Update on the 2010 UWTV Survey of the Aran, Galway Bay and Slyne Head *Nephrops* Grounds

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Introduction

The prawn (*Nephrops norvegicus*) are common around the Irish coast occurring in geographically distinct sandy/muddy areas were the sediment is suitable for them to construct their burrows. The Irish *Nephrops* fishery is extremely valuable with landings in recent years worth around € 30 m at first sale supporting an important indigenous processing industry. The *Nephrops* fishery 'at the back of the Aran Islands' can be considered the mainstay of the Ros a Mhíl fleet. Without this *Nephrops* fishery the majority of vessels in the fleet would cease being economically viable (Meredith, 1999). Given these socio-economic realities good scientific information on stock status to enable sustainable management of the resources are urgently required.

This is the ninth data point in a time series of UWTV surveys on the 'Aran grounds'. The survey covers three distinct mud patches; the Aran Ground, Galway Bay and Slyne Head. These have approximate areas of 940, 41 and 26 km^2 respectively. For the first time in 2009 this survey was used to develop catch options for the stock using a bias corrected survey estimate as an absolute measure of stock size and recent discard rates and mean weight to forecast catch (ICES, 2009a). This report details the results of the 2010 survey and updates the catch option table using the most recent survey estimate.

Material and methods

Stations in Galway Bay and Slyne Head were either randomly picked or selected based on previously completed tows. A randomised fixed grid design is used for the Aran grounds where a point is picked at random and stations are carried out at a fixed distance north-south and east-west. The distance between stations varied somewhat but is currently 2.25 nautical miles. An adaptive approach is taken where by stations are continued past the known perimeter of the ground until the burrow densities are close to zero. The boundary use to delineate the edge of the ground was based on information from the fishing industry and has not been changed since 2002.

Survey timing was generally standardised to June each year. In 2004, bad weather prevented the completion of the survey in June so approximately 50% of the stations were carried out one month later in July. In 2003, poor weather and technical problems meant that coverage was poor compared with the other years. In 2010 all three *Nephrops* grounds were surveyed successfully in June.

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 second. The navigational data was quality controlled using an "r" script developed by the Marine Institute (ICES, 2009b). In addition depth was logged for the duration of the tow.

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 1 shows individual's counting performance 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 undergone, 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 the classification. In addition the numbers of *Nephrops* burrows complexes (multiple burrows in close proximity which appear to be part of a single complex are only counted once), *Nephrops* in and *Nephrops* out of burrows counted by each scientist for each one-minute interval was recorded. Notes were also recorded on the occurrence of trawl marks, fish species and other species during the one-minute interval. Finally, if any there was any time during the one-minute where counting was not possible 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). Consistency and bias between individual counters was examined using Figure 3. Figure 4 and Figure 5 shows the variability in density between minutes and operators (counters) for each station.

The main change in protocol relates to the amount of time recounted. Following the recommendation of SGNEPS the time for verified recounts was reduced from 10 to 7 minutes (ICES, 2009b).
There was also a minor data revision to survey years 2006 and 2008 due to the amalgamation of survey data to a SQL server. This revision did not change the overall perception of the survey series (Table 1(a,b), Figure 6).

The resultant recount data were screened for one minute intervals with an unusually large deviation between recounts. Means of the burrow and *Nephrops* recounts were standardised by dividing by the survey area observed. The USBL data were used to calculate distance over ground of the sledge. The field of view of the camera at the bottom of the screen was estimated assuming that the sledge was flat on the seabed (i.e. no sinking). This field of view was confirmed for all of tows using lasers during the 2010 survey

To account for the spatial co-variance and other spatial structuring a geo-statistical analysis of the data was also carried out using SURFER Version 8.02 for stations within the main fishing area the Aran Grounds for all years. The spatial structure of the density data was studied through variograms. Initial 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 between 1-1.4 and maximum lag distance of between 19-20 km. A model variogram $\gamma(h)$, was produced with a nugget component and a exponential 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: Exponential Variogram Model

$$\gamma(h) = C\left(1 - e^{-h}\right)$$

Where C is the scale for the structural component of the variogram and h is the aniostrophically.

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, 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 (+- 30 million burrows) with the exception of 2004 when the spatial coverage was poor.

Results

Landings, effort and LPUE trends for FU17 are given in Figure 7. These indicate that landings increased throughout the 1990s with some fluctuations peaking in 1999 at >1,400 t since then there has been a general decline in landings with an increase in 2010 on 2009 figure by 40% to 991 t. Effort in the "*Nephrops* directed fleet" shows a declining trend since 1998 and LPUE has remained fairly stable over the time series and both have increased in 2010.

A histogram of the observed burrow densities for 2010 and previous years on the Aran Grounds is presented in Figure 8. This shows large inter-annual variation in modal burrow densities.

The geostatistical structural analysis is shown in the form of variograms in Figure 9. There are a few outliers apparent but they appear have little leverage on the variogram models observed. With the exception of 2006 a nugget is apparent in most years. There is weak evidence of a sill at around 12km in some years but it is not clear and the logarithmic model used does not have a sill. A comparison of the observer and expected density estimates confirms that there is good concordance between the observation and model estimates in Figure 10.

The blanked krigged contour plot and posted point density data are shown in Figure 11. The krigged contours correspond very well to the observed data. The results indicate the densities have fluctuated considerably over the time series and throughout the ground. The fluctuations are not limited to a single station but instead occur fairly homogeneously across the ground. In general the densities are higher towards the western side of the ground rather and there is a notable trend towards lower densities towards the east. On the south western boundary there are indications of high densities close to the boundary. In this area there is a sharp transition from mud to rocky substrate and work is underway to define this boundary more accurately.

The revised summary statistics from this geostatistical analysis are given in Table 1(b) and plotted in Figure 12. The 2010 estimate of 827 million burrows is a 15% increase from 2009. The estimates have fluctuated widely since the survey commenced. The estimation variance of the survey as calculated by EVA is relatively low (CVs in the order <5%). The 2010 estimate is just below the mean of the series (842 million burrows) but given the fluctuations observed to date it is difficult to conclude how significant that is.

Figure 13 shows the standardised length frequency distributions of *Nephrops* caught using a beam trawl on the Aran grounds during the 2006 to 2010 surveys. No fishing was carried out on surveys in 2003, 2004, 2005 or 2008 due to time constraints as a result of poor weather conditions. In 2010 small individuals ranging from 4 - 7 CL mm were caught by the beam trawl (4 meter beam). It is not known for certain if such small *Nephrops* construct their own burrows or if they co-habitat in burrows of larger individuals. Resin casts of burrow systems in other areas have shown large and small animal interactions (Marrs et al, 2004). Figure 14 shows the tows where *Nephrops* <=10 CL mm were caught and black crosses indicate stations where unusually small *Nephrops* burrows systems were observed during 2010 UWTV survey.

Discussion

The UWTV survey series for the Aran Grounds was first developed in 2002 and has become the main source of fishery independent information on this stock. Sampling of the fishery has been sporadic although normal sampling resumed in 2008 and fishery dependent data is subject to some quality concerns (ICES, 2009c). The methods employed during the Aran UWTV surveys have recently been discussed and well documented by WKNEPHTV, WKNEPHBID and SGNEPS (ICES, 2007, 2008 and 2009b). The uncertainty estimates in the survey were examined initially using EVA during WKNEPH 2009 and updated for all years here. This analysis indicates that the survey method (randomised grid and geostatistical estimation of abundance) does estimate the abundance very precisely compared with other approaches.

