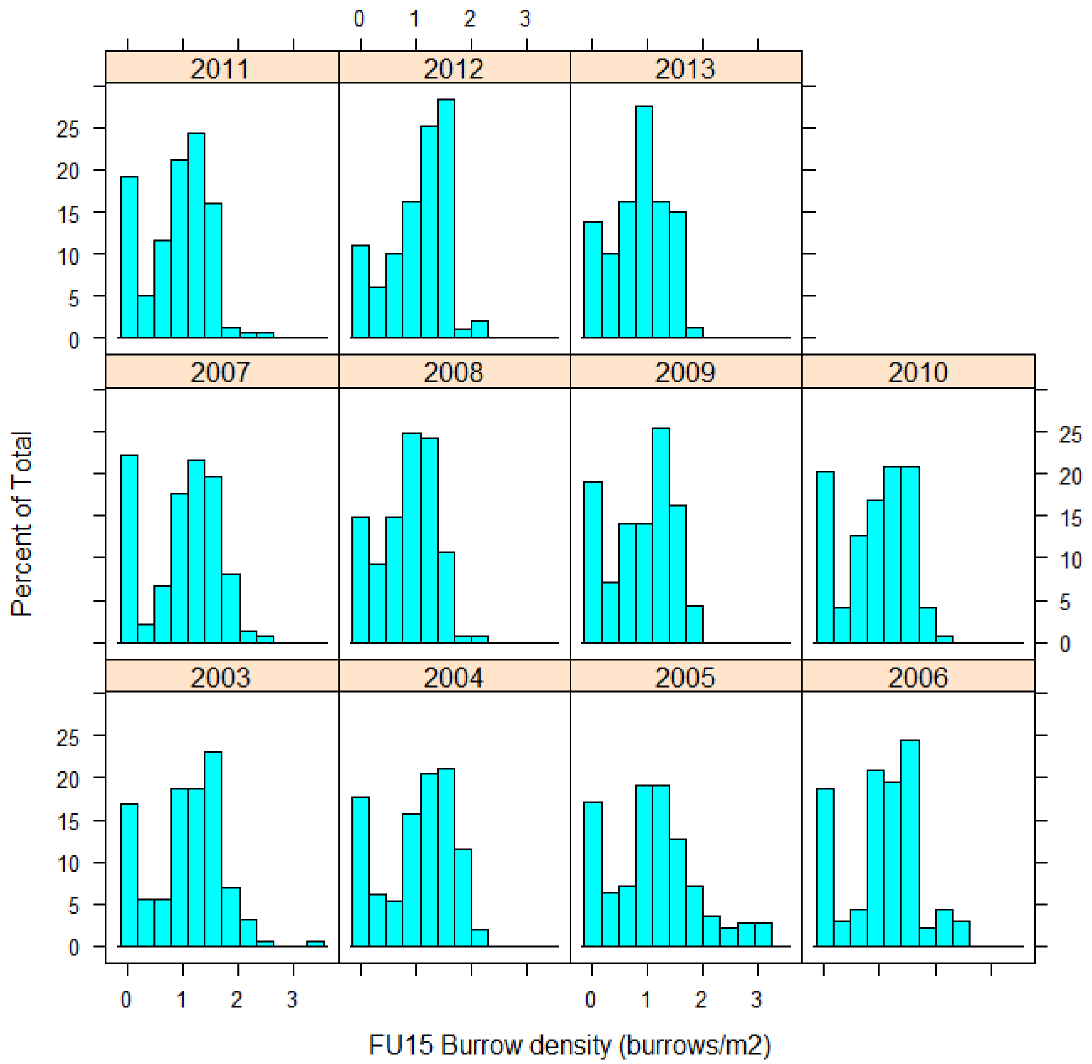

Figure 5: FU15 western Irish Sea grounds: Histogram of burrow density distributions by year from 2003-2013.

