Celtic Sea *Nephrops* Grounds 2011 UWTV Survey Report

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Introduction

The prawn (*Nephrops norvegicus*) are common in the Celtic Sea occurring in geographically distinct sandy/muddy areas were the sediment is suitable for them to construct their burrows (Figure 1). The Celtic Sea area (Functional Units 19-22) supports a large multi-national targeted *Nephrops* fishery mainly using otter trawls and yielding landings in the region of ~6,000 t annually over the last decade (ICES, 2011). *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, 2009 & 2011).

This is the sixth in a time series of UWTV surveys in the Celtic Sea carried out by the Marine Institute, Ireland. The 2011 survey was multi disciplinary in nature; the specific objectives are listed below:

1. To complete randomised fixed survey grid of ~100 UWTV with 3 nautical mile (Nmi) spacing stations on the "Smalls" *Nephrops* ground (FU22).
2. To carry out ~20 UWTV indicator stations in the wider Celtic Sea if time allows.
3. To obtain 2011 quality assured estimates of *Nephrops* burrow distribution and abundance on the "Smalls" *Nephrops* ground (FU22). These will be compared with those collected previously.
4. To collect ancillary information from the UWTV footage collected at each station such as the occurrence of sea-pens, other macro benthos and fish species and trawl marks on the sea bed.
5. To collect oceanographic data using a sledge mounted CTD.
6. To collect sediment samples.
7. To sample *Nephrops* and macro benthos using a 4 m beam trawl deployed at ~10 stations.

This report details the final UWTV results of the 2011 survey and also documents other data collected during the survey.

Material and methods

The survey design for the main area the Smalls *Nephrops* ground FU22 is a randomised fixed grid where a point is picked at random and stations are carried out 3 nautical miles north-south and east-west. 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 sediment maps and previously collected UWTV data. An adaptive approach is taken whereby stations are continued past the known perimeter of the ground until the burrow densities are close to zero. Indicator stations in the Labadie Bank, Nymphe Bank and Seven Heads were randomly picked based on integrated logbook VMS data.

The 2011 Celtic Sea survey took place on RV Celtic Voyager between 1st to 10th July. Survey timing was generally standardised to July each year. In 2006, 18 indicator stations and the Smalls Grounds stations were covered (Figure 1). In 2007 to 2011, poor weather and technical problems did not allow the indicator stations to be surveyed. The protocols used were those reviewed by WKNEPHTV 2007 (ICES, 2007).

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 a USBL transponder) were recorded every 1 to 2 seconds. The navigational data was quality controlled using an "r" script developed by the Marine Institute (ICES, 2009b). In addition CTD profile was logged for the duration of each tow using a Seabird SBE 9. This data will be processed later. Small geo-referenced sediment samples were taken where time allowed and frozen for later particle size analysis. All sediment samples were taken using the MI Shipex Grab and sediment was taken from the surface to around 10 cm depth.

Four beam trawl tows were conducted randomly across the Smalls ground once TV operations were successfully achieved. All *Nephrops* caught were sorted by sex and maturity category, weighed and measured using the NEMESYS electronic measuring system. The fish catch was sampled by weight (kgs) only and the benthic catch by weight (g) and number. The UWTV station positions, grab sample locations and tracks for the four beam trawl tows are shown in Figure 2.

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, 2009). Figure 3 shows individual's counting performance in 2011 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). 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 4). Consistency and bias between individual counters was examined using Figure 5. There were no obvious problems.

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 assuming that the sledge was flat on the seabed (i.e. no sinking). This field of view was confirmed for the majority of tows using lasers during the 2011 survey. Occasionally the lasers were not visible at the bottom of the screen due to sinking in very soft mud (the impact of this is a minor under estimate of densities at stations where this occurred). Figure 6 and Figure 7 shows the variability in density between minutes and operators (counters) for each station. These show that the burrow estimates are fairly consistent between minutes and counters.

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 for stations within the main fishing area the Smalls Grounds. The spatial structure of the density data was studied through variograms. Initially 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 1416.666667 and maximum lag distance of between 24-25 km. A model variogram $\gamma(h)$, was produced with a linear component (Equation 8). 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.

Equation 8: Linear Variogram Model

$$\gamma(h) = Co + S \cdot h$$

Where *Co* is the unknown nugget effect and *S* is the unknown slope.
The resulting annual variograms were used to create krigged grid files and the resulting cross-validation data were plotted. If the results looked reasonable 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 mean, variance, standard deviation, coefficient of variation, domain area and total burrow abundance estimate.

Although SURFER was used to estimate the burrow abundance this does not provide the krigged estimation variance or CV. This was carried out using the EVA: Estimation VAriance software (Petitgas and Lafont, 1997). The EVA burrow abundance estimates were all extremely close to the Surfer estimate (+- 100 million burrows) with the exception of 2009 when the spatial coverage was poor.

Results

A histogram of the observed burrow densities for 2006 to 2011 on the Smalls *Nephrops* Grounds is presented in Figure 8. Boundary stations have been excluded where they occur outside a polygon based on the VMS activity of the *Nephrops* targeting fleet. This shows some inter-annual variation in modal burrow densities. In most years two modes are apparent at relatively high density (~0.9-1.0/m^2) and at moderate density (0.3-0.5/m^2). The 2011 survey results also show this pattern and there are no observations of burrow density above 1.5/m^2.

The geo-statistical structural analysis is shown in the form of variograms in Figure 9. There is a weak evidence of a sill at around 25km in 2007 and 2008. A comparison of the observed and expected density estimates – cross validation plots for each year is given in Figure 10. There is good concordance between the observation and model estimates though there may be some underestimation

The blanked krigged contour plot and posted point density data are shown in Figure 11. The krigged contours correspond well to the observed data. The results indicate that in 2006 high densities were apparent throughout the central part of the Smalls ground. Densities subsequently decreased in 2007 with an increase in 2011. In general the densities are higher towards the south and central area of the ground.

The summary statistics from this geo-statistical analysis are given in Table 1 and Figure 12. The 2011 estimate of 1632 million burrows is above average but 16% below the maximum of the series observed in 2006. The estimation variance of the survey as calculated by EVA is relatively low (CVs in the order <6%). The summary statistics for the indicator stations are given in Table 2.

Figure 13 shows the standardised length frequency distributions of *Nephrops* caught using a beam trawl on the Smalls ground during the 2006 to 2011 surveys. The results indicate large numbers of recruits in both sexes with modal length around 17mm CL in 2006 which did not occur since then. Figure 14 depicts a modelled (binomial GM) maturity ogive for female *Nephrops* where 50% of the females are mature at 23 CL mm. Figure 15 is a summary of the length frequency by tow. There is both variability in the sample size and structure between tows. Carapace lengths ranged from 10 mm to 53 mm for one large male.

Table 3 summarises the fish catches where *Trisopterus esmarki* (commonly known as Norway pout) was recorded in all beam tows with the highest catch of 10.336 kgs recorded in tow 4. A summary of the benthic components by tow in presented in Table 4, where *Nucula nucleus* (nut clam) was the most abundant and recorded in all tows. It is also important to note that the mud burrowing shrimp *Calocaris macandrae* was also recorded. The burrow of this species can cause confusion in identification in areas of very soft mud and high densities of *Nephrops* burrows such as the western Irish Sea *Nephrops* ground, but this species is not deemed to be problematic in the Smalls ground. *Goneplax rhomboids,* a burrowing crab species, was also recorded in three tows.

Sea-pen distribution across the Smalls *Nephrops* grounds is mapped in Figure 16. All sea-pens were identified from the video footage as *Virgularia mirabilis*. Trawl marks were noted at 37% of the stations surveyed with trawl marks present for the entire transect for 7% of stations.

Discussion

Data for assessment of *Nephrops* in this area has been rather sparse in the past. This survey was initiated by Ireland in 2006 to address these data deficiencies and improve the scientific basis for managing the stock. In 2011 the survey information up to 2010 was used as the main basis for the ICES assessment and advice for "the Smalls" (FU 22) for the first time (ICES, 2011a&b). ICES concluded that the *Nephrops* stock was fished at a sustainable rate (ICES, 2011b). The 2011 burrow abundance estimates have increased slightly (~ 10%) this result will not change the ICES conclusion made in June. 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.

As in most other years the 2011 survey focused effort on "the Smalls" ground (FU22). It was not possible to complete the planned indicator stations due to time constraints linked to weather and technical down time. In recent years "the Smalls" (FU 22) has accounted for around 38% or 2,300 t of the total landings (~ 5,500 t) from the wider Celtic Sea (FU19, 20, 21 & 22) (ICES, 2011b). The Smalls represents around 32% of the total area where *Nephrops* are currently fished in the Celtic Sea (based on areas shown in Figure 1). The Smalls ground is particularly important to the Irish demersal fleet accounting for around 13% of the fishing effort by vessels >15m between 2006 - 2009 (Gerritsen, et al. submitted). While it is likely that the *Nephrops* populations in the Celtic Sea are linked in a meta-population sense, further information is needed to estimate stock size and exploitation rates for the other *Nephrops* grounds. The diverse nature of the habitat and wide spatial distribution means designing and routinely executing an UWTV survey for the remaining areas particularly challenging. Integrating UWTV survey work with the Irish Groundfish Survey could be a way to address this challenge in the future.