For this particular survey occupancy and edge effects become critical when using the survey as an absolute abundance estimate. WKNEPH 2009 estimated the cumulative over estimation bias to be in the order of 1.3. Occupancy is assumed to be one *Nephrops* per burrow. The fishing intensity on the Aran Grounds is high with trawls sweeping the area of the ground several times annually. Given the high intensity of trawling it is likely that unoccupied burrows are filled in quickly. The edge effect bias is more difficult to quantify. This has been estimated by WKNEPH 2009 by double

counting footage, once counting all complexes and then counting only those that remain within the field of view when passing off the bottom of the screen. The difference between these counts are the edge burrows and half of these together with those that remain on the screen are used to estimate the bias.

The WKNEPH reported developed a methodology for developing catch options based directly on the surveys (ICES, 2009a). In addition, WKNEPH developed a methodology for estimating long term fishing mortality reference points. The lack of sampling data meant that stock specific reference points could not be developed for FU17. The methodology was used by WGCSE to develop a catch option table according to the stock annex (ICES, 2009c). Table 2 is an updated catch option table for FU17 using the 2010 survey estimate, mean weight and proportion retained by the fishery from 2010 sampling programme.

In conclusion, the survey estimates themselves are precisely estimated given the relatively homogeneous distribution of burrow density and the modelling of spatial structuring. Large fluctuations in burrow abundance have been observed in this short time series but landings and LPUE trends are not well correlated with these. The 2010 survey is a statistically significant 15% increase compared with 2009. Ultimately there still remains a degree of subjectivity in the production of UWTV abundance estimates. In the provision of catch options based on the bias corrected absolute survey estimates additional uncertainties related to the bias correction factor, mean weight in the landings and the discard rates also arise.

References

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Marrs, S.J., Atkinson, R.J.A, C.J Hills, J.M. (1996) Calibration of towed underwater TV technique for use in stock assessment of *Nephrops norvegicus*. Study project in support of the Common Fisheries Policy XIV/1810/CI/94, call for proposals 94/C 144/04.

Petitgas and Lafont, 1997. EVA (Estimation VAriance). A geostatistical software on IBM-PC for structure characterization and variance computation. Version 2.

Table 1(a): Unrevised summary geostatistics for the *Nephrops* UWTV surveys of the Aran Grounds from 2002-2010.

Ground	Year	Number of stations	Mean Density (No./M2)	Estimation Standard Deviation	Domain Area (m2)	Geostatistical abundance estimate (million burrows)	CV on Burrow estimate
	2002	49	0.84	0.02	943	818	4%
	2003	41	1.01	0.06	943	989	5%
	2004	64	1.43	0.04	943	1397	3%
	2005	70	1.09	0.04	936	1063	3%
	2006	**67**	**0.66**	**0.02**	**932**	**640**	**3%**
	2007	71	0.93	0.02	942	906	3%
	2008	**62**	**0.57**	**0.02**	**842**	**515**	**3%**
	2009	82	0.73	0.02	940	718	2%
Aran	2010	91	0.85	0.02	937	827	2%

Table 1(b): Summary geostatistics for the *Nephrops* UWTV surveys of the Aran Grounds from 2002-2010 with data revisions in 2006 and 2008.

Ground	Year	Number of stations	Mean Density (No./M2)	Estimation Standard Deviation	Domain Area (m2)	Geostatistical abundance estimate (million burrows)	CV on Burrow estimate
	2002	49	0.84	0.02	943	818	4%
	2003	41	1.01	0.06	943	989	5%
	2004	64	1.43	0.04	943	1397	3%
	2005	70	1.09	0.04	936	1063	3%
	***2006**	**67**	**0.64**	**0.02**	**932**	**616**	**3%**
	2007	71	0.93	0.02	942	906	3%
	***2008**	**63**	**0.56**	**0.02**	**906**	**536**	**3%**
	2009	82	0.73	0.02	940	718	2%
Aran	2010	91	0.85	0.02	937	827	2%

* Minor data revision due to transfer of survey data to SQL server.

Table 2: Summary statistics for the *Nephrops* UWTV surveys of the Galway Bay and Slyne Head grounds from 2002-2010.

Ground	Year	Number of stations	Mean Density (No./M^2)	Area Surveyed (M^2)	Burrow count	Standard Deviation	Var	Standard Error	t-value	95%CI	CV_{iid} (Relative SE)
	2002	7	1.58	1,299	2,017	0.37	0.14	0.14	2.45	0.34	8.80%
	2003	3	1.6	591	941	0.29	0.09	0.17	4.3	0.73	10.60%
	2004	9	0.73	2,312	1,625	0.42	0.18	0.14	2.31	0.32	19.40%
	2005	4	1.67	661	1,107	0.2	0.04	0.1	3.18	0.32	6.00%
	2006	3	1.01	522	522	0.25	0.06	0.15	4.3	0.63	14.50%
	2007	5	1.14	890	992	0.24	0.06	0.11	2.78	0.29	9.30%
	2008	10	0.42	1,907	859	0.31	0.1	0.1	2.26	0.22	23.40%
	2009	8	0.93	1,207	1,116	0.16	0.03	0.06	2.36	0.14	6.20%
Galway Bay	2010	10	1.61	1,284	1,757	0.43	0.19	0.14	2.26	0.31	8.6%
	2002	5	0.85	1,216	1,027	0.19	0.04	0.08	2.78	0.23	9.90%
	2003	-	-	-	-	-	-	-	-	-	-
	2004	3	0.68	827	531	0.27	0.07	0.15	4.3	0.66	22.70%
	2005	3	0.55	531	294	0.05	0	0.03	4.3	0.13	5.60%
	2006	3	0.41	526	210	0.2	0.04	0.11	4.3	0.49	28.10%
	2007	4	0.63	841	547	0.31	0.1	0.15	3.18	0.49	24.60%
	2008	-	-	-	-	-	-	-	-	-	-
	2009	6	0.4	531	144	0.22	0.05	0.09	2.57	0.23	22.50%
Slyne Grounds	2010	9	0.74	1,117	928	0.43	0.19	0.14	2.31	0.33	19.6%

Table3: Updated management option table for FU17 with 2010 survey estimate included.

