Aran, Galway Bay and Slyne Head *Nephrops* Grounds (FU17) 2014 UWTV Survey Report and catch options for 2015.

Imelda Hehir[1], Jennifer Doyle[1], Colm Lordan[1], Macdara O'Cuaig[1], Orla Hannify[1], Ross Fitzgerald[1], Sean O'Connor[1], Mossie Keith[1], Áine Murphy[1], Michael Sheridan[2] and Yolanda Vila[3].

[1] Marine Institute, Oranmore, Galway, Ireland.
[2] Galway and Mayo Institute of Technology, Galway, Ireland.
[3] Instituto Español de Oceanografía, Centro Oceanográfico de Cádiz, Cádiz, Spain

Version 2 October, 2014

Abstract

This report provides the main results and findings of the thirteenth annual underwater television on the Aran, Galway Bay and Slyne head *Nephrops* grounds, ICES assessment area; Functional Unit 17. The survey was multi-disciplinary in nature collecting UWTV, fishing, CTD and other ecosystem data. In total 33 UWTV stations were successfully completed in a randomised isometric grid design at 3.5nmi or 6.5km intervals over the known range of the stock on the Aran Grounds. The mean burrow density observed in 2014, adjusted for edge effect, was 0.29 burrows/m². The final krigged burrow abundance estimate was 287 million burrows with a CV (or relative standard error) of 4 %. Abundance estimates have fluctuated considerably over the time series. The 2014 abundance estimate was 9% lower than in 2013 and the lowest estimate in the 13 year time series. Raised abundance estimates for Galway Bay and Slyne Head were also low for those areas. Using the 2014 abundance estimate together with updated parameters for mean weight and proportions of removals retained implies catch advice, fishing at F_{msy} ($=F_{35\%spr}$), of 584 tonnes and landings of 524 tonnes in 2015. *Nephrops* accounted for approximately 70% of the benthic catch by weight from 5 beam trawl tows. The relatively high numbers caught around 15 CL mm (carapace length) may indicate strong incoming recruitment. *Virgilaria mirabilis* was the most common of the two sea-pen species observed on the UWTV footage. *Funiculina quadrangularis* was observed at one station on the Slyne Head *Nephrops* ground.

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

Suggested citation:
Hehir, I., Doyle, J. , Lordan, C., O'Cuaig, M., Hannify, O., Fitzgerald, R., O'Connor, S., Keith, M., Murphy, A., Sheridan, M., and Vila, Y. 2014. Aran, Galway Bay and Slyne Head *Nephrops* Grounds (FU17) 2014 UWTV Survey Report and catch options for 2015. Marine Institute UWTV Survey report.

Introduction

The prawn (*Nephrops norvegicus*) are common around the Irish coast occurring in geographically distinct sandy/muddy areas where the sediment is suitable for them to construct their burrows. The *Nephrops* fishery in VII is extremely valuable with landings in 2013 worth around € 80 m at first sale. The *Nephrops* fishery 'at the back of the Aran Islands' can be considered the mainstay of the Ros a Mhíl fleet. Estimated landings of 1295 t in 2013 were worth and approximately €7 m at first sale. 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 and exploitation rates are required to inform sustainable management of this resource.

Nephrops spend a great deal of time in their burrows and their emergence behaviour is influenced by several factors: time of 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 & 2013). This is the thirteenth annual UWTV survey of the 'Aran grounds'. The survey covers three geographically discrete mud patches; the Aran Ground, Galway Bay and Slyne Head all of which lie within the ICES assessment area Functional Unit 17 (FU17) (Figure 1). The 2014 survey was multi disciplinary in nature; the specific objectives are listed below:

1. To complete randomised fixed isometric survey grid of 31 UWTV with 3.5 nautical mile (Nmi) spacing stations on the "Aran" *Nephrops* ground.
2. To carry out >5 UWTV indicator stations on the Galway Bay and Slyne Head *Nephrops* ground.
3. To obtain 2014 quality assured estimates of *Nephrops* burrow distribution and abundance on the "Aran" *Nephrops* ground (FU17). 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 sample *Nephrops* and macro benthos using a 4 m beam trawl deployed at ~10 stations.
7. To use the time saved (from reduced grid in FU17 Aran Grounds) to extend the UWTV survey to FU16 Porcupine.

This report details the final UWTV results of the 2014 survey and also documents other data collected during the survey. The 2014 abundance are used to generate catch options for 2015 in line with the recommendations and procedures outlined in the stock annex for FU17 (ICES, 2014).

Material and methods

Since 2012 the survey design has been based a randomised isometric grid with stations every 3.5Nmi or 6.5km. This spacing was used to achieve good spatial coverage over the known extent of the ground and to generate burrow surface that reflects the underlying abundance. The same ground boundary has been used for the Aran grounds throughout the time series. Stations in Galway Bay and Slyne Head were randomly picked from an area defined by

previously collected UWTV data, VMS data (Gerritsen & Lordan, 2011) and multi-beam backscatter data (Figure 1 & 2).

Survey timing was generally standardised to June each year. In 2003, poor weather and technical problems meant that coverage was poor compared with the other years. 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 and 2008 due to weather downtime stations could not be completed at Slyne Head. In 2014 all three *Nephrops* grounds were surveyed successfully during June on RV Celtic Voyager.

The operational protocols used were those reviewed by WKNEPHTV 2007 (ICES, 2007) and employed on other UWTV surveys in Irish waters. These protocols can be summarised as follows: At each station the UWTV sledge was deployed. Once stable on the seabed a 10 minute tow was recorded onto DVD. Time referenced video footage was collected by one video camera with a field of view or 'FOV' of 75 cm. Vessel position (DGPS) and position of sledge (using a USBL transponder) were recorded every 2 seconds. The navigational data was quality controlled using an "r" script developed by the Marine Institute (ICES, 2009b) an example is shown in Figure 3. In 2014 the USBL navigational data was used to calculate distance over ground for all stations.

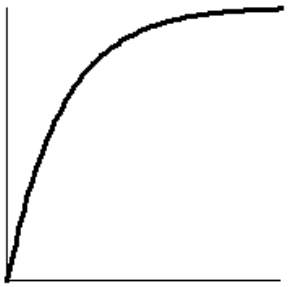
In line with SGNEPS recommendations all scientists were trained/re-familiarised using training material and validated using reference footage for the Aran Grounds prior to recounting at sea (ICES, 2009b). Figure 4 shows individual's counting performance in 2014 against the reference counts as measured by Linn's concordance correlation coefficient (CCC). A threshold of 0.5 was used to identify counters who needed further training. Once this training and testing process had been undertaken, all recounts were conducted by two 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 for each one-minute interval. Following the recommendation of SGNEPS the time for verified recounts was 7 minutes (ICES, 2009b).

The occurrence of trawl marks, fish species and other species was also recorded for each minute. Abundance categories of sea-pen species were also recorded due to OSPAR Special Request (ICES 2011). A key was devised to categorise the densities of seapens based on SACFOR abundance scale (Table 1) 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. Consistency and bias between individual counters was examined using Figure 5. There is some variability between counters but no obvious bias or excessive deviations.

The recount data were screened for one minute intervals with any unusually large deviation at sea. These minutes were re-verified by means of consensus counts. Mean density was calculated by dividing the total number of burrow systems by the survey area observed. The 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 using lasers during the 2014 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).