No signal of *Nephrops* recruitment was observed in 2011 compared to that noted in 2006, however, only four tows were conducted over the northern part of the grid due to time constraints in 2011. Variability between *Nephrops* catch and size structure between the tows is linked to *Nephrops* emergence patterns as well as the underlying density. Macrobenthos data from the trawl catches was collected for the first time this year. The dominant species by weight and number was the nut clam *Nucula nucleus* followed by *Nephrops norvegicus* and then *Lunatia* species (necklace shell). Overall there is a similar benthic species composition between the tows reflecting the habitat type encountered which is generally sandy mud. No sea-pens were caught by the beam trawl despite the common occurrence of *Virgularia mirabilis* observed on the video footage. This illustrates that the catchability of epibenthic species in the beam trawl is often very different to what is visible on video footage. These different sampling methods may not always reflect underlying occurrence or abundance.

Three other burrowing species: *Goneplax rhomboids* (box crab), *Calocaris macandrae* (mud burrowing shrimp) and *Munida sarsi* (squat lobster) were recorded. Of those *Munida sarsi* was the most abundant. The burrows of these species can lead to confusion with *Nephrops* burrows in areas of soft mud and high burrow densities. 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 & 2009).

A broad diversity of fish species were caught (22 species). Of these *Trisopterus esmarki* (poor cod) was the most abundant followed by *Melanogrammus aeglefinus* (haddock) and the flatfish species *Lepidorhombus whiffiagonis* (megrim). These species are typically encountered in the catches of surveys and commercial vessels on "the Smalls".

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 and grab samples will be processed at a later stage. This information is relatively easy to collect and over time will augment the knowledge base on habitat and oceanographic regime.

The main objectives of the survey were successfully met for the sixth successive year. The UWTV coverage and footage quality was excellent on "the Smalls". Weather and technical downtime meant that indicator stations were not achieved and the number of beam trawls was limited to 4 out of a planned 10. 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 Philip Baugh (Captain) and crew of the RV. Celtic Voyager for their good will and professionalism during the survey and also to Lukasz Pawlikowski P&O Maritime IT & Instrumentation Technician**,** for handling all onboard technical difficulties. To Aodhan Fitzgerald of RV Operations at the Marine Institute for organising survey logistics. And thanks to the Marine Institute staff onboard for their hard work and enthusiasm.

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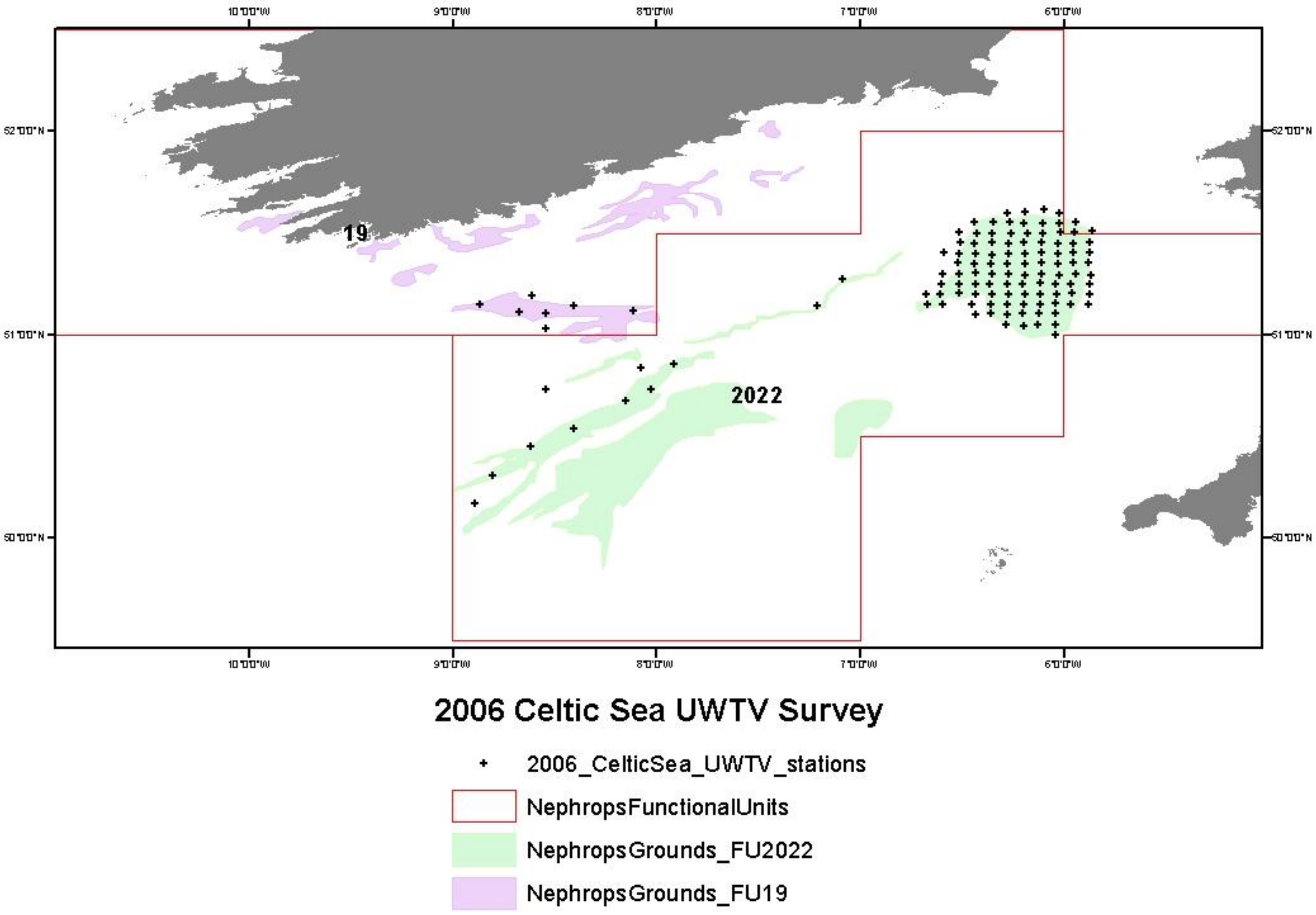

Figure 1: Stations completed on the 2006 UWTV Celtic Sea survey and *Nephrops* ground in the Celtic Sea.

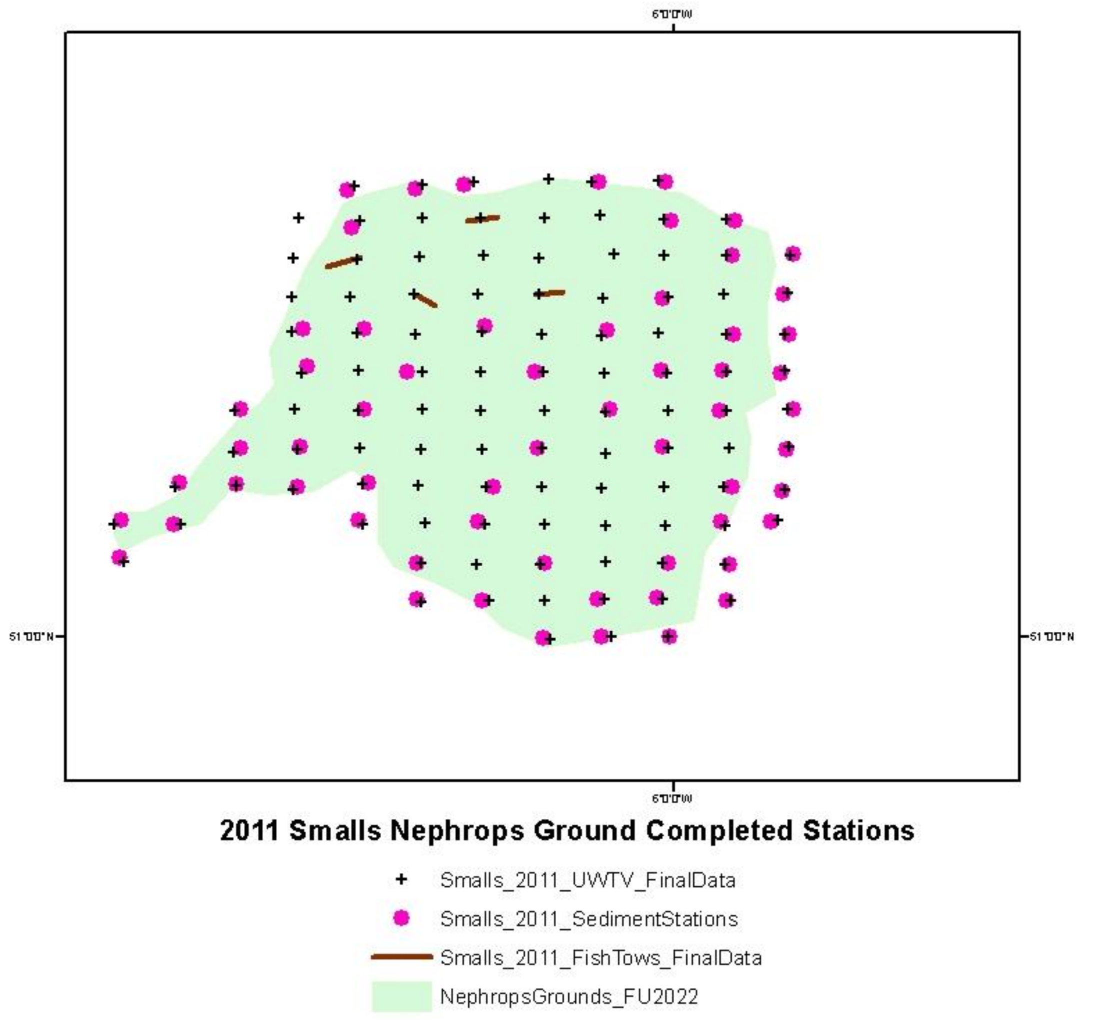

Figure 2: Stations completed on the 2011 UWTV Celtic Sea survey.