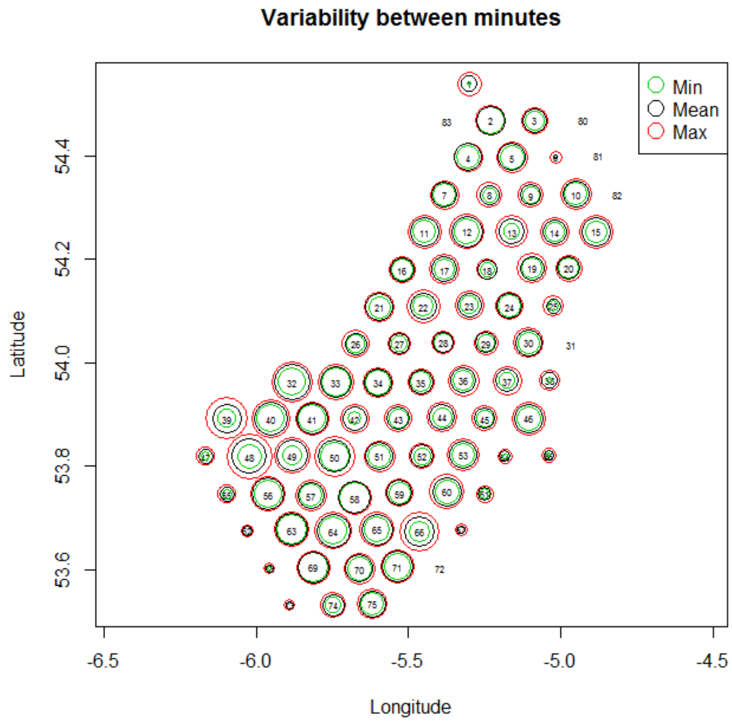

Figure 6: FU15 western Irish Sea grounds: Plot of the variability in density between minutes for each station in 2013.

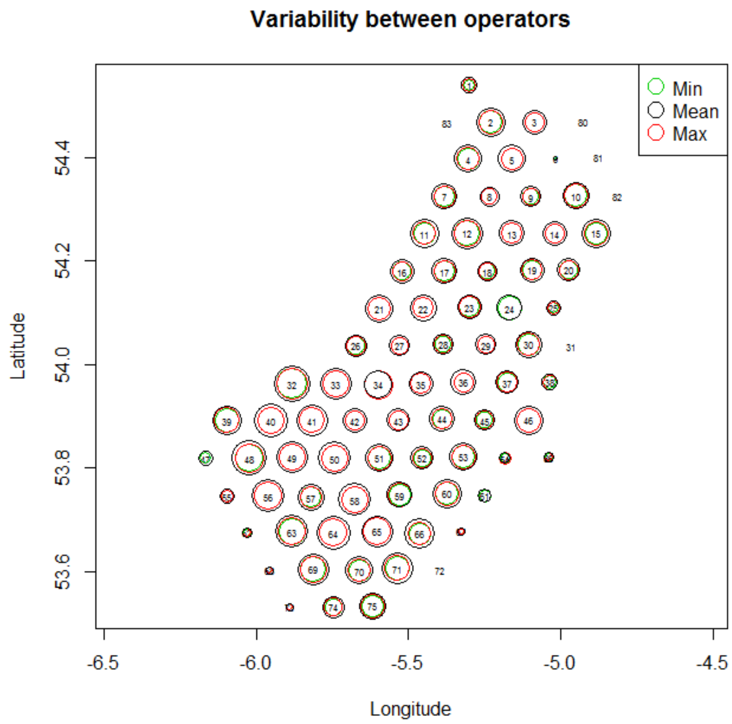

Figure 7: FU15 western Irish Sea grounds: Plot of the variability in density between operators (counters) for each station in 2013.