			Implied fishery	
	Harvest rate	Survey Index (millions)	Retained number (millions)	Landings (tonnes)
MSY framework	9.7%	636	41	1,012
F_{2009}	7%	636	29	720
$F_{0.1\ Combined}$	6.0%	636	25	626
$F_{max\ Combined}$	9.7%	636	41	1,012
	0%	636	0	0
	2%	636	8	208
	4%	636	17	416
	6%	636	25	624
	8%	636	34	832
	10%	636	42	1,040
	12%	636	51	1,248
				Basis
Landings Mean Weight (Kg)		0.0246		Sampling 2008 & 2009
Survey Overestimate Bias		1.30		WKNEPH 2009
Survey Numbers (Millions)		827		UWTV Survey 2010
Prop. Retained by the Fishery		0.67		Sampling 2008 & 2009

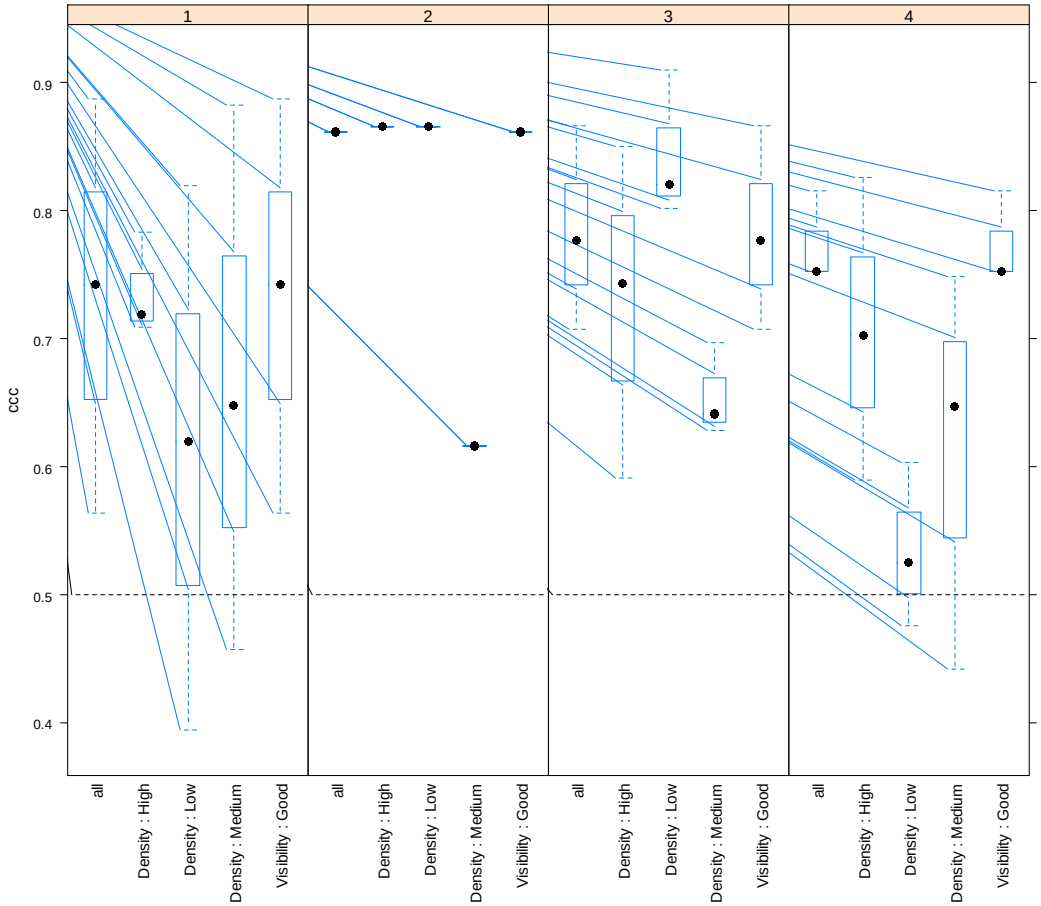

Figure 1: Counting performance against the reference counts as measured by CCC for FU17. Each panel represents an individual. The x-axis (from left to right), all stations pooled, high density, low density, medium density and visibility good.

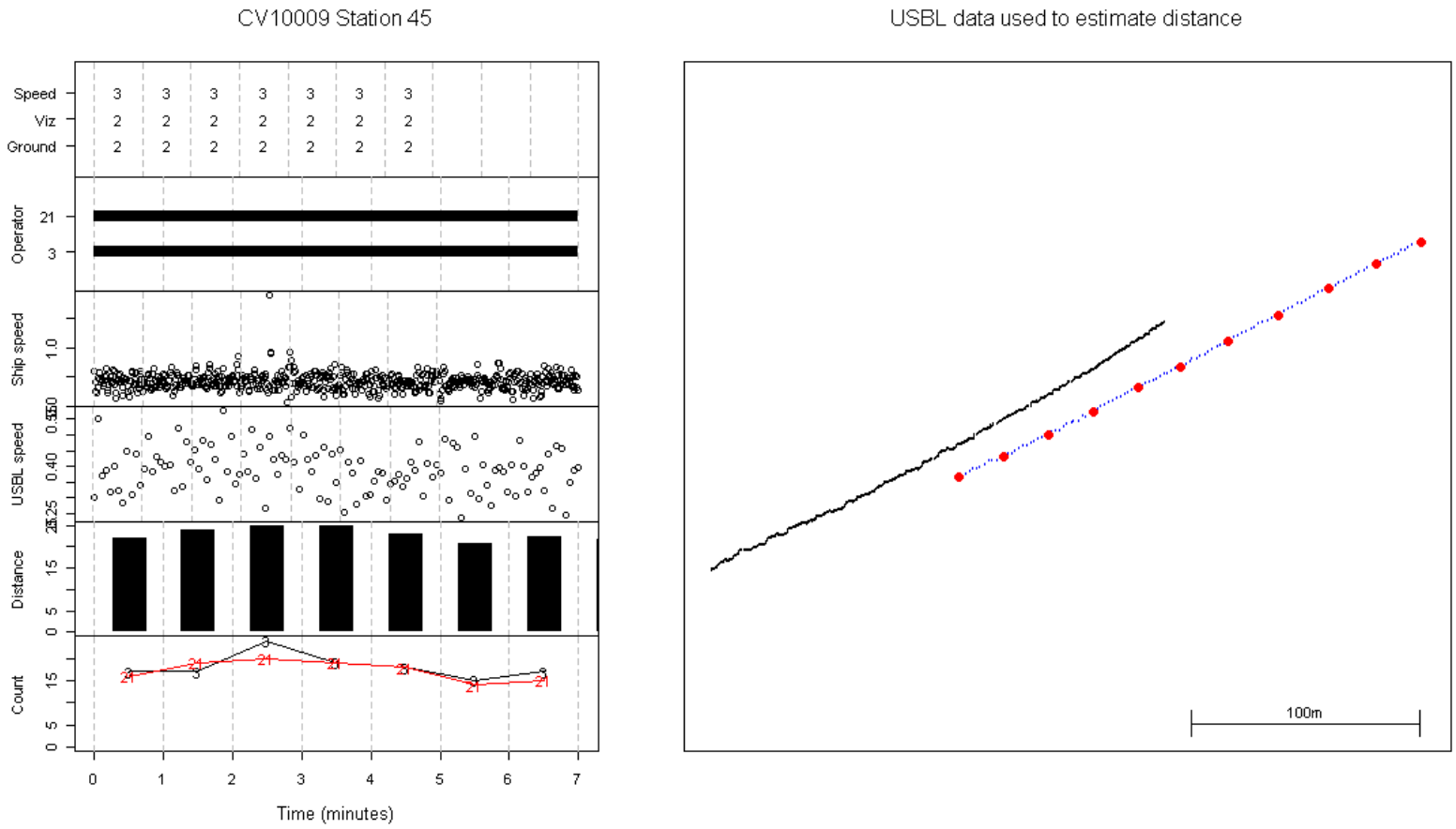

Figure 2: R tool quality control plot of station 45 UWTV Survey Aran Grounds FU17 2010.