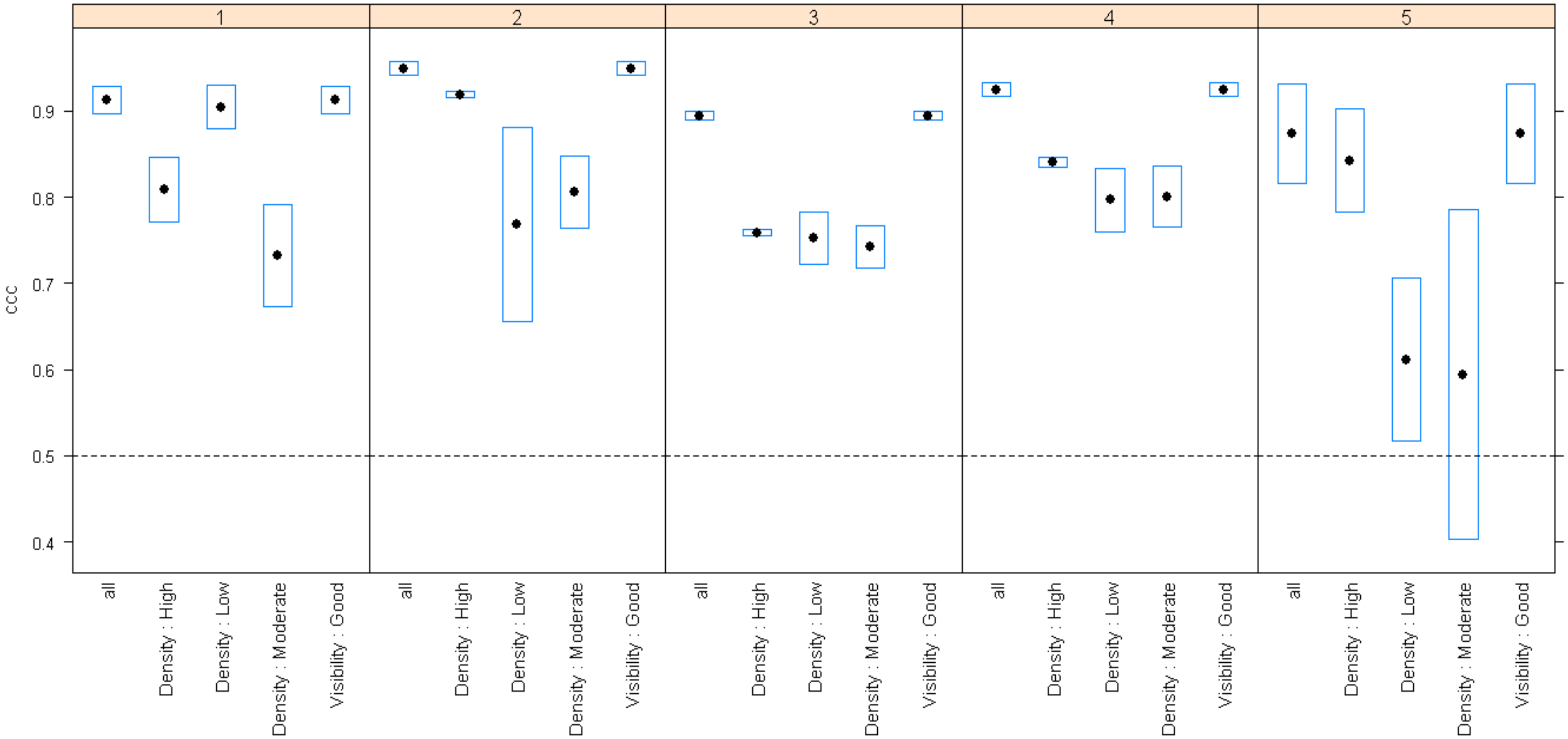

Figure 3: 2011 Counting performance against the reference counts as measured by Linn's CCC for the Smalls ground. Each panel represents an individual. The x-axis (from left to right), all stations pooled, high density, low density, medium density and visibility good.

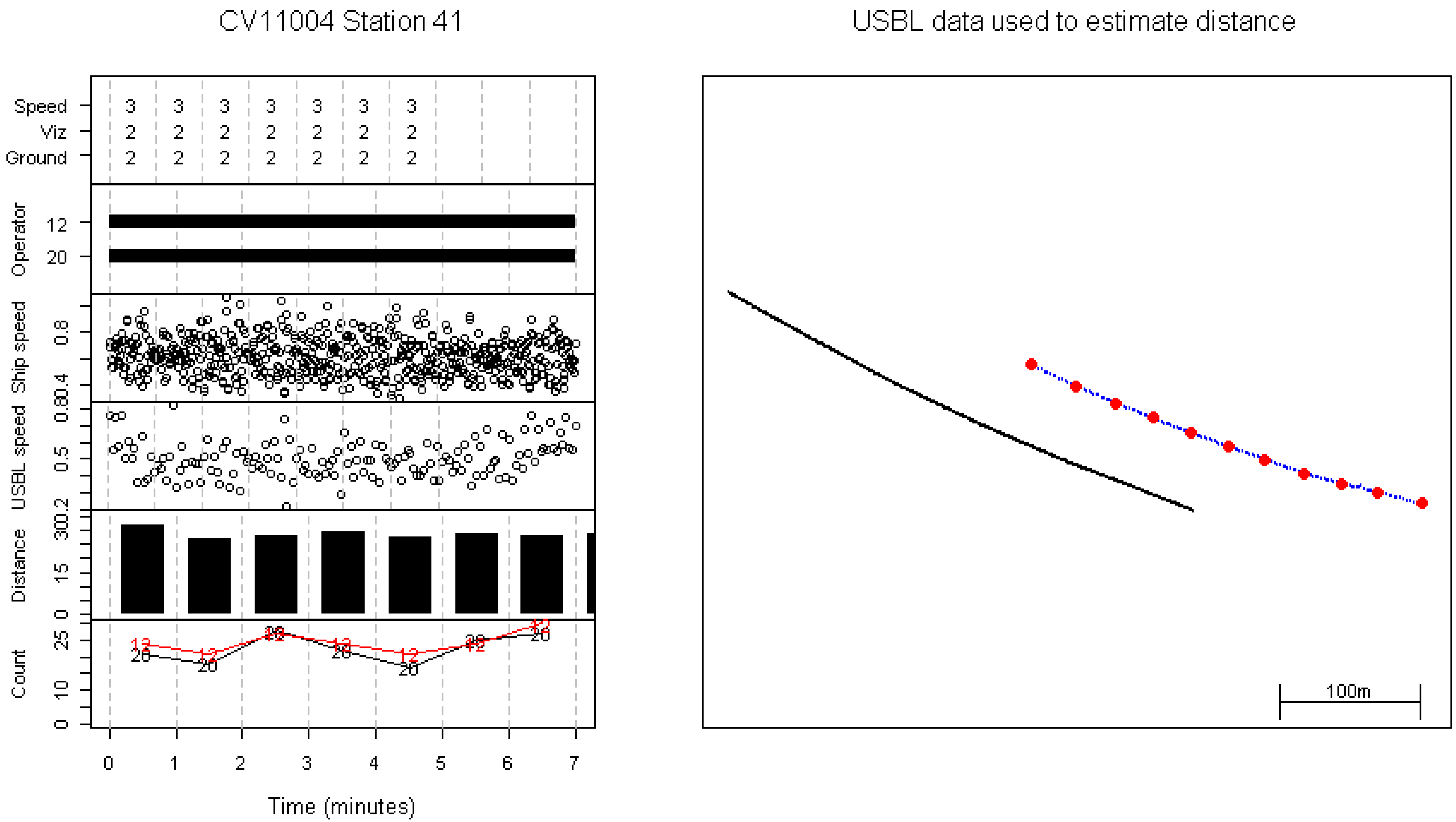

Figure 4 : r - tool quality control plot for station 41 of the Smalls Grounds FU22 UWTV Survey 2011.