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 2014 there was no need to include addition stations, with assumed zero density outside the known distribution of *Nephrops* or suitable sediment, in the krigging process. An un-weighted and un-smoothed omni-directional variogram was constructed with a lag width of approximately 1000m and maximum lag distance of between 17-20 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 were all extremely close to the Surfer estimate (+- 55 million burrows) with the exception of 2004 when the spatial coverage was poor.

To estimate the abundance for Galway Bay and Slyne Head grounds, the area of each ground based on a VMS delimited polygon was calculated in ArcGIS10 and an average value used (Table 2). The abundance estimation is the product of the mean density and ground area. The sample variances, standard errors, t-values and 95% CI were calculated for each ground.

For each UWTV station a CTD profile was logged for the duration of each tow using a sled mounted and calibrated Seabird SBE37. The sensor takes readings every 5 seconds and is processed to calculate an average bottom temperature and salinity for each cast and Surfer contour plots (Figure 11) are presented in this report. CTD data for Slyne Head and Galway bay are also available but not plotted as the area of these grounds is <150 km².

Five beam trawl tows were conducted randomly across the Aran grounds once TV operations were successfully completed. All *Nephrops* caught were sorted by sex and maturity category,

weighed and measured using the NEMESYS electronic measuring system. A length stratified sub-sample of *Nephrops* was taken for each haul where individual length, whole weight, tail weight and maturity were recorded. This year samples of males were frozen for measuring appendix masculina lengths back in the laboratory. The results of the male maturity study will be available later. The fish catch was identified to species level and sampled by weight (kgs) only. The benthic catch was identified, weighed (g) and counted. The UWTV station positions and tracks for the five valid beam trawl tows are shown in Figure 1.

Results

The station positions for the 33 stations on the Aran grounds, 5 in Galway Bay and 4 at Slyne head are shown in Figure 2. A combined violin and box plot of the observed burrow densities from 2006 to 2014 is presented in Figure 6. This shows relatively large inter-annual variation in mean, median and density ranges over time. Density increased in first three years of the time series but then declined significantly in 2006. Since then there has been a gradual downward trend. The 2014 median of adjusted[1] density was between 0.32 burrow/m^2. It was very noticeable that there was a substantial reduction in density throughout the ground with no high density (> 0.7/m^2) observed. Figure 7 and Figure 8 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.

The geostatistical structural analysis is shown in the form of variograms in Figure 9. There are a few outliers apparent but they appear to have little leverage on the variogram models observed. There is weak evidence of a sill at around 12km in some years but it is not clear and the exponential model used does not have a sill. The blanked krigged contour plot and posted point density data are shown in Figure 10. 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 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 (Figure 1). The decline in density throughout the area over the last three years is striking. Densities in the middle and northern part of the ground are in general 50% lower than was observed in 2011.

The summary statistics from this geo-statistical analysis for the Aran Grounds are given in Table 3 and Figure 11. The 2014 adjusted estimate of 287 million burrows is a 9% lower than in 2013. The estimation variance of the survey as calculated by EVA is relatively low (CVs in the order <4%). The 2014 adjusted abundance estimate is 54% below the geometric mean of the series (534 million burrows). The abundance estimates for the Aran Grounds have fluctuated considerably each year to date but there is a declining trend in recent years.

The summary statistics for the stations on Slyne head and in Galway Bay are given in Table 4. The abundance estimates for Galway Bay *Nephrops* ground and for Slyne Head *Nephrops* ground also are shown in Figure 11. The Galway Bay estimates fluctuate widely but appear to

[1] Note the "adjusted" density estimates in this report are adjusted by dividing by 1.3 to take account of edge effect over estimation of area viewed during UWTV transects (see Campbell et al 2009).

be highly correlated with the Aran ground (except 2004). Estimates for the Slyne Head ground also fluctuate considerably but show no significant correlation with the other areas. The uncertainty bounds for both areas also fluctuate and inter-annual changes are only statistically significant in a few years. On average the Aran Grounds account for ~88% of the total estimated burrow abundance from FU17. Galway Bay and Slyne Head account for 9% and 3% respectively.

Figure 12 shows the standardised length frequency distributions (LFDs) by sex of *Nephrops* caught using a beam trawl on the Aran grounds between 2006 and 2014 surveys. No fishing was carried out on surveys prior to 2006 or in 2008 (due to time constraints as a result of poor weather conditions). For plotting purposes the individuals <10 CL mm caught in 2010 were split evenly between males and females as it is not possible to accurately assign sex to individuals that small. There is weak indication of a year class signal in 2010 and 2011 but few individuals less than 20 CL mm in most years. The mean lengths for both sexes in the survey have been fairly stable over time around the overall average of 27.61 CL mm. It should be noted that there is some variability between the sample sizes and structure for individual hauls shown in Figure 13. In 2014 there is an obvious mode in both sexes at around 15 CL mm which are presumable the 2013 year class. The majority of this year class are <17 CL mm the assumed selection length for the UWTV survey.

In 2014 various morphometric measurements were made during the survey. The estimated length-weight parameters are given in Table 5 together with those currently used in data raising by ICES for this stock. Bias correction factors for the length-weight conversions are also provided since linear models were fitted to the log CL and log weight data. Male growth was allometric and no significant difference was observed for the b parameter compared to that currently used for the stock. Female growth was also allometric and the estimated b parameter was statistically different ($p>0.01$) than that used by ICES. Figure 14 depicts a modelled maturity ogive (binomial GM) for female *Nephrops* where 50% of the females are mature at 22.5 CL mm. The 2014 results of the study of appendage masculina length (mm) will be presented at a later stage as processing will be undertaken ashore rather than at sea for this fine-scale study.

A summary of the benthic taxa by tow is presented in Table 6. *Lunatia species* (necklace shell) was the most abundant species and was recorded in all tows. *Goneplax rhomboids,* a burrowing crab species, was also caught in all of the tows. *Munida rugosa* (squat lobster) was recorded in two tows and this species makes shallow burrows which are often observed in the survey footage from the northern sector of the Porcupine Banks (FU16). *Eledone cirrhosa* (curled octopus) was also recorded, this species is a noted predator of crustaceans and has been filmed lying close to the *Nephrops* burrow entrances on the Smalls ground (FU22). Table 7 summarises the fish catches. Six fish species were recorded in all beam tows; *Lophius piscatorius* (white-bellied monkfish), *Lepidorhombus whiffiagonis* (megrim), *Glyptocephalus cynoglossus* (witch), *Merluccius merluccius* (hake),*Callionymus lyra (common dragonet) and Hippoglossoides platessoides* (dab). *Lophius piscatorius* was the biggest catch recorded of 1.472 kgs in tow 4.

The sea-pen presence-absence observations across the *Nephrops* grounds are mapped in Figure 15 using the key described in Table 1. The majority of sea-pens were identified from the video footage as *Virgularia mirabilis* and there was one observation of *Funiculina quadrangularis* on the Slyne Head patch. *V.mirabilis* was also present at stations where trawl marks were recorded. This seapen species was recorded as frequently present at 43% and

occasionally present at 68% of total stations. Trawl marks were noted at 55% of the Aran stations surveyed with trawl marks present for the entire video transect for 3% of stations. Trawl marks were present at one station at Galway Bay and at all stations at Slyne Head.