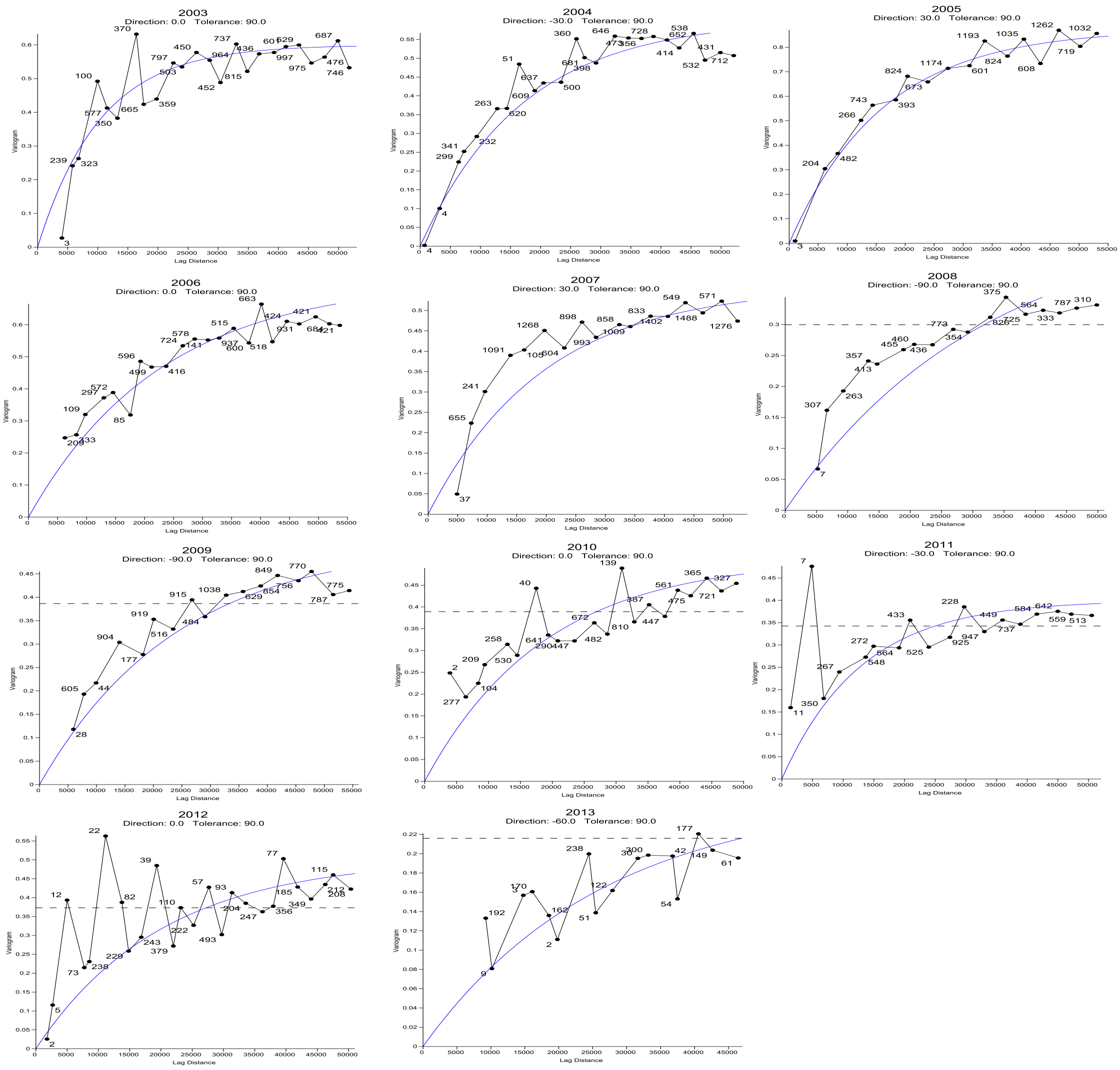

Figure 8: FU15 western Irish Sea grounds: Omnidirectional mean variograms by year from 2003-2013.