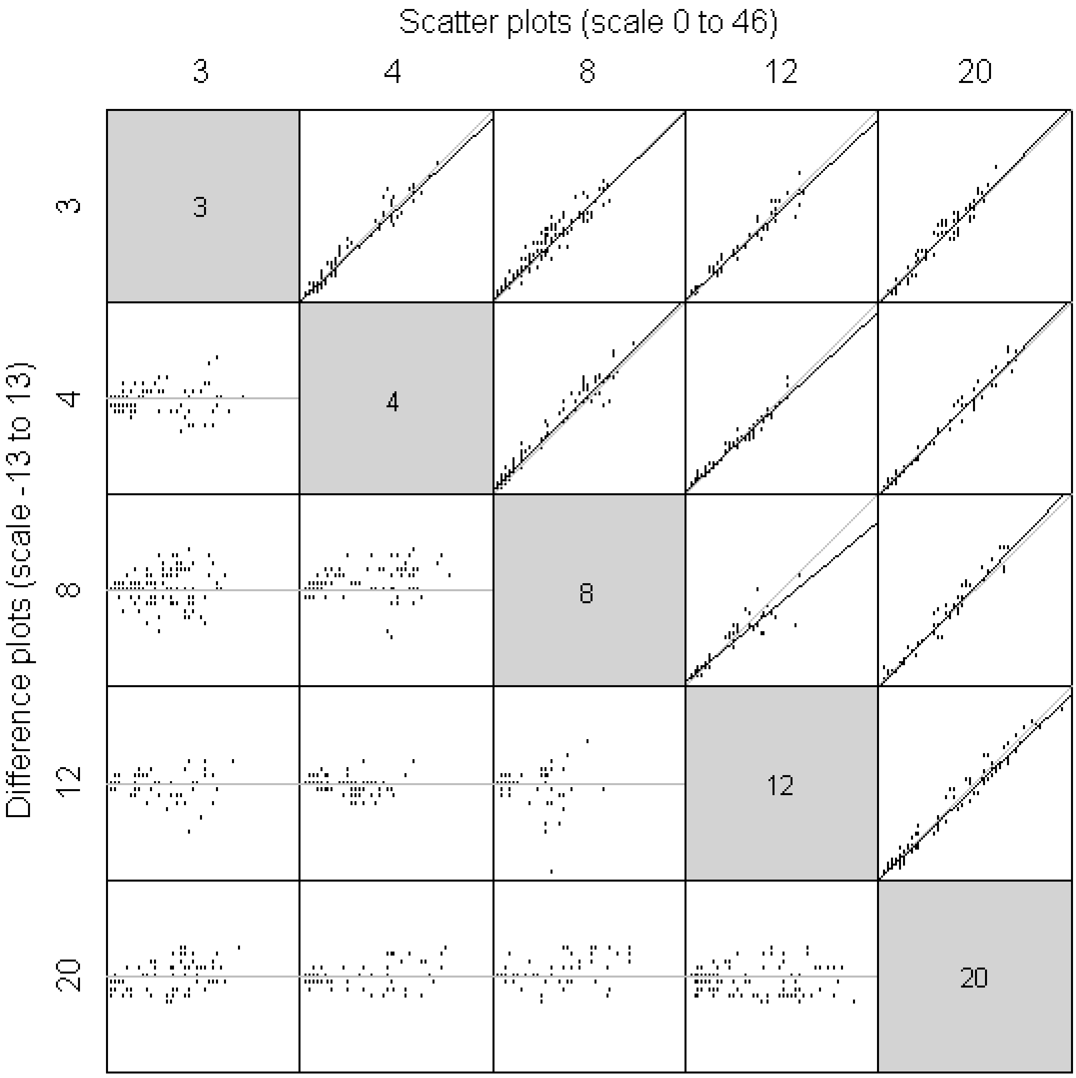

Figure 5 : Scatter plot analysis of counter trends during 2011 UWTV Survey of the Smalls Grounds FU22.

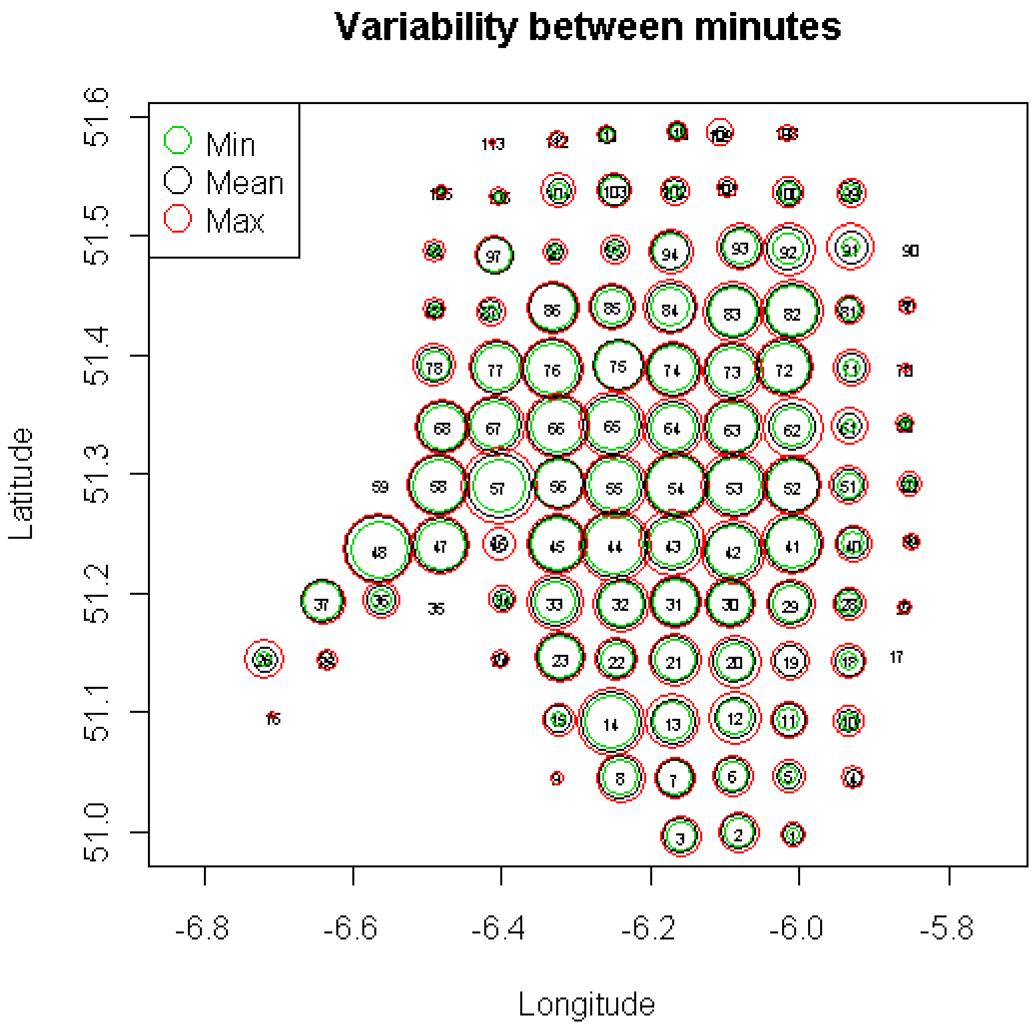

Figure 6 : Plot of the variability in density between minutes for each station in 2011 survey.

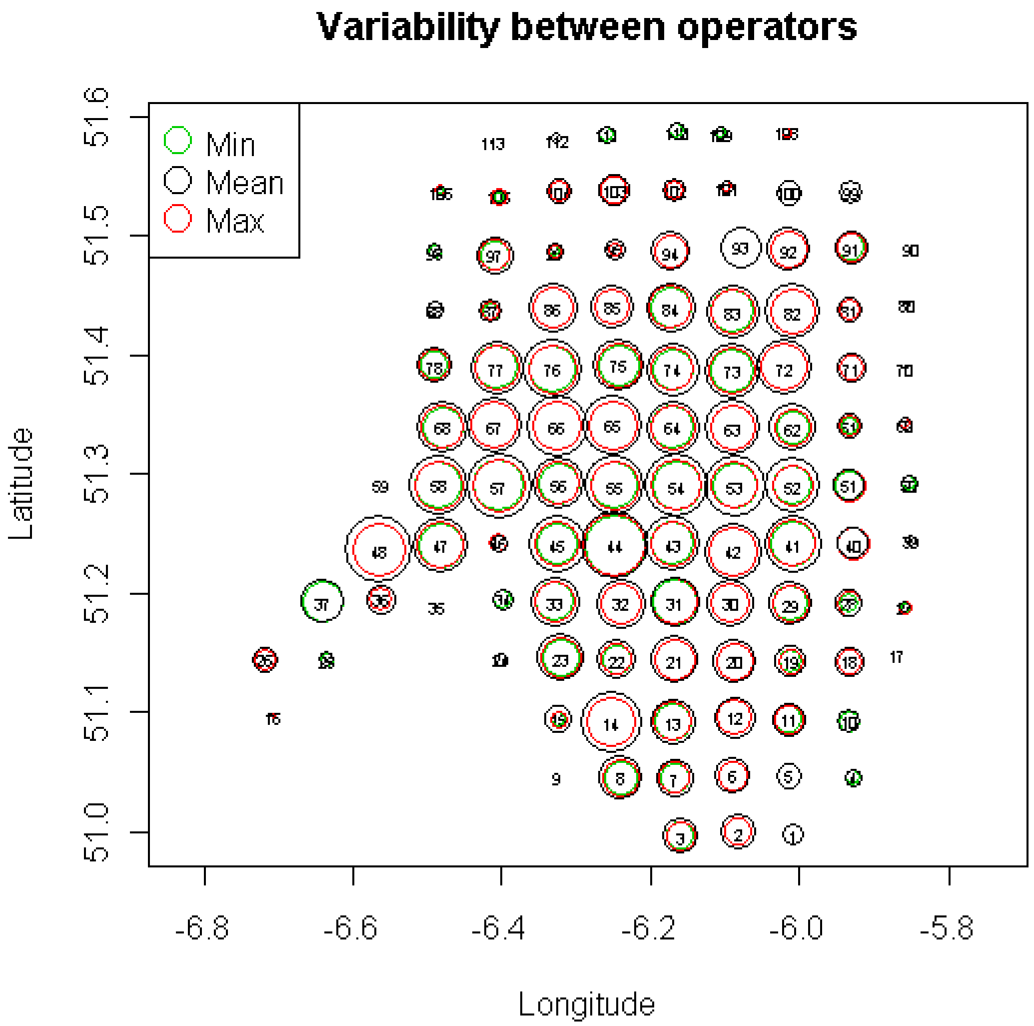

Figure 7 : Plot of the variability in density between operators (counters) for each station in 2011 survey.