A summary of the CTD results collected during the survey are presented in Figure 16. The bottom temperature on the main Aran Grounds and Slyne head was around 9.5^{o}C with slightly warmer water to the east. In Galway Bay the bottom temperature was significantly higher >11^{o}C. The highest bottom salinities were on the Aran ground with significantly lower salinities towards the east in Galway Bay.

The input parameters for the catch option tables, mean weight and proportions of removals retained, are given in Table 8 (ICES, 2014). The catch and landings options at various different fishing mortalities are calculated in line with the stock annex using the 2014 survey abundance. Fishing at F_{msy} ($=F_{35\%spr}$) in 2014 would result in catches of 584 tonnes and landings of 524 t.

Discussion

Observed burrow densities have fluctuated a lot over time in this area. This is in contrast to the rather stable burrow abundance estimates in FU15 and FU22 over similar time frames (Lordan et al, 2014 and Ligas et al., 2014). The burrow abundance decreased significantly over the time series and the 2014 survey estimate is the lowest in the 13 year time series. No lower abundance limit or MSY $B_{trigger}$ has been defined by ICES for FU17. This was mainly due to the relative shortness of the time series to date. There has been no objective way of setting a MSY $B_{trigger}$ from UWTV surveys other than using a lowest observed abundance when a suitably long time series exists. WGNEPS 2014 is due to discuss methods of estimate MSY $B_{trigger}$ and other possible biomass reference points (e.g. B_{buff}) later this year. In the last years the large reduction in burrow abundance was very striking across the whole ground. It was particularly obvious in the northern parts of the ground where the once heavily bioturbated sea bed was now very flat and featureless.

The fishing mortality in 2012 and 2013 was well above the target (F_{msy}). Despite the low abundance in the last three surveys the landings and Lpue have remained high level with around average effort (ICES, 2014). There is a significant negative correlation ($p < 0.001$) between Lpue and abundance (Figure 17). This suggests that either that at low abundance catchability increases or that an increase in catching efficiency in the last three years has caused the low abundance or indeed a mixture of both. Previous survey reports speculated that the explanation for high variability in abundance could be linked to the survey observing variable recruitment or that natural mortality may be high and/or variable on this ground. The high catches around 15 CL mm in beam trawl for the first time in the time series maybe an indication of a strong 2013 year class. In defining the reference points it is assumed that only individuals >17 CL mm make countable burrows.

This stock will be benchmarked in 2015. This benchmark will improve the boundary definition for the main Aran ground area (Figure 1) and integrate the burrow abundance estimates for Galway Bay and Slyne Head. For the moment these underestimates in stock abundance are taken into account within the bias correction factor applied for the whole of FU17 advice. This new information may require a revision of this bias correction factor. The reference points will also need to be reassessed on the basis of improved recent sampling data

and fishery information. The recent biological sampling data, including data collected on this survey, should be investigated during the benchmark to see if length-weight or maturity parameters require revision. The length-weight parameters for females were significantly different from those currently used. This was not the case last year but was also true in 2012.

Macrobenthos data from the trawl catches was collected for the fourth year. The dominant species by weight was *Nephrops norvegicus* followed by *Lunatia species* (necklace shell) and then *Crangon* species (brown shrimp). Overall there is a similar benthic species composition between the tows reflecting the habitat type encountered which is generally homogenous sandy mud. *Virgularia mirabilis* were caught by the beam trawl and recorded in 4 tows and this reflects the common occurrence of this species observed on the video footage. Two other burrowing species: *Goneplax rhomboids* (box crab) and *Munida rugosa* (squat lobster) were recorded. Of those *Goneplax rhomboids* 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 & 2009b).

A broad diversity of fish species were caught (20 species). Of these *Lophius piscatorius* (white-bellied monkfish) was the most abundant followed by *Lepidorhombus whiffiagonis* (megrim). These species are typically encountered in the catches of surveys and commercial vessels on the Aran grounds.

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 2009b).

The CTD data collected during the survey will augment the knowledge base on habitat and oceanographic regime.

The main objectives of the survey were successfully met for the thirteenth successive year. The UWTV coverage and footage quality was excellent throughout the survey. Also the number of beam trawls was limited to 5 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 Colin McBrearty (Master) and crew of the RV. Celtic Voyager; Jason White, Tommy Greely, Adam Rahilly, Finbar Goggin, Lar Kirwan and Tommy Barry for their good will and professionalism throughout the survey. Thanks also to Antony English P&O Maritime IT & Instrumentation Technician**,** for handling all onboard technical difficulties. Thanks to Aodhan Fitzgerald RVOPs and Rob Bunn FEAS at the Marine Institute for organising survey logistics. Thanks to Gordon Furey, Barry Kavanagh and Tom O'Leary P&O Maritime for shore side support. Kieran Lyons and Alan Berry processed the CTD data.

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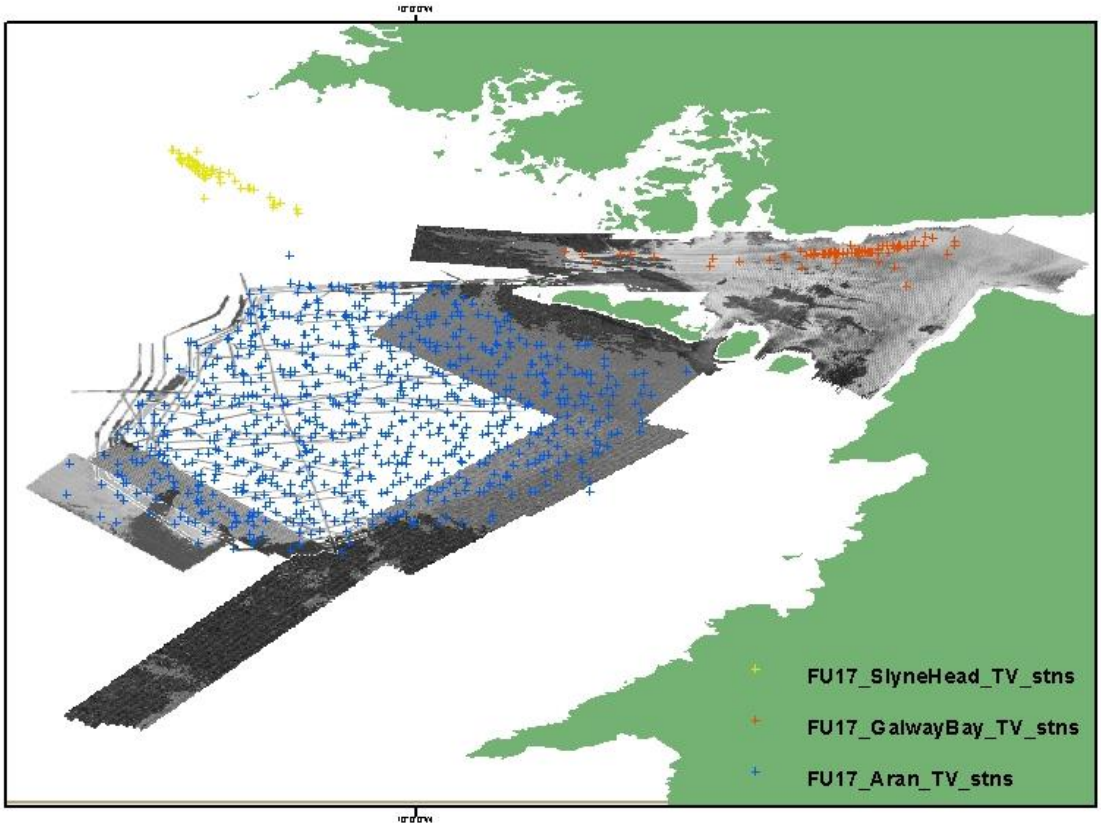

Figure 1: The spatial distribution of all UWTV survey stations from 2002-2014 in Functional Unit 17 overlaid on multibeam backscatter data (source: INFOMAR 2005-2014). Darker backscatter indicates harder seabed substrate.