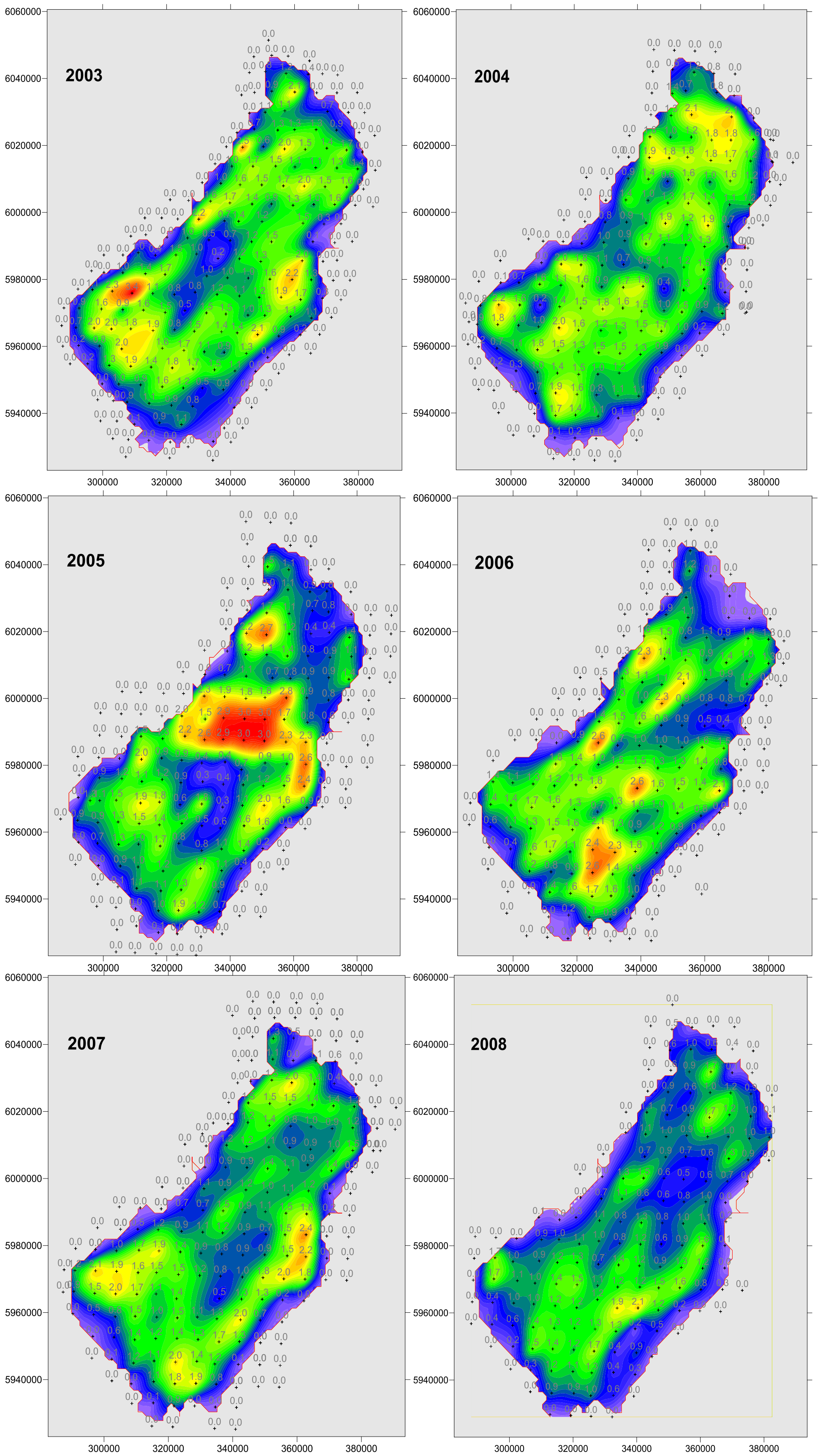

Figure 9: FU15 western Irish Sea grounds: Contour plots of the krigged density estimates by year from 2003 -2008.