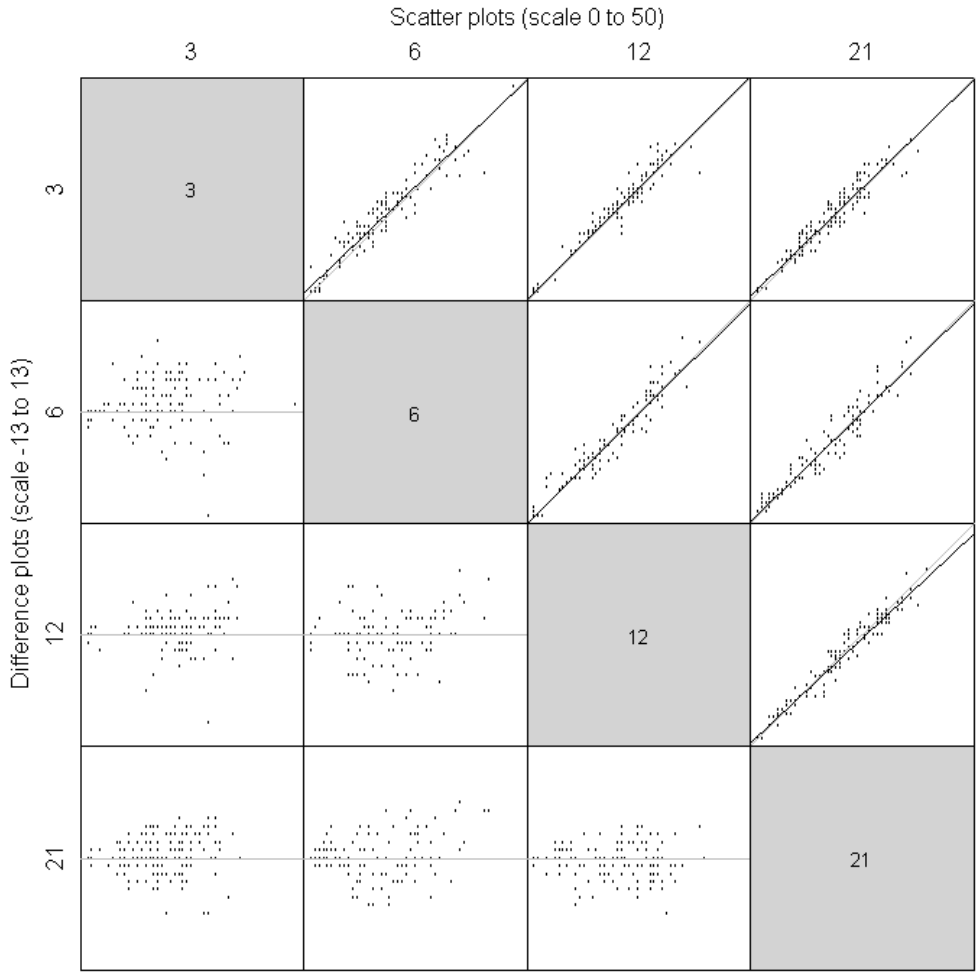

Figure 3: Scatterplot analysis of counter trends during 2010 survey of the Aran Grounds.

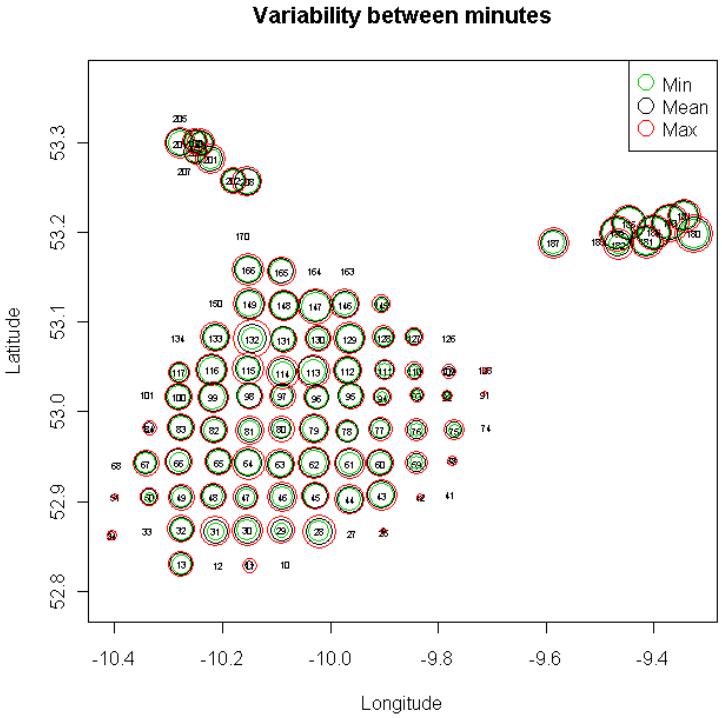

Figure 4: Plot of the variability in density between minutes - Aran Ground UWTV 2010 survey.

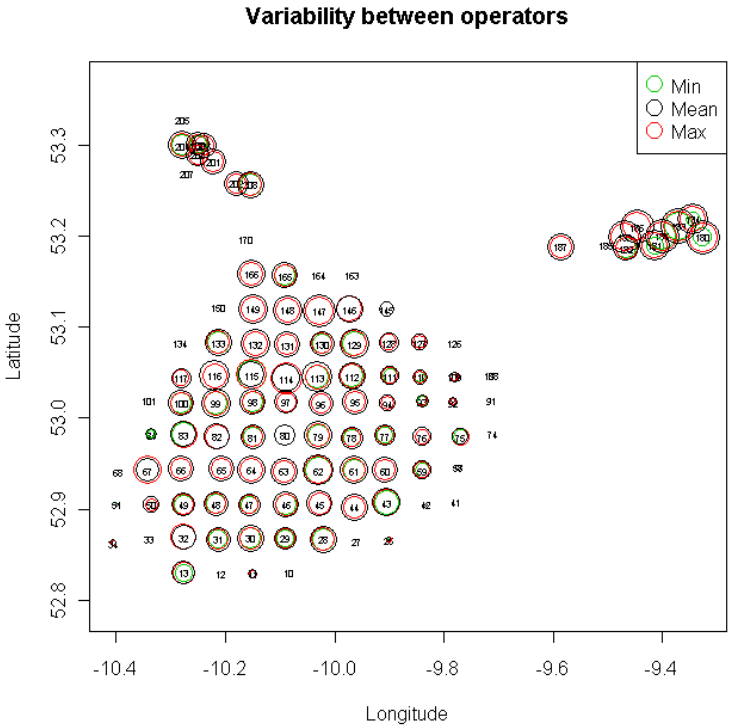

Figure 5: Plot of the variability in density between operators for each station Aran Ground UWTV 2010 survey.