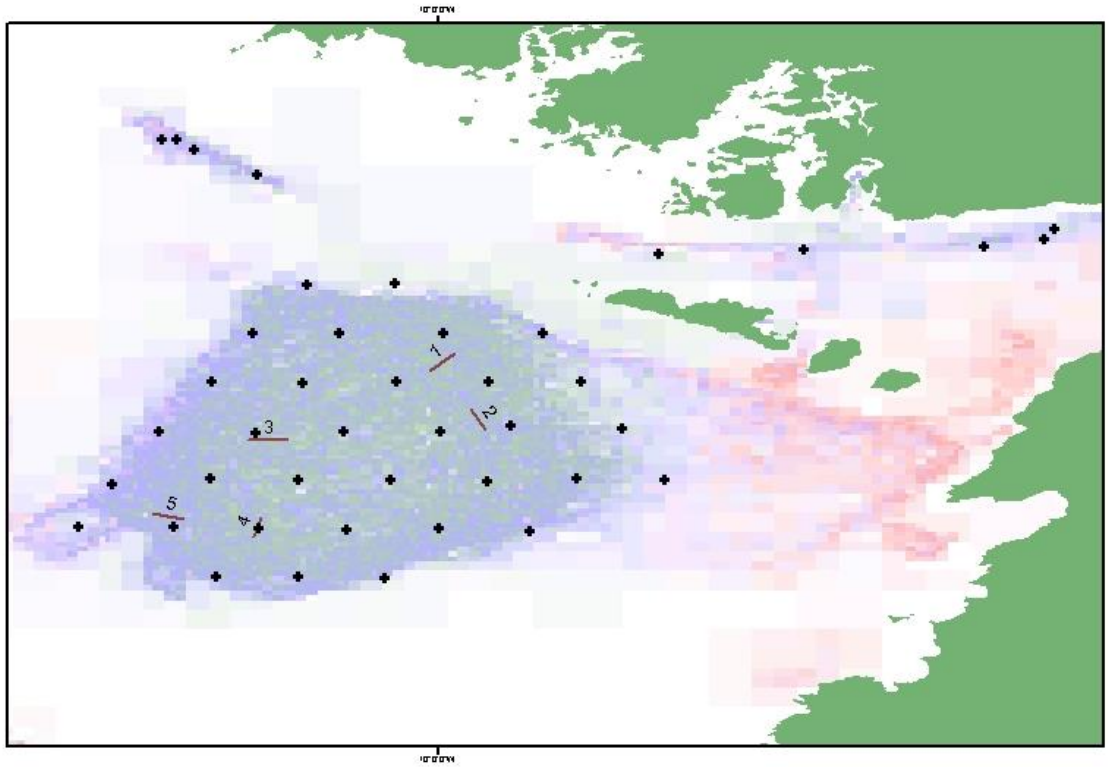

Figure 2: FU17 Aran grounds: UWTV Stations and 5 beam trawl tows completed in 2014 overlaid on a heat map *Nephrops* directed fishing activity between 2006-2012.

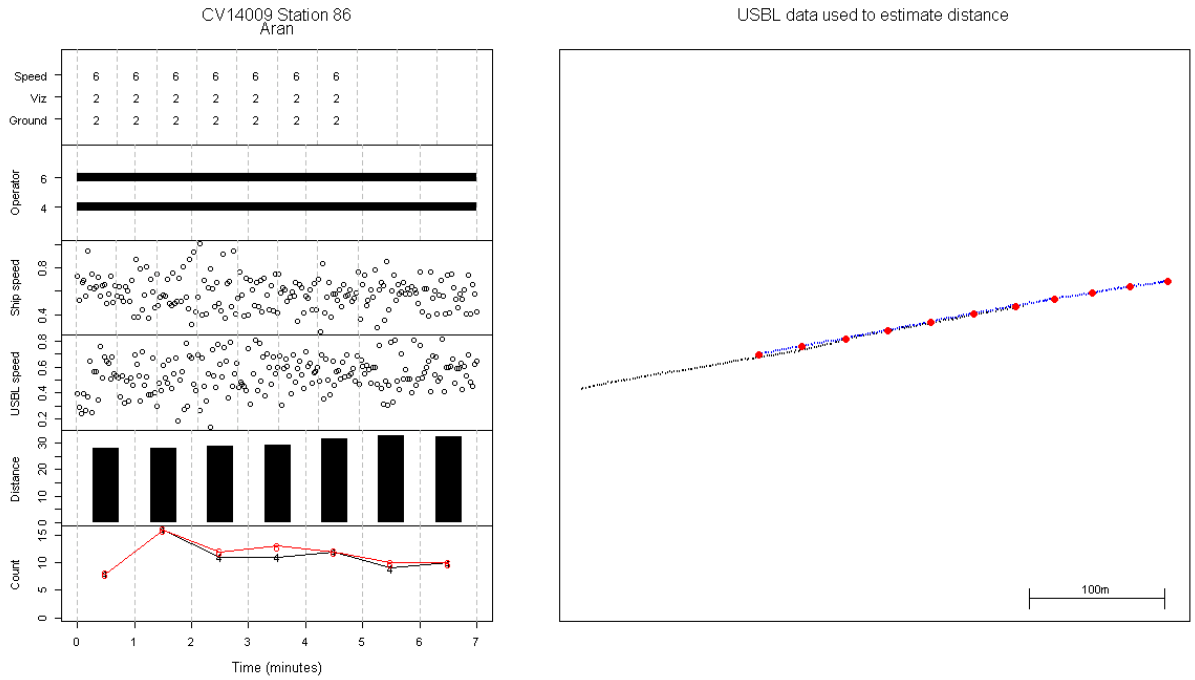

Figure 3 : FU17 Aran grounds: r - tool quality control plot of station 86 of the 2014 survey.