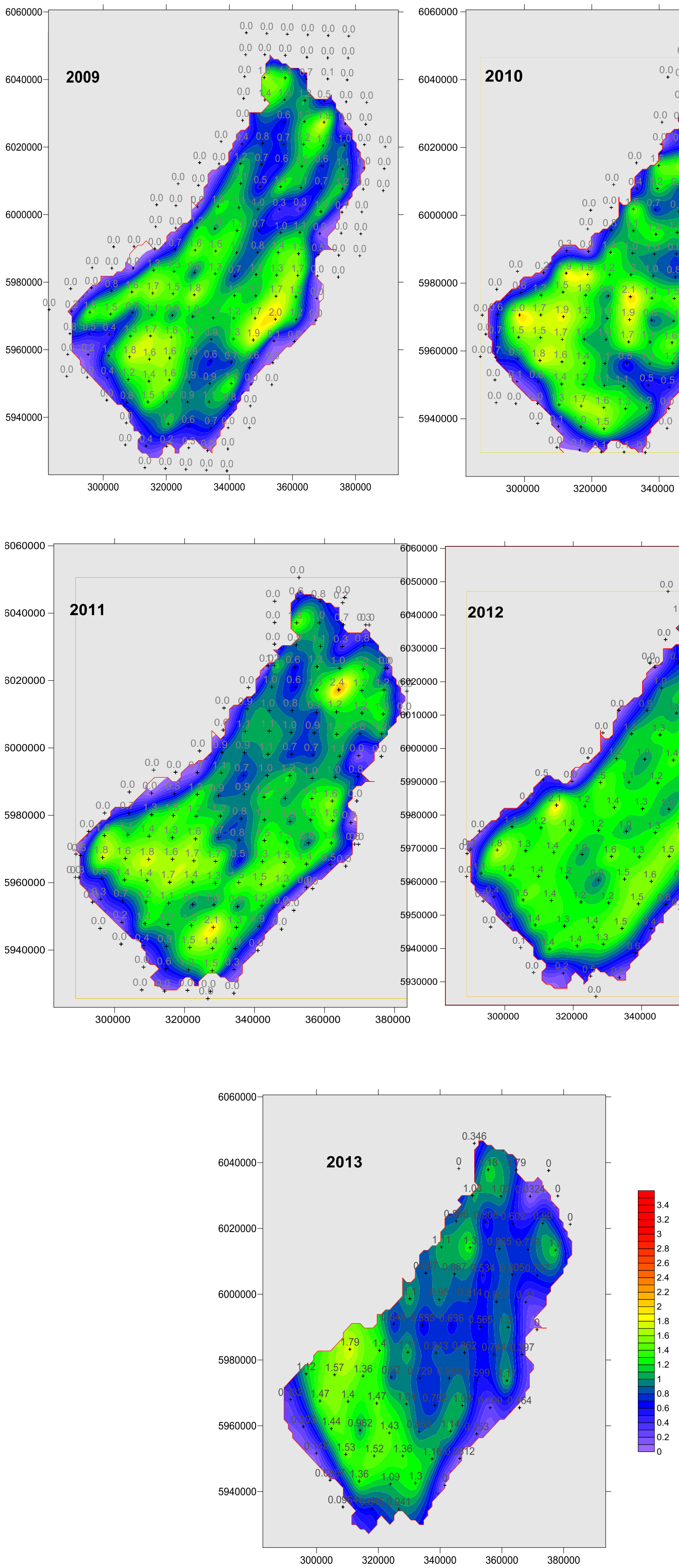

Figure 10: FU15 western Irish Sea grounds: Contour plots of the krigged density estimates by year from 2009 -2013.