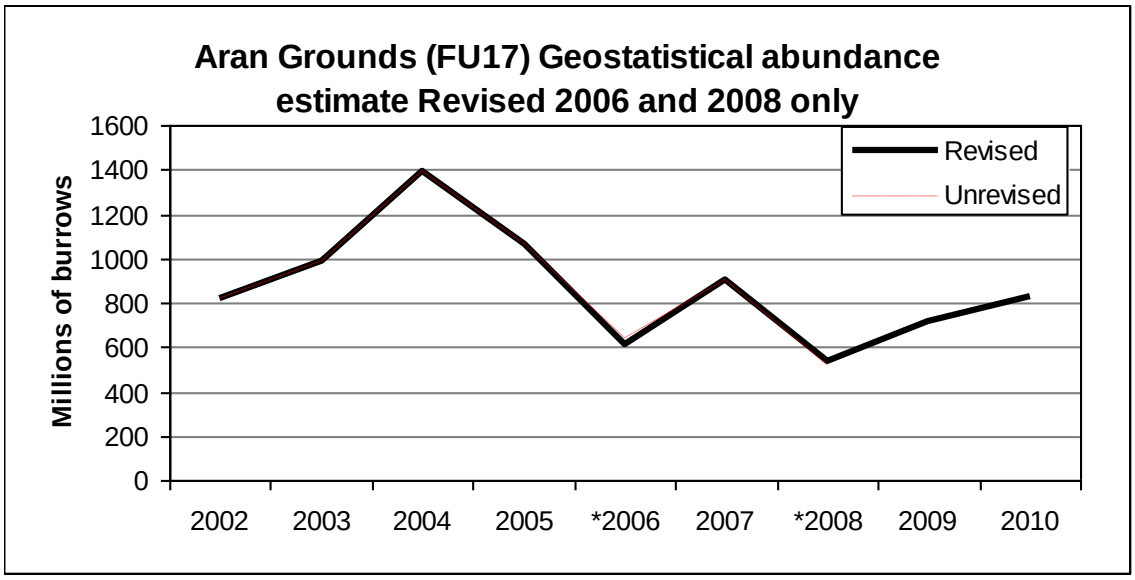

Figure 6: Time series of geostatistical abundance estimates (in millions of burrows) for the Aran Grounds where 2006 and 2008 were revised due to amalgamation of survey data to SQL server.

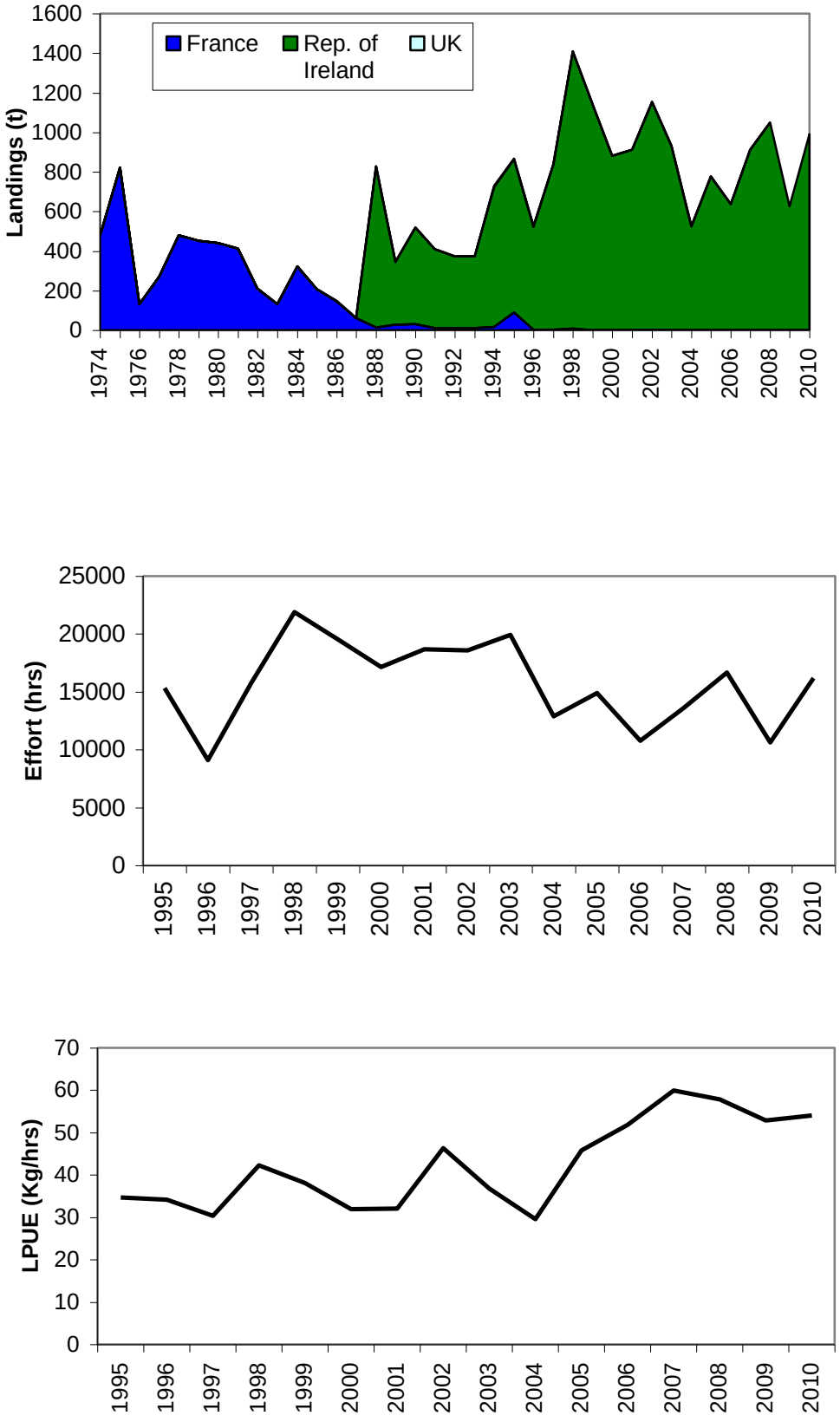

Figure 7: Landings, effort and LPUE trends for the Aran Grounds (FU 17). Note effort and LPUE is for the "*Nephrops* directed fleet" only.