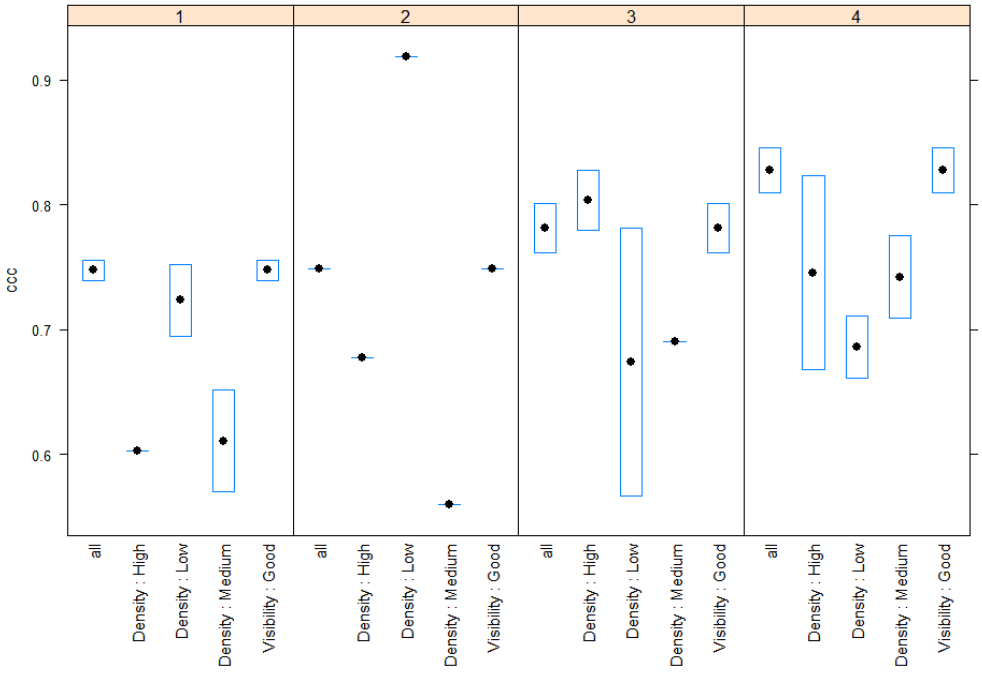

Figure 4: FU17 Aran grounds: 2014 Counting performance against the reference counts as measured by Linn's CCC for FU17 "Aran grounds". Each panel represents an individual. The x-axis (from left to right), all stations pooled, high density, low density, medium density and visibility good.

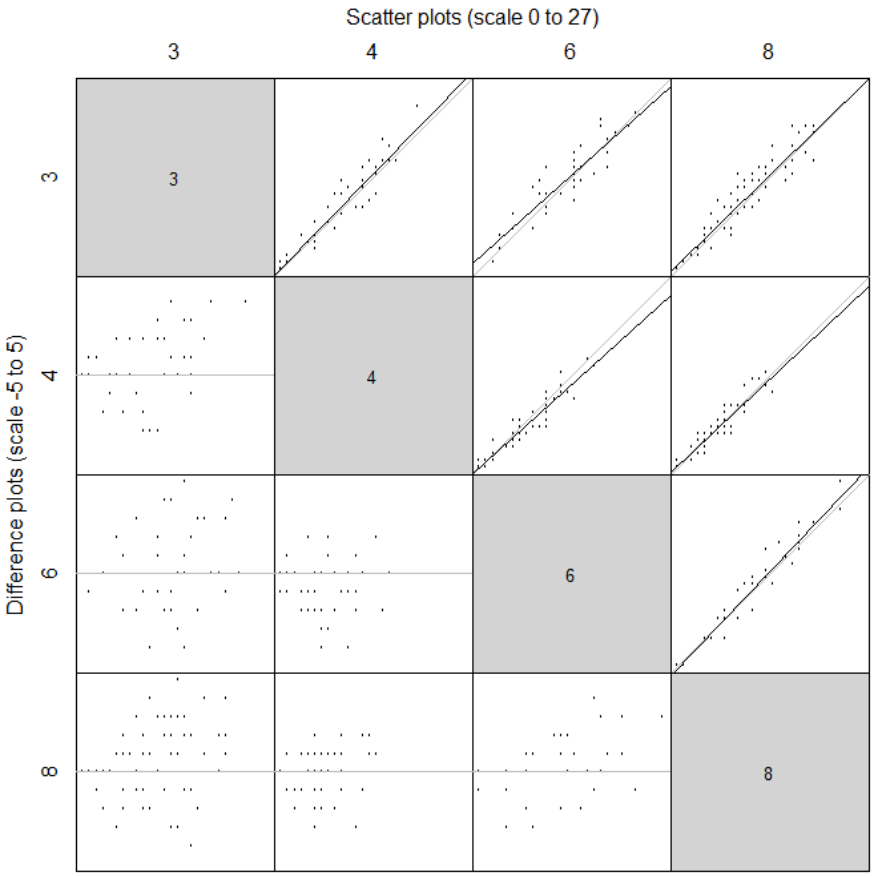

Figure 5: FU17 Aran grounds: Scatter plot analysis of counter correlations for the 2014 survey.

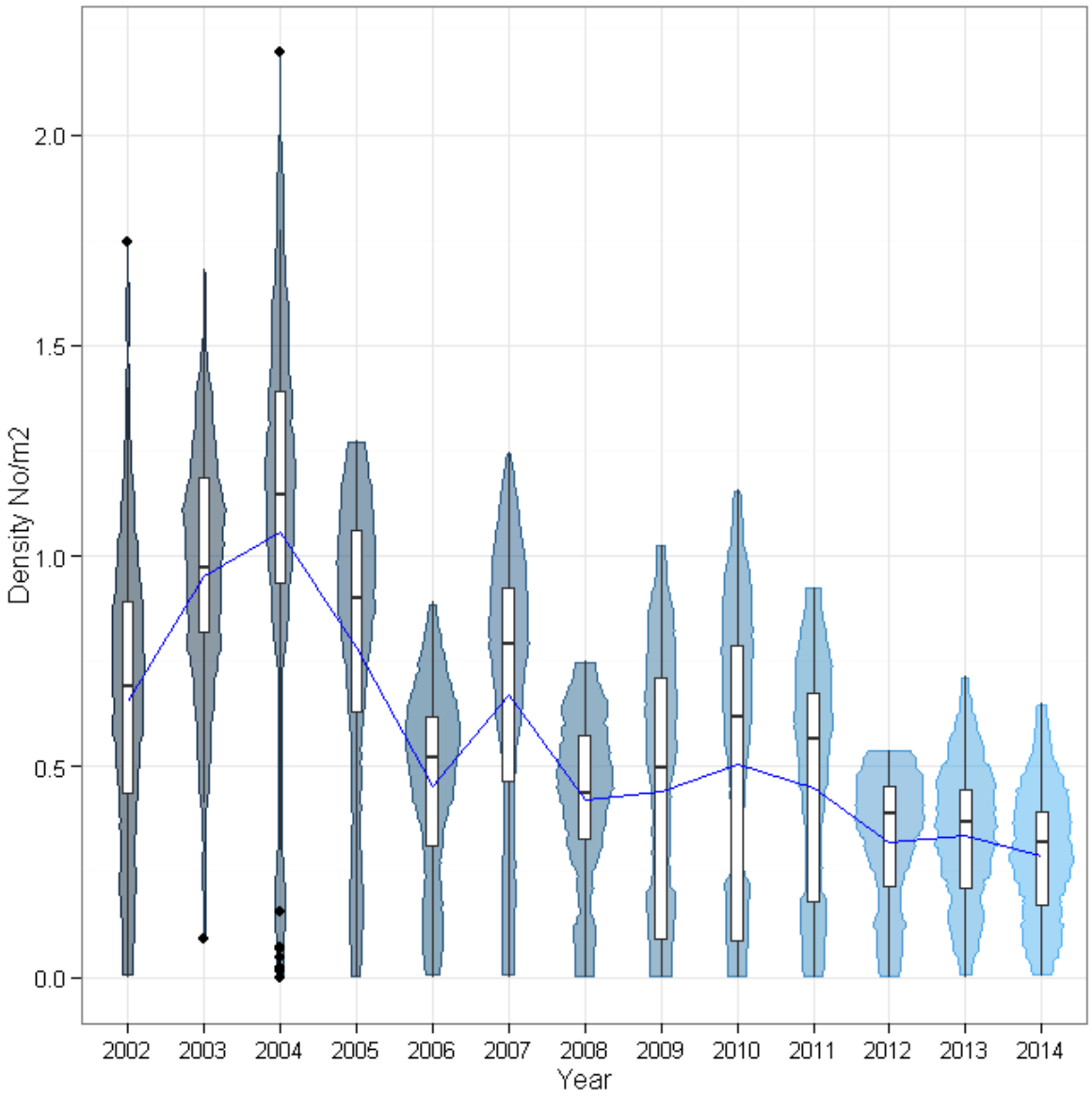

Figure 6: FU17 Aran grounds: Violin and box plot a of adjusted burrow density distributions by year from 2006-2014. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers.