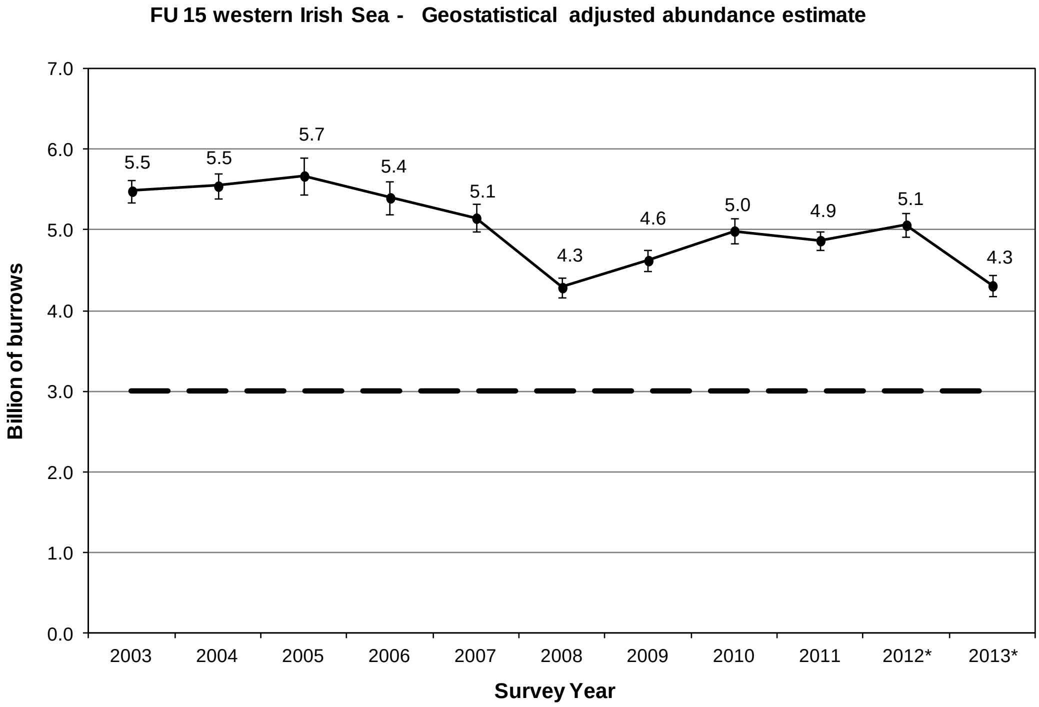

Figure 11: FU15 western Irish Sea grounds: Time series of geo-statistical adjusted abundance estimates (in billions of burrows) from 2003 -2013. Error bars correspond to the 95% confidence intervals. Dashed line is $B_{trigger}$ of 3.0 billion burrows.