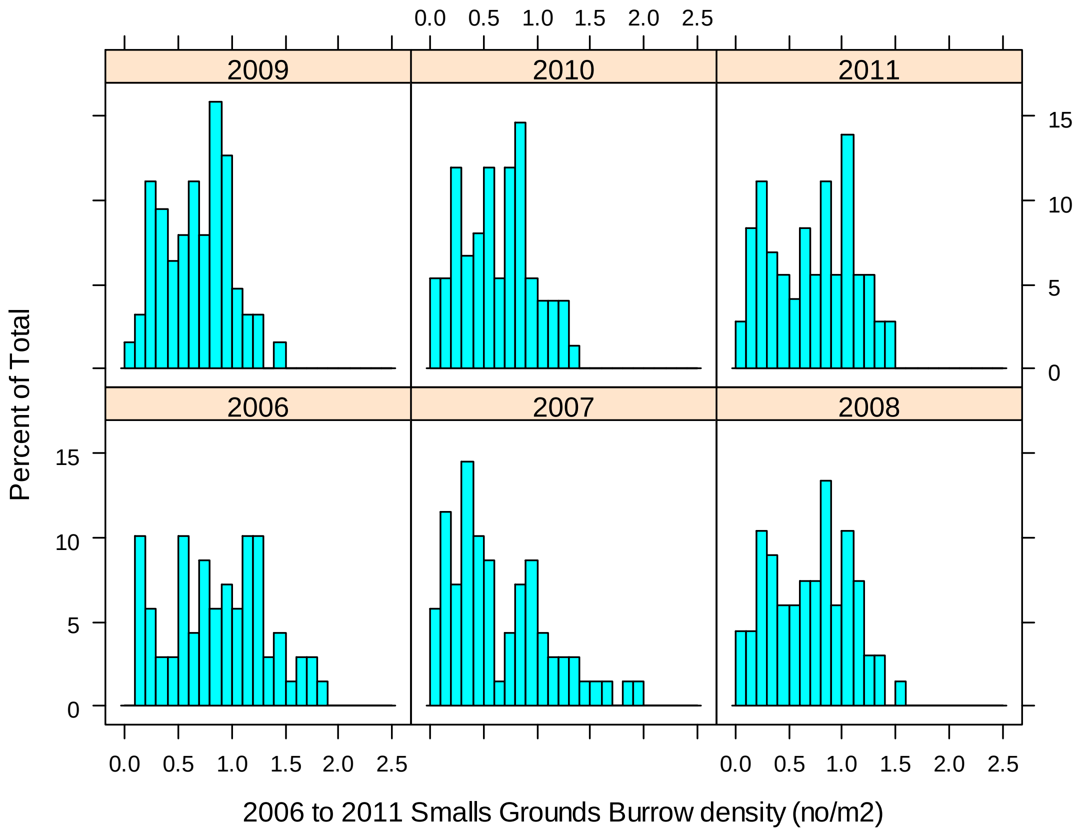

Figure 8: Burrow density distributions for the Smalls Grounds by year from 2006-2011.

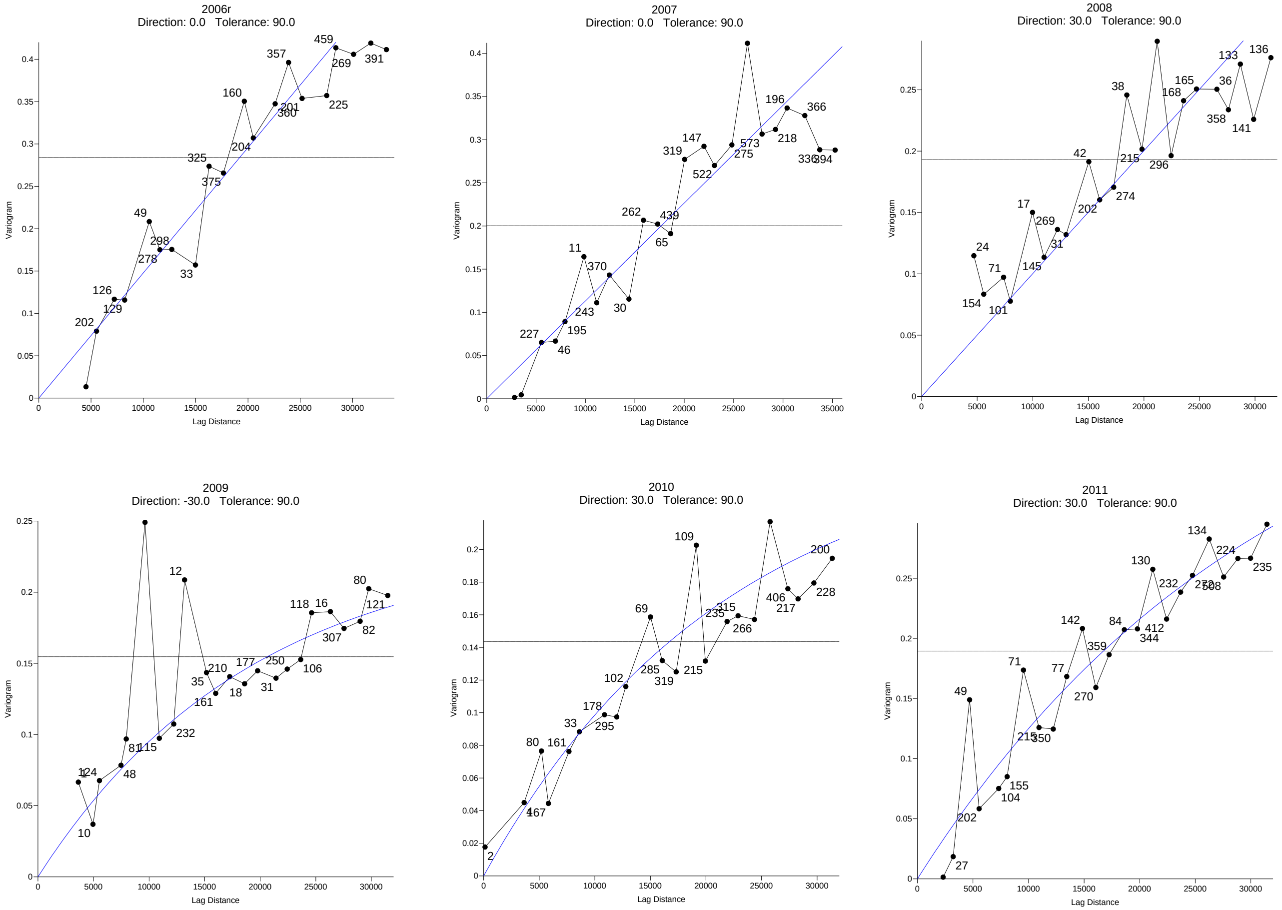

Figure 9: Omnidirectional mean variograms for the Smalls Grounds by year from 2006-2011.