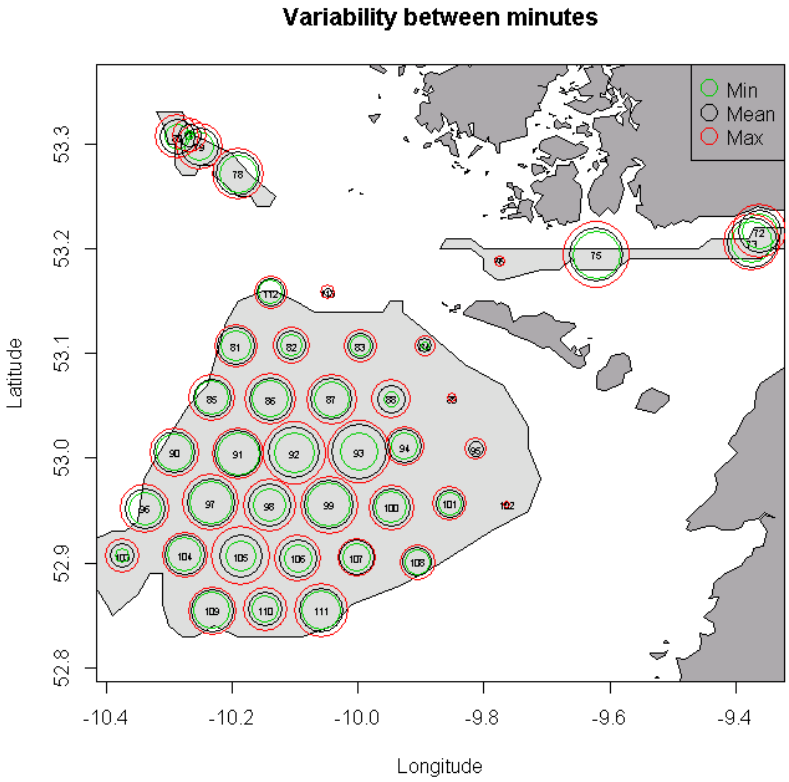

Figure 7: FU17 Aran grounds: Plot of the variability in density between minutes for each station in 2014.

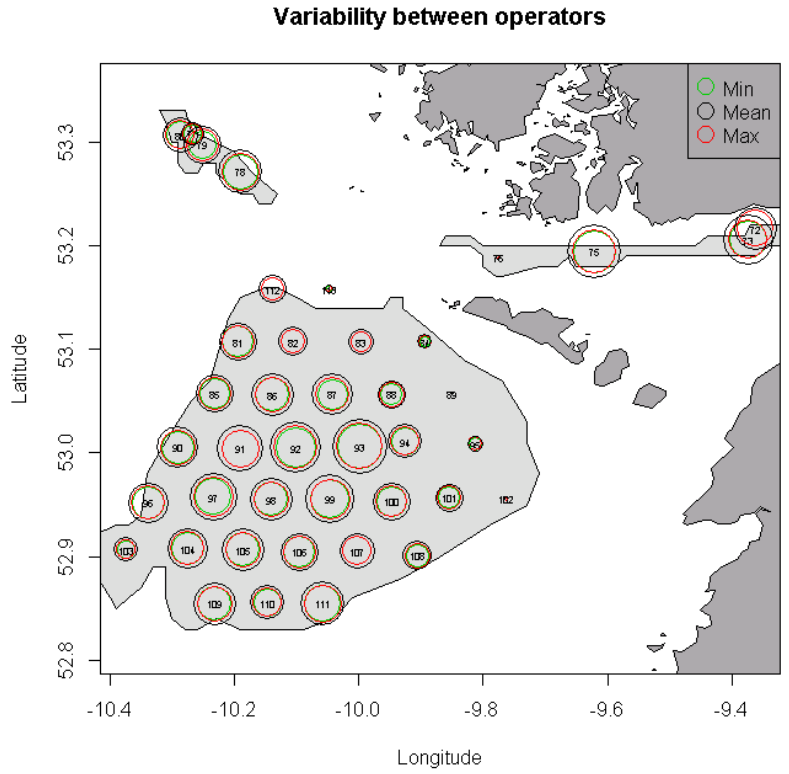

Figure 8: FU17 Aran grounds: Plot of the variability in density between operators (counters) for each station in 2014.