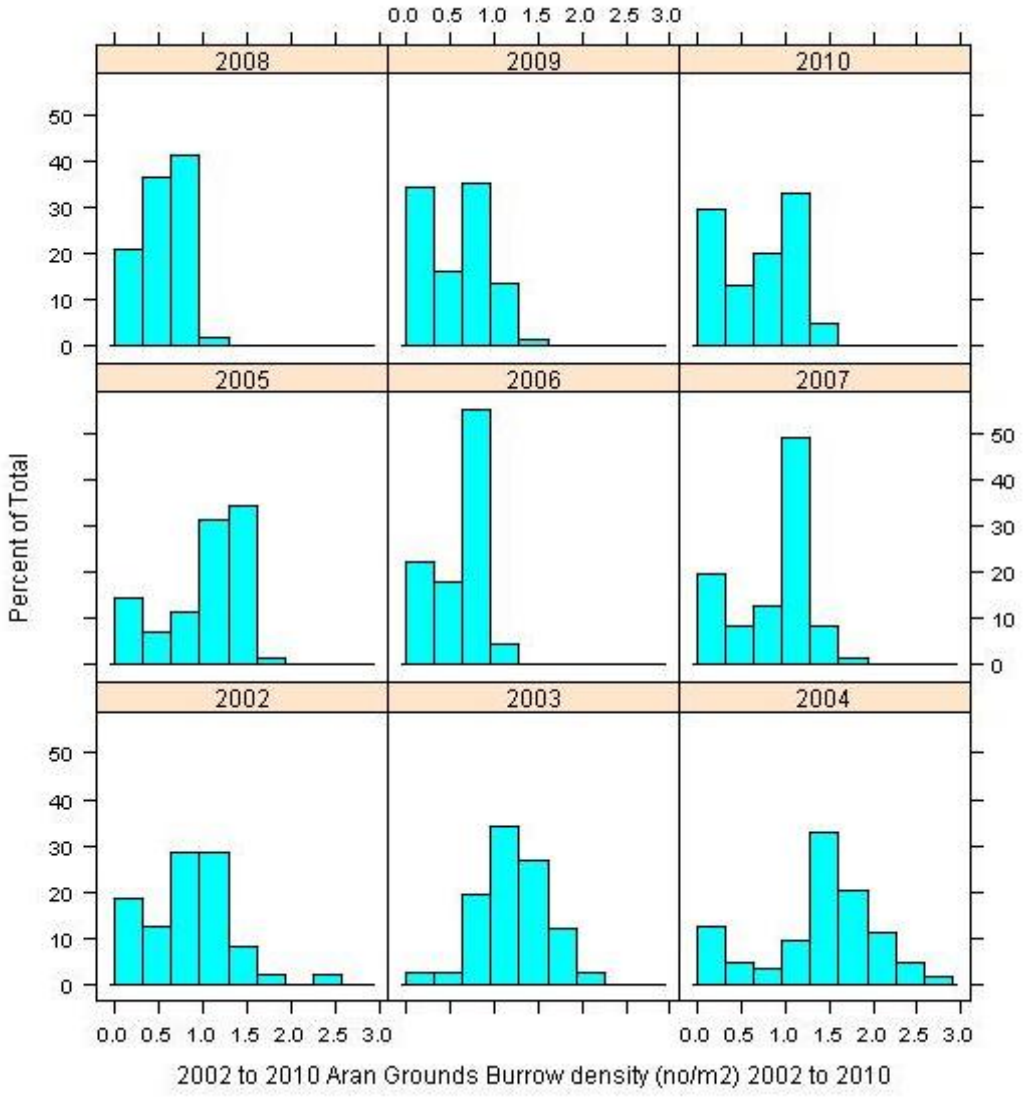

Figure 8: Burrow density distributions for the Aran Grounds by year from 2002-2010.

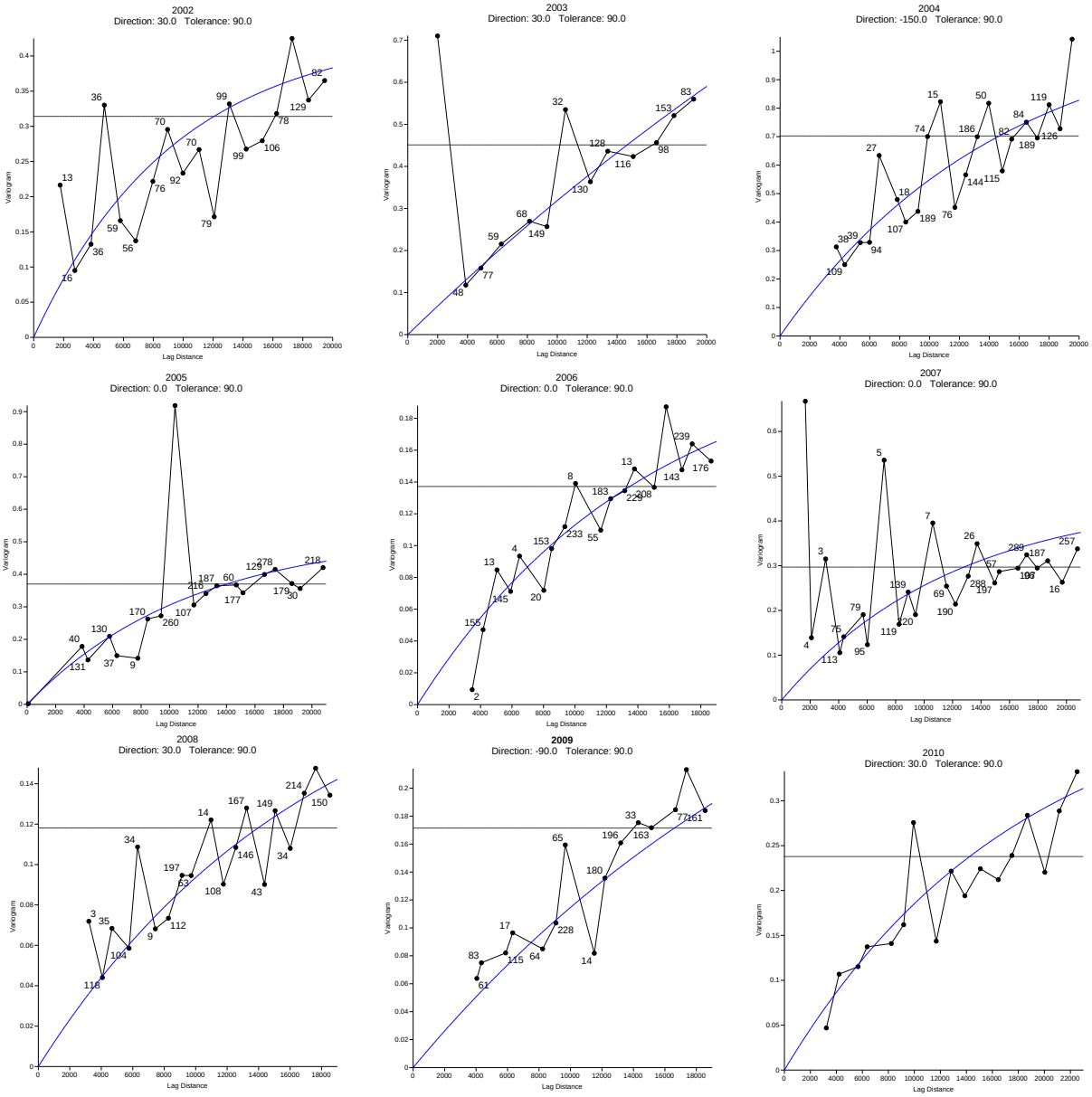

Figure 9: Omnidirectional variogram models used for krigging for the Aran Grounds from 2002-2010.