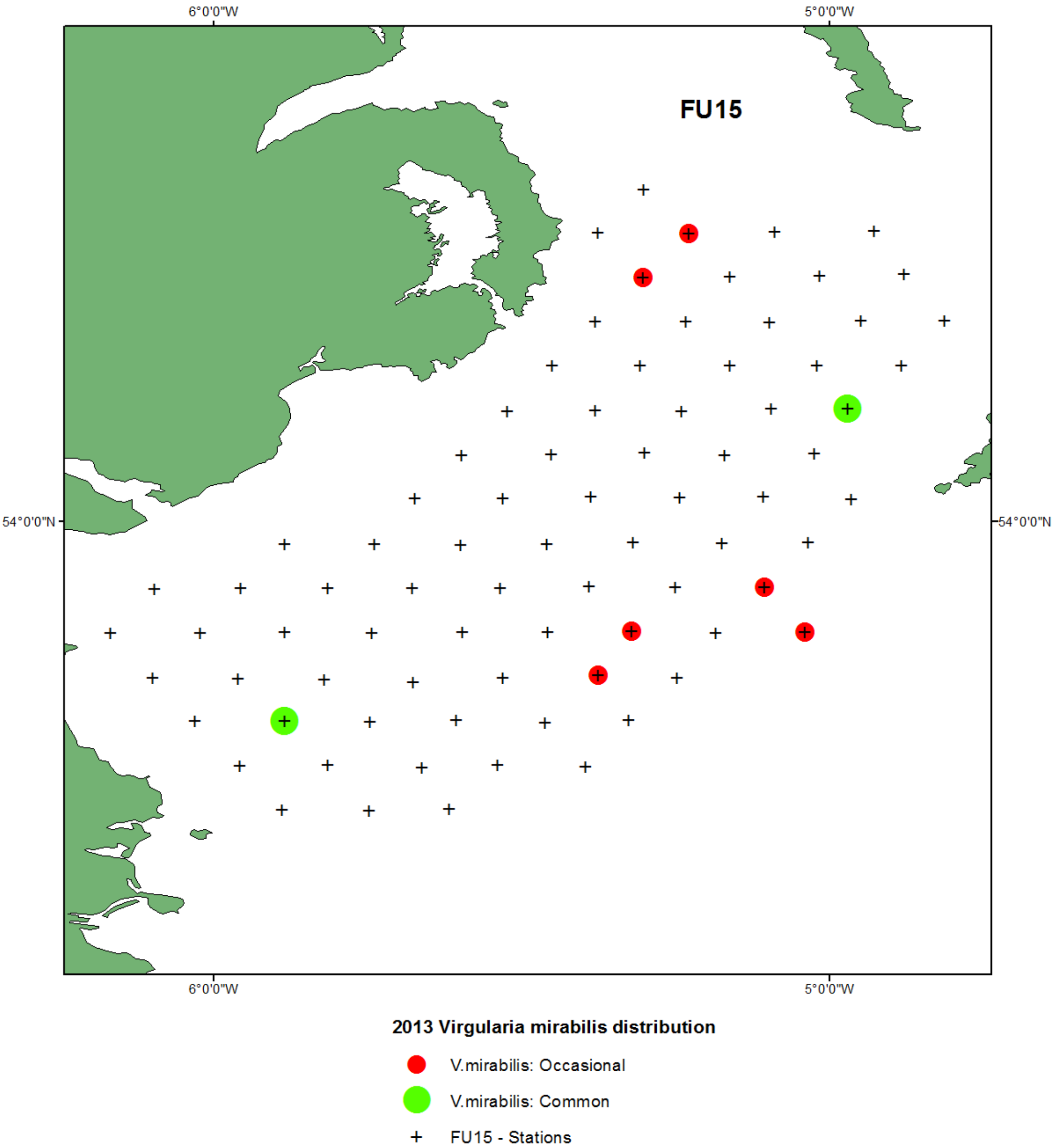

Figure 12: FU15 western Irish Sea grounds: Stations where *Virgularia mirabilis* was identified during 2013.

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 geo-statistical results from 2003-2013.

FU 15	Year	Number of stations	Mean Density adjusted (burrows./m²)	Domain Area (km²)	Geo-statistical 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%
	*2013	80	0.78	5278	4.3	3%

*reduced isometric grid

Table 4: FU15 western Irish Sea grounds: Short-term forecast management option table giving catch options for 2014 using the 2013 UWTV survey estimate.

Basis	Total catches*	Landings	Dead discards**	Surviving discards**	Harvest rate
	L+DD+SD	L	DD	SD	for L+DD
F_{MSY} proxy	9914	8244	1504	167	17.1%
F_{2013}	11486	9551	1742	194	19.8%
$F_{0.1}$	6144	5109	932	104	10.6%
$F_{35\%SPR}$	7764	6456	1178	131	13.4%

Weights in tonnes.
* Total catches are the landings plus dead and surviving discards.
** Total discard rate is assumed to be 27.9% of the catches (in number, average of the last three years, 2010–2012); discard survival is assumed to be 10%.