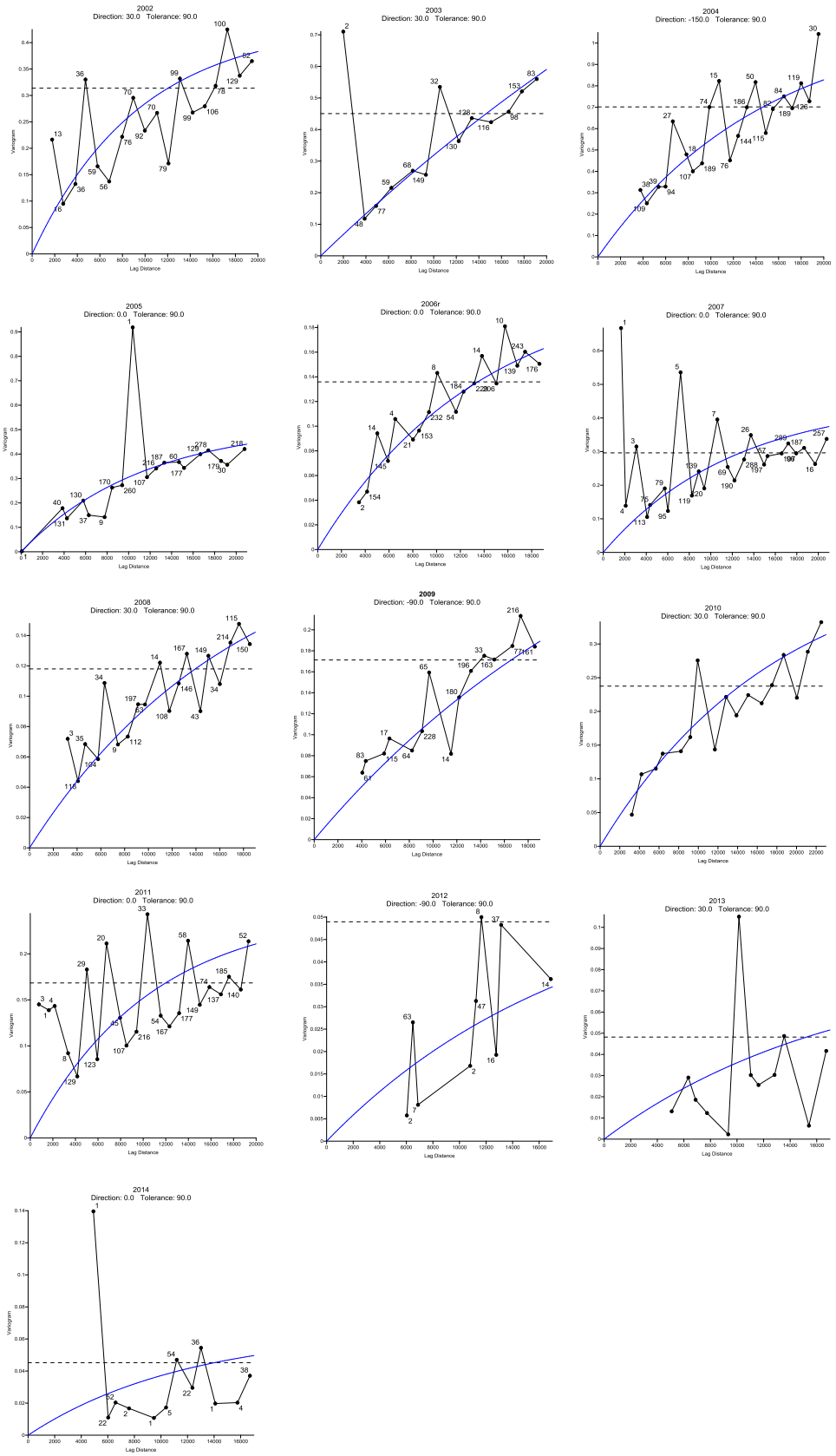

Figure 9: FU17 Aran grounds: Omnidirectional mean variograms by year from 2002 (top left) - 2014 (bottom left).

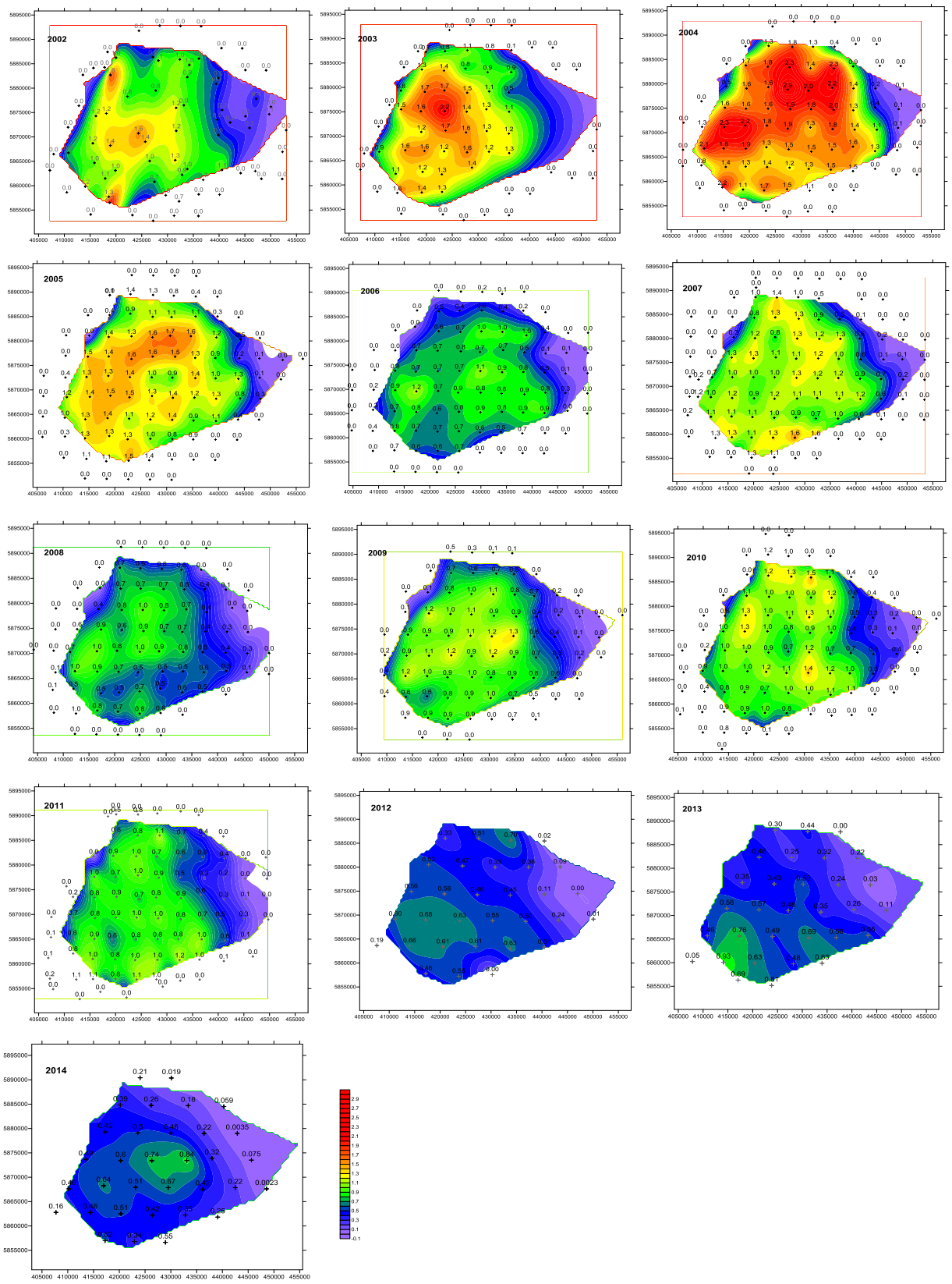

Figure 10: FU17 Aran grounds: Contour plots of the krigged density estimates by year from 2002 (top left) - 2014 (bottom left).

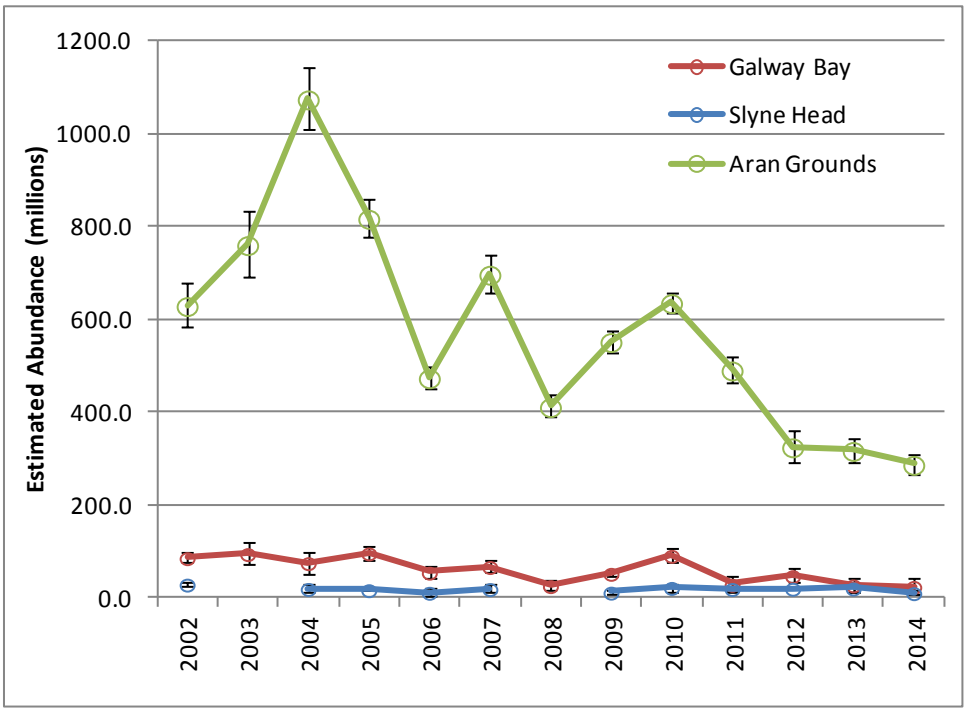

Figure 11: FU17 Aran grounds: Time series of abundance estimates for the Aran Grounds, Galway Bay and Slyne Head (error bars indicate 95% confidence intervals).