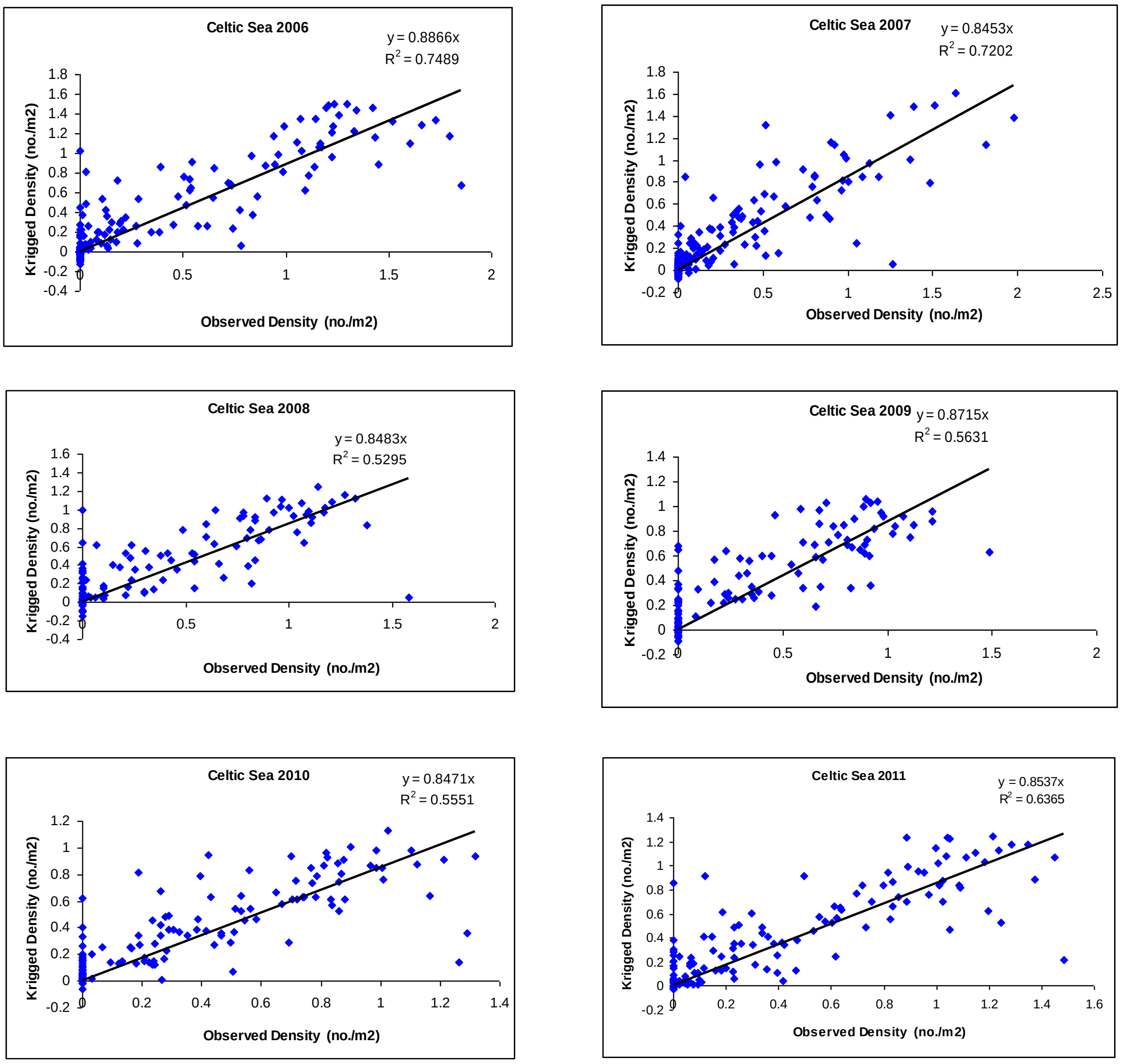

Figure 10: Cross validation plots for the Smalls Grounds by year from 2006-2011.

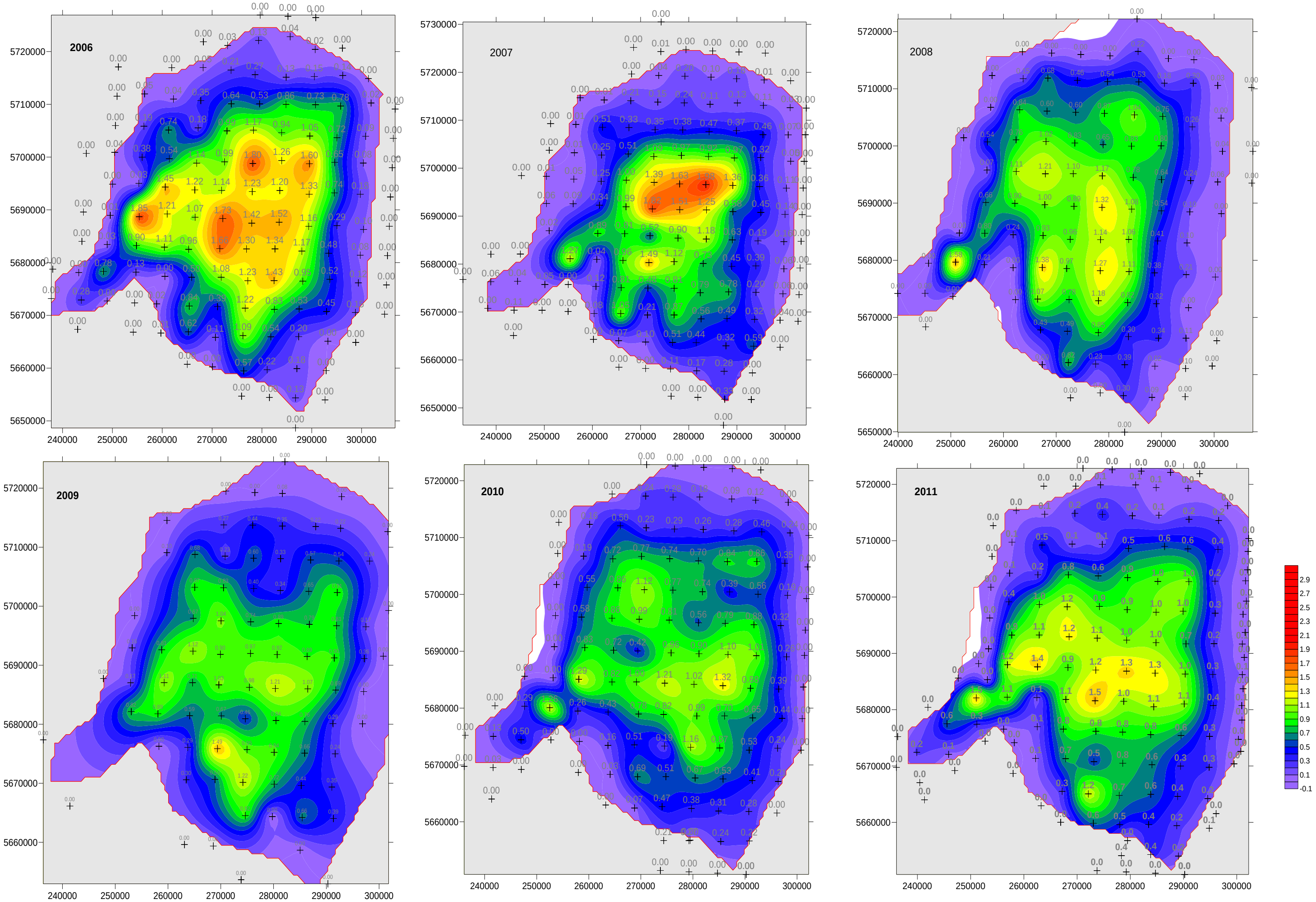

Figure 11: Contour plots of the krigged density estimates for the Smalls Grounds from 2006-2011.

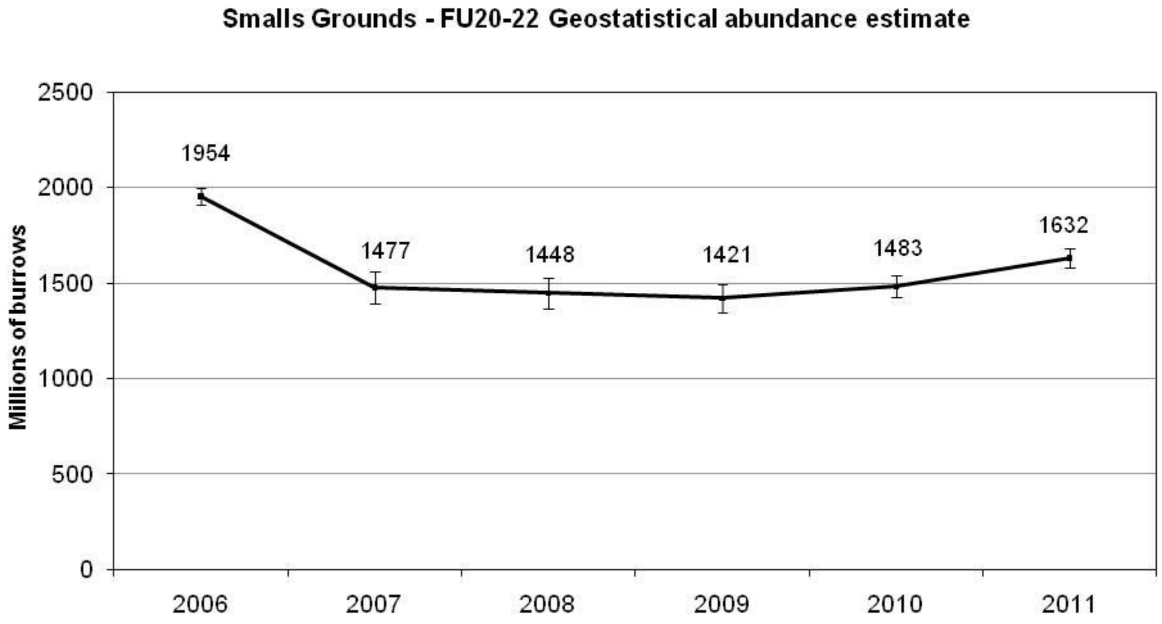

Figure 12: Time series of geo-statistical abundance estimates (in millions of burrows) for the Smalls Grounds from 2006-2011.