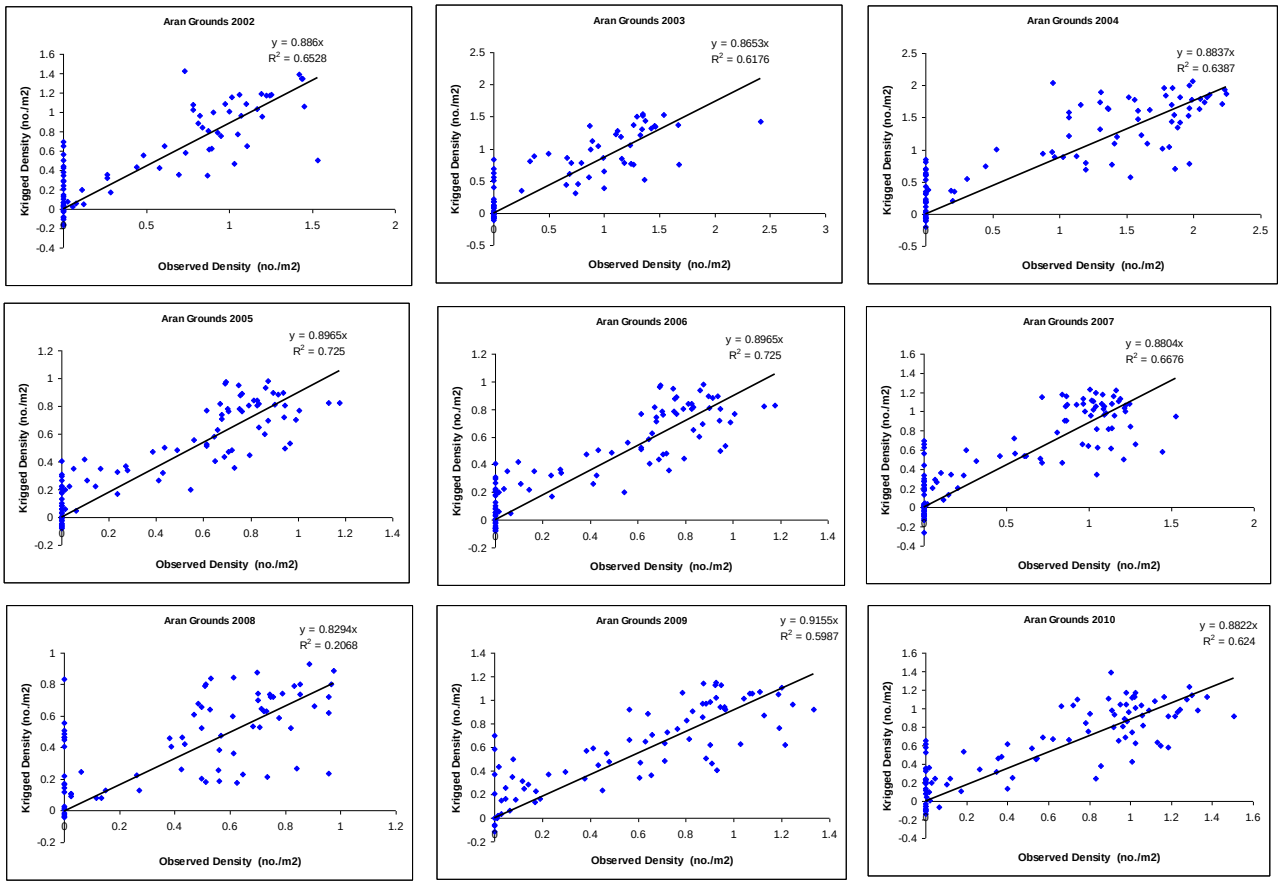

Figure 10: Cross validation plots for the Aran Grounds by year from 2002-2010.

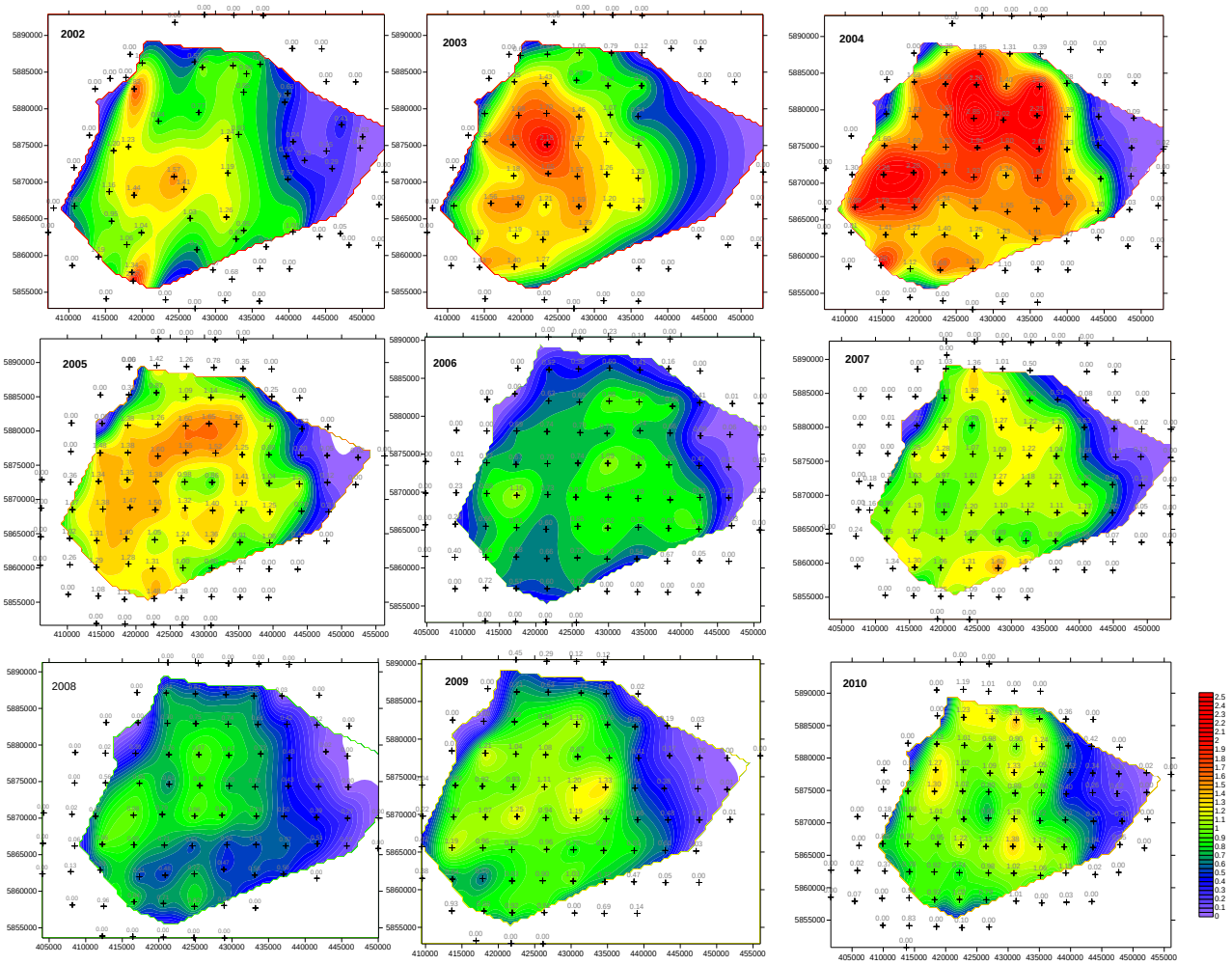

Figure 11: Contour plots of the krigged density estimates for the Aran Grounds from 2002-2010.