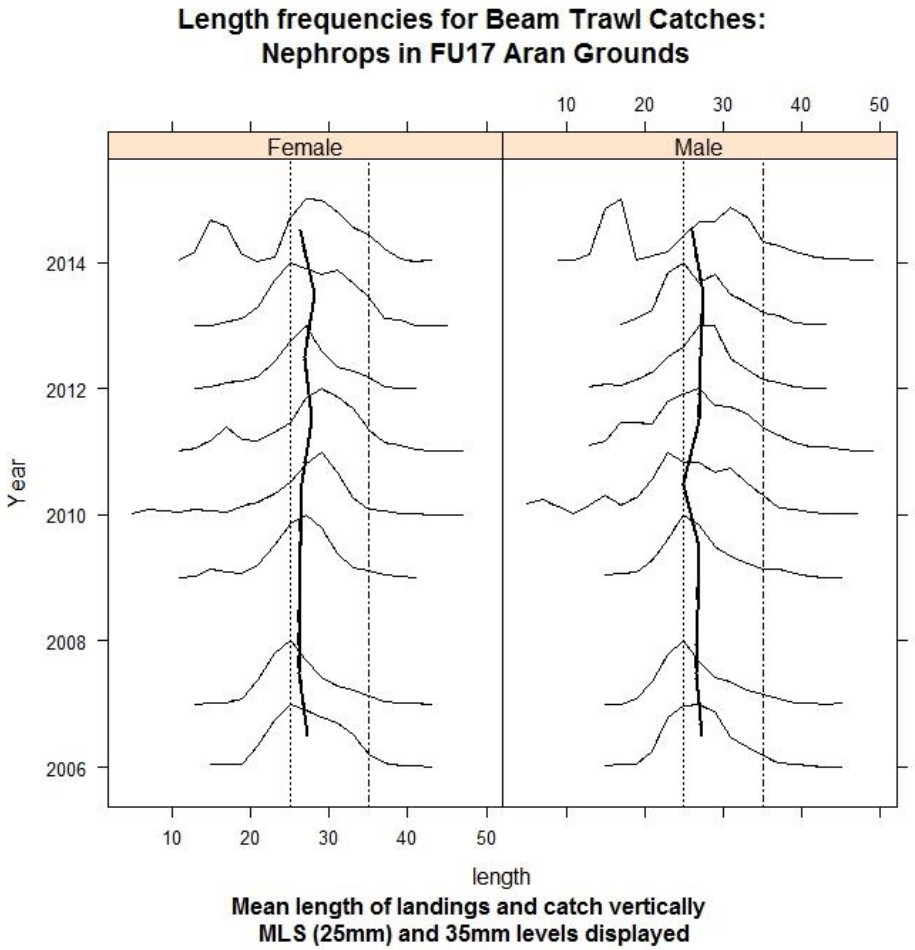

Figure 12: FU17 Aran grounds: Standardised length frequency distributions for male and female *Nephrops* caught using beam trawl during 2006 to 2014 UWTV surveys on the "Aran Grounds" (except 2008).

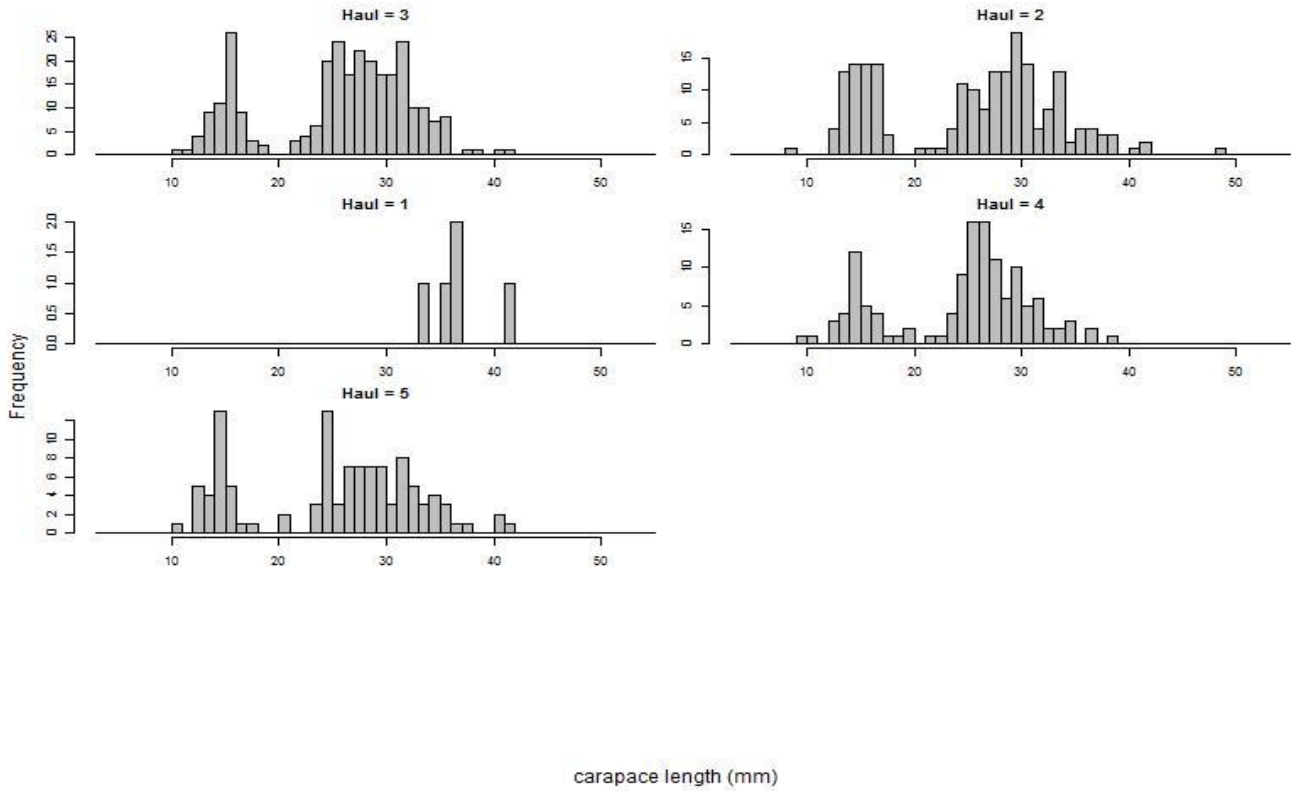

Figure 13: FU17 Aran grounds: 2014 *Nephrops* length frequencies by haul.