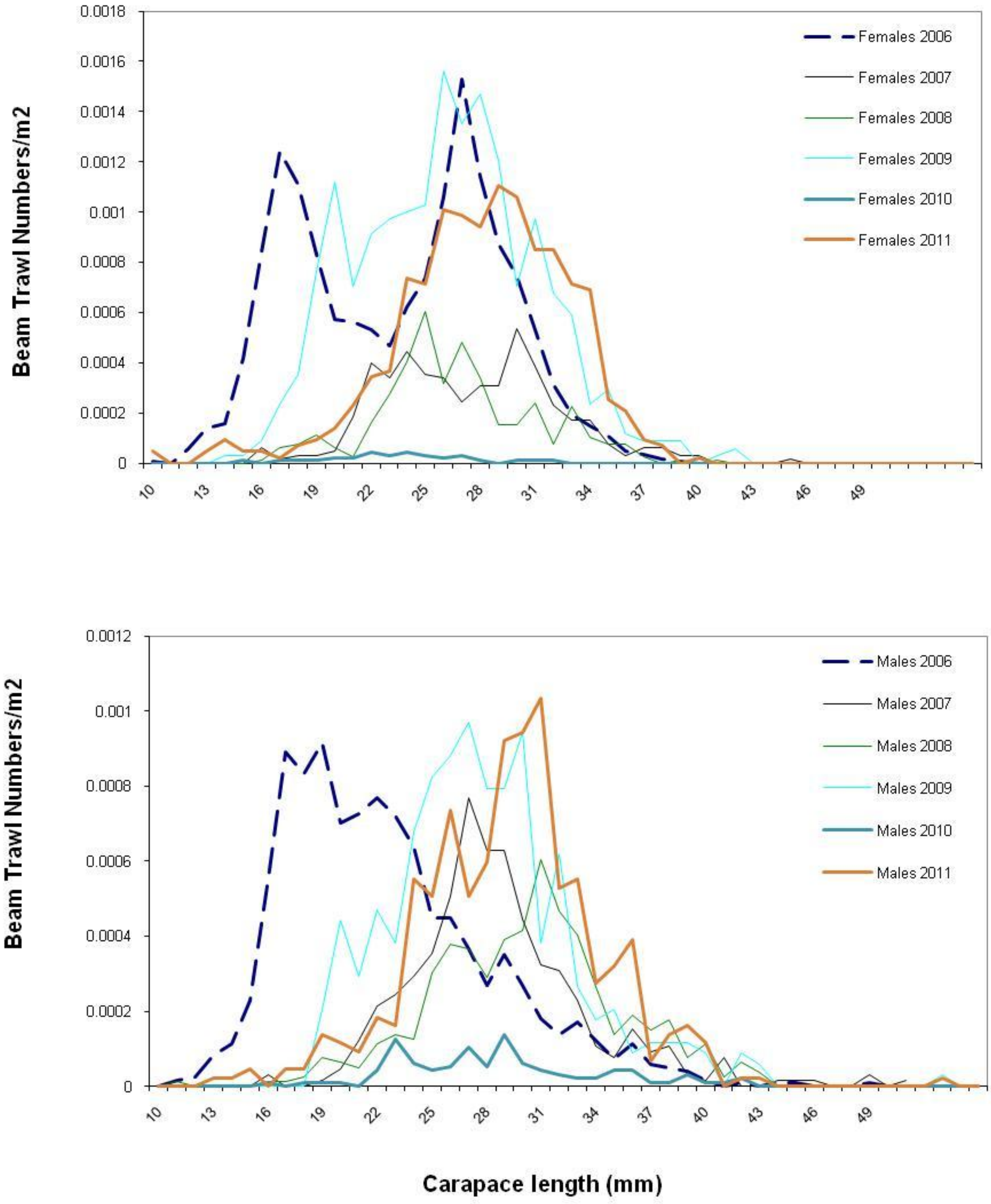

Figure 13: Standardised length frequency distributions for *Nephrops* caught using beam trawls (nos/m^2) in July 2006 to 2011 on the "Smalls" Celtic Sea *Nephrops* ground.

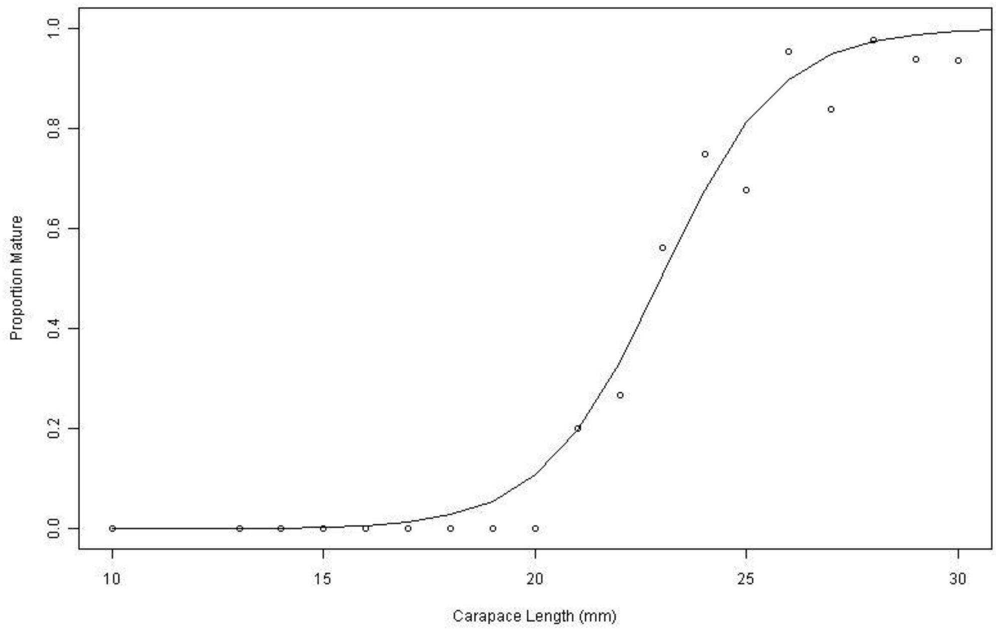

Figure 14: 2011 Female *Nephrops* maturity ogive.

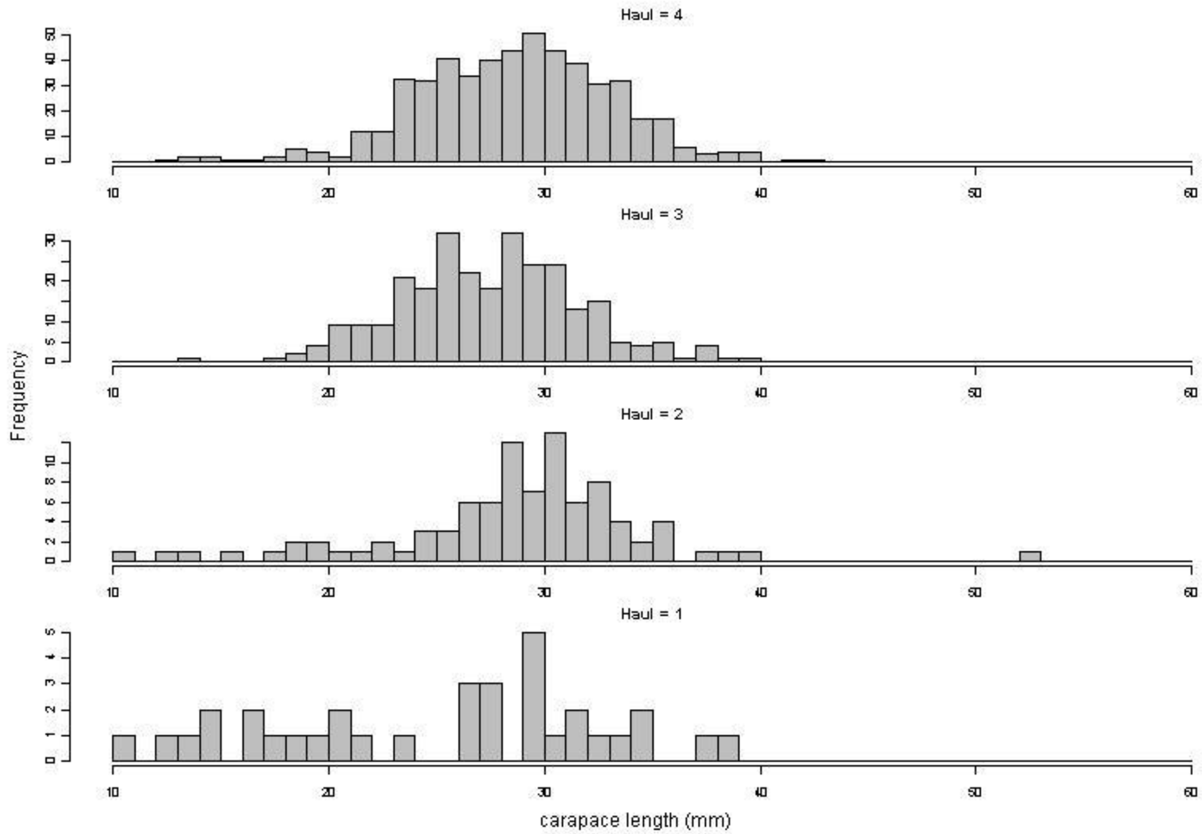

Figure 15: 2011 *Nephrops* length frequencies by haul.