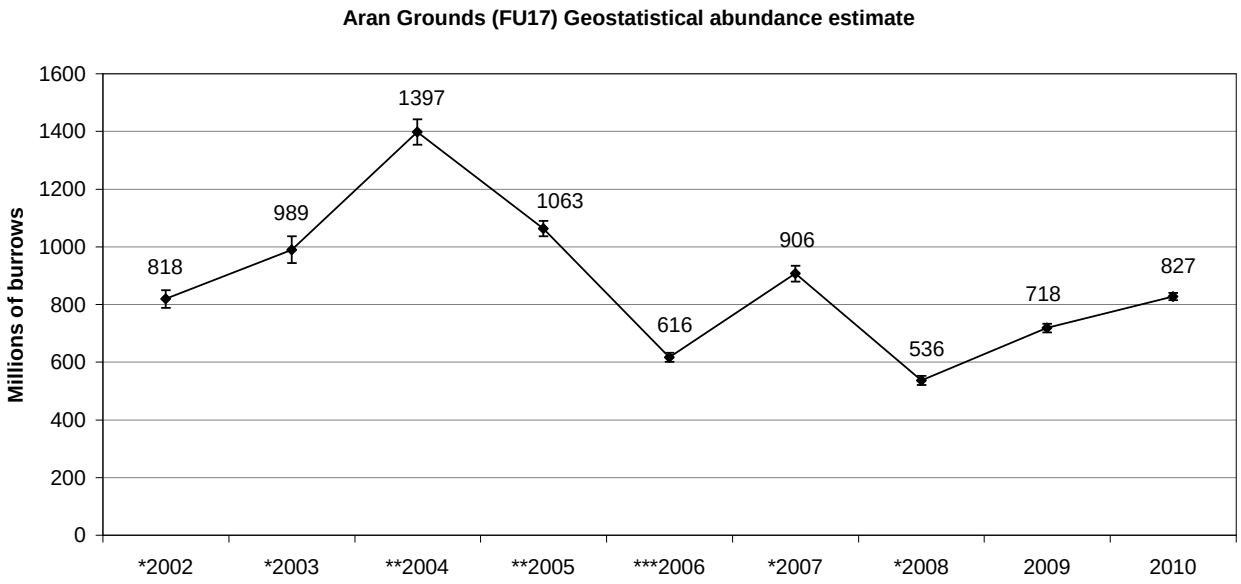

Figure 12 :Time series of geostatistical abundance estimates (in millions of burrows) for the Aran Grounds from 2002-2010.

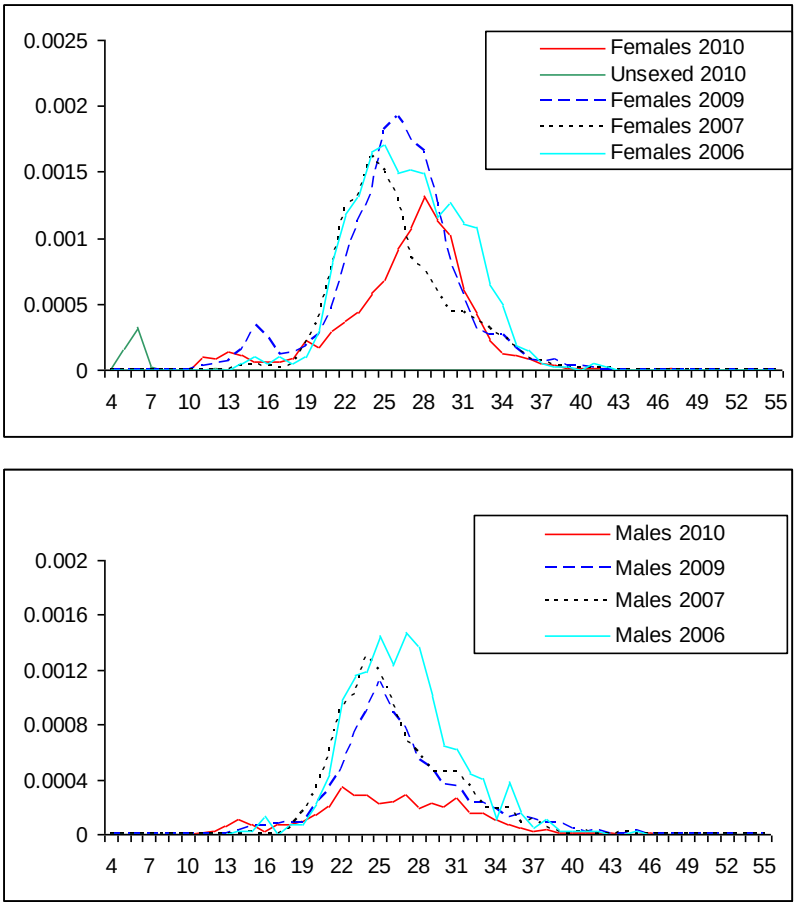

Figure 13 : Standardised length frequency distributions for *Nephrops* caught using beam trawls (nos/m^2) in June 2006 to 2010 on the Aran Grounds *Nephrops* ground.

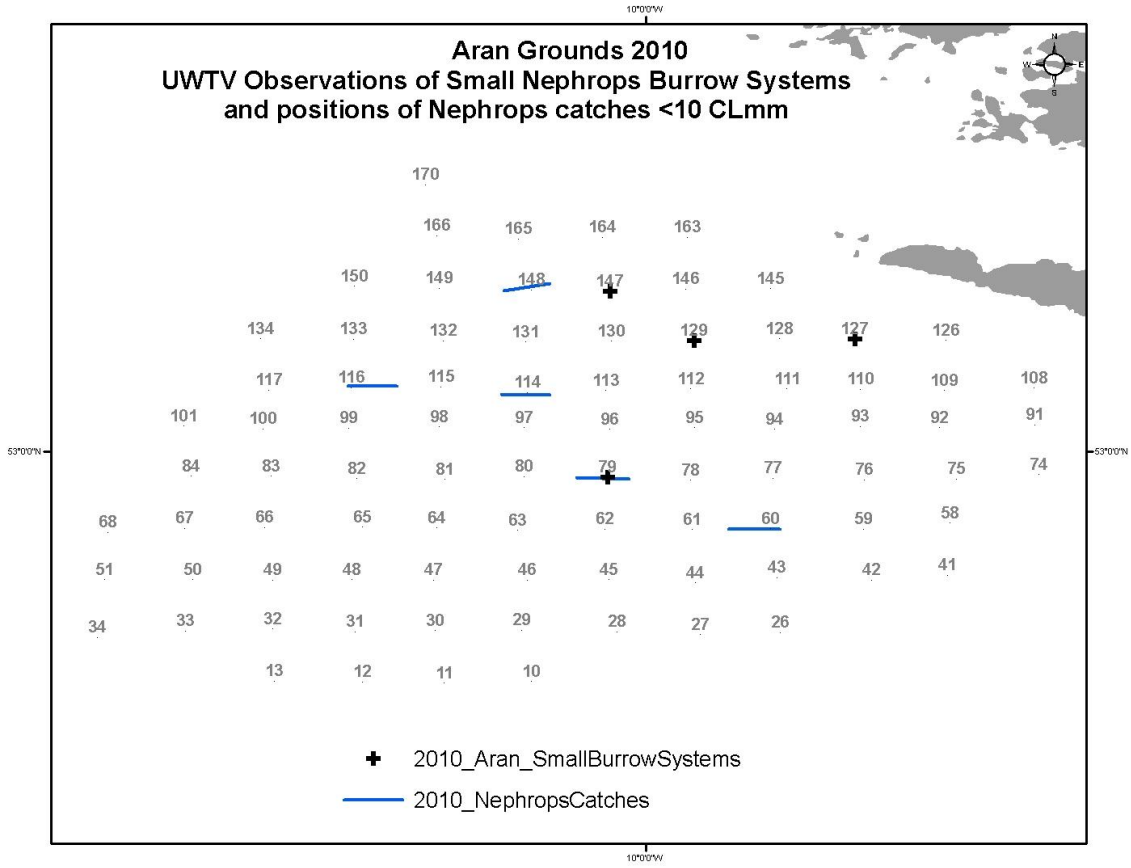

Figure 14 : Blue lines represent tows where *Nephrops* <=10 CL mm were caught and black crosses indicate stations where unusually small *Nephrops* burrows systems were observed during 2010 UWTV survey.