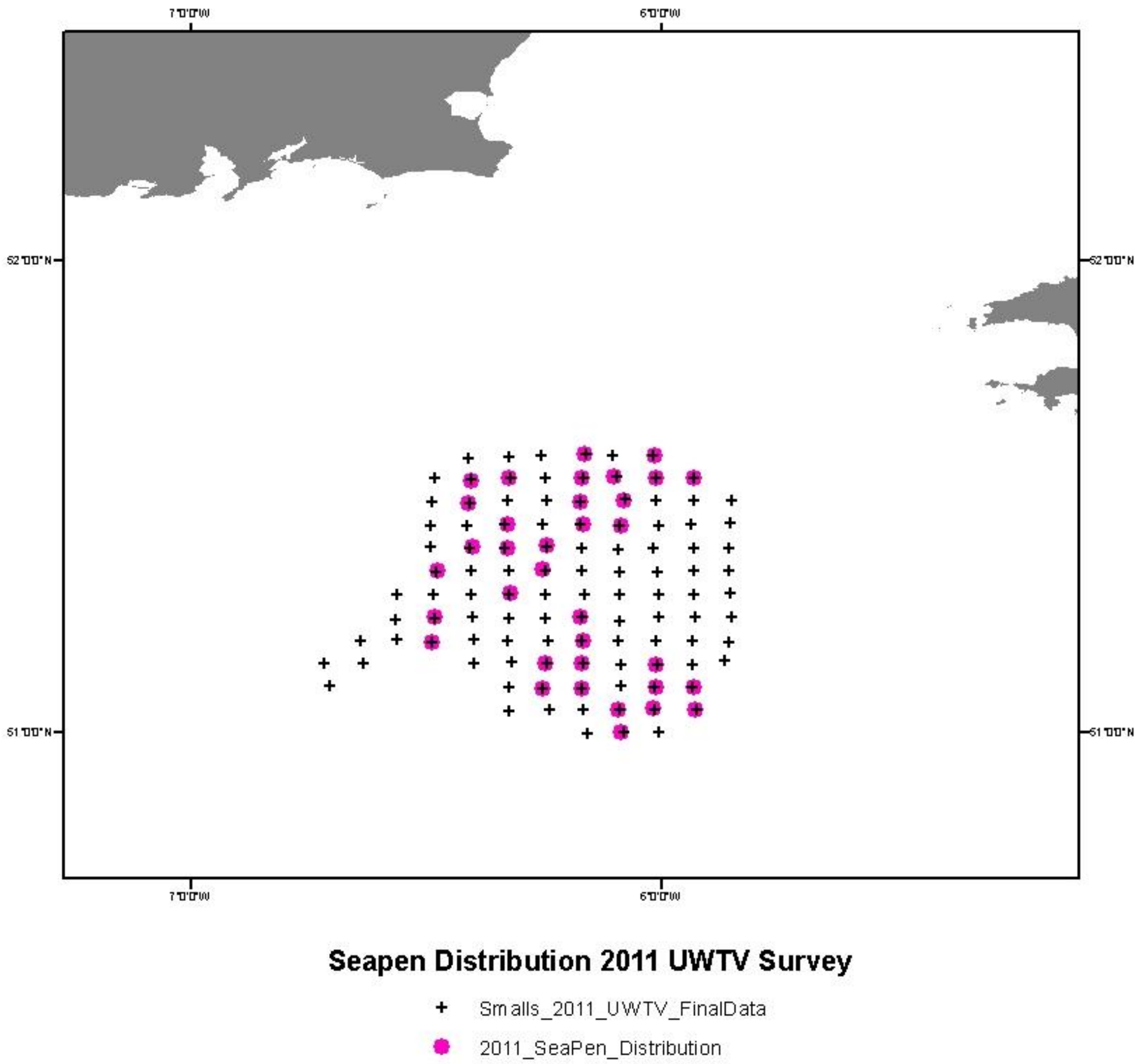

Figure 16: Stations where *Virgilaria mirabilis* was identified during the 2011 survey.

Ground	Year	Number of stations	Mean Density (no./m2)	Domain Area (km2)	Geostatistical Abundance (millions of burrows)	CV on Burrow estimate
	2006	100	0.63	2962	1954	2%
	2007	107	0.48	2955	1477	6%
	2008	76	0.47	2698	1448	6%
	2009	67	0.47	2824	1421	5%
	2010	90	0.49	2861	1483	4%
Smalls (FU22)	2011	107	0.53	2881	1632	3%

Table 1: Summary geostatistics for the Nephrops UWTV surveys of the Smalls Ground from 2006-2011.

Ground	Year	Number of stations	Mean Density (No./M2)*	Area Surveyed (M2)	Burrow count	Standard Deviation	95%CI	CV
	2006	9	0.42	1,322	760	0.37	0.28	29%
	2007	-	-	-	-	-	-	-
	2008	-	-	-	-	-	-	-
	2009	-	-	-	-	-	-	-
	2010	-	-	-	-	-	-	-
Labadie Bank	2011	-	-	-	-	-	-	-
	2006	2	0.27	195	89	0.39	3.47	100%
	2007	-	-	-	-	-	-	-
	2008	-	-	-	-	-	-	-
	2009	-	-	-	-	-	-	-
	2010	-	-	-	-	-	-	-
Nymphe Bank	2011	-	-	-	-	-	-	-
	2006	7	0.23	995	293	0.25	0.23	41%
	2007	-	-	-	-	-	-	-
	2008	-	-	-	-	-	-	-
	2009	-	-	-	-	-	-	-
	2010	-	-	-	-	-	-	-
Seven Heads	2011	-	-	-	-	-	-	-

*random stratified estimates are given for the Labadie Bank, Nymphe Bank and Seven Heads grounds.

- - Area not surveyed in 2007 to 2011 due to weather and time constraints

Table 2 : Summary geostatistics for the Nephrops UWTV indicator stations in the Celtic Sea from 2006-2011.

Species by weight (Kg)	Tow1	Tow2	Tow3	Tow4	Total weight by species
CALLIONYMUS LYRA			0.050	0.112	0.162
ENCHELYOPUS CIMBRIUS		0.320		0.530	0.850
EUTRIGLA (CHELIDONICTHYS) GURNARDUS				0.102	0.102
GADUS MORHUA			3.010	0.324	3.334
GAIDROPSARUS VULGARIS	0.228				0.228
GLYPTOCEPHALUS CYNOGLOSSUS	0.482	0.650	1.570	1.150	3.852
GOBIES			0.025	0.001	0.026
HIPPOGLOSSOIDES PLATESSOIDES	0.110	0.086	0.260	0.886	1.342
LEPIDORHOMBUS WHIFFIAGONIS	0.632		1.644	3.302	5.578
LIMANDA LIMANDA			0.042		0.042
LOPHIUS PISCATORIUS		0.182			0.182
MELANOGRAMMUS AEGLEFINUS		0.302	0.698	4.652	5.652
MERLANGIUS MERLANGUS		0.216	0.314	0.688	1.218
MERLUCCIUS MERLUCCIUS				0.582	0.582
MICROCHIRUS VARIEGATUS	0.066		0.082	0.560	0.708
MICROSTOMUS KITT				0.930	0.930
PLEURONECTES PLATESSA					0.000
SCYLIORHINUS CANICULA (Female)		0.098		2.014	2.112
SCYLIORHINUS CANICULA (Male)				0.550	0.550
SOLEA SOLEA			0.084	0.360	0.444
TRISOPTERUS ESMARKI	0.006	0.794	0.668	10.336	11.804
TRISOPTERUS MINUTUS		0.180	0.548	0.184	0.912
ZEUGOPTERUS PUNCTATUS	0.008				0.008
Total weight by tow (Kg)	1.532	2.828	8.995	27.263	40.618

Table 3 : Summary of fish catches by tow from fishing operations.

	Tow1		Tow2		Tow3		Tow4	
Species	Weight (g)	Number	Weight (g)	Number	Weight (g)	Number	Weight (g)	Number
Aequipecten opercularis	0	0	0	0	16	4	0	0
Alyconium glomeratum	0	0	0	0	18	21	10	1
Anemone spp	18	2			28	2	22	2
Aphrodite aculeata	300	21	116	14	28	2	120	4
Astarte sulcata	114	17	0	0	38	4	2	1
Asterias rubens	80	1	0	0	236	41	1,174	606
Astropecten irregularis	62	3	48	2	80	7	906	62
Broken Shell	9,017		4,606		7,029		3,782	
Buccinum undatum	78	1	0	0	0	0	460	5
Calocaris macandrae	0	0	2	3	0	0	0	0
Corystes cassivelaunus	32	2			94	8	26	2
Crangon allmanni	340	339	584	631	599	611	334	448
Crinoid spp	0	0	0	0	643	135	50	15
Cyanea	0	0	0	0	30	1	0	0
Dichelopandulus bonneri	592	175	552	68	858	257	34	17
Eledone cirrhosa	760	6	0	0	0	0	168	3
Goneplax rhomboides	0	0	2	1	46	9	18	5
Liocarcinus depurator	204	31	40	4	22	2	30	3
Liocarcinus holsatus	0	0	1	2	10	5	11	14
Lunatia spp	1,268	211	36	5	454	101	699	54
Macropodia spp	12	8	2	3	0	0	10	11
Munida sarsi	20	4	2	1	6	2	0	0
Nephrops norvegicus	588	34	1,622	92	3,974	275	8,769	518
Nucula nucleus	16,907	12,610	6,914	4,560	552	575	2	3
Ophiuridae spp	0	0	1	3	0	0	0	0
Pagurus alatus	0	0	0	0	0	0	36	1
Pagurus bernardus	0	0	124	8	348	11	0	0
Pagurus spp	28	5			228	35	155	60
Pasiphaea spp	2	1	1	2	0	0	0	0
Polychaete spp	0	0	1	2	0	0	0	0
Pontophilus spinosa	12	17	20	28	2	2	4	3
Processa spp	6	4	1	2	2	2	15	16
Scalpellum scalpellum	15	108	6	5	0	0	0	0
Sepiola spp	0	0	1	1	0	0	0	0
Stichastrella rosea	0	0	0	0	0	0	10	1
Suberites	0	0	0	0	114	80	42	1
Whelk egg case	0	0	0	0	0	0	48	2
Worm cases	0	0	12	5	2	3	4	3
Xantho pilipes	0	0	32	3	0	0	0	0
Total weight (Kg)	30.455		14.726		15.457		16.940	
Total numbers		13,600		5,445		2,195		1,861

Table 4 : Summary of benthic catch by tow in weight (g) and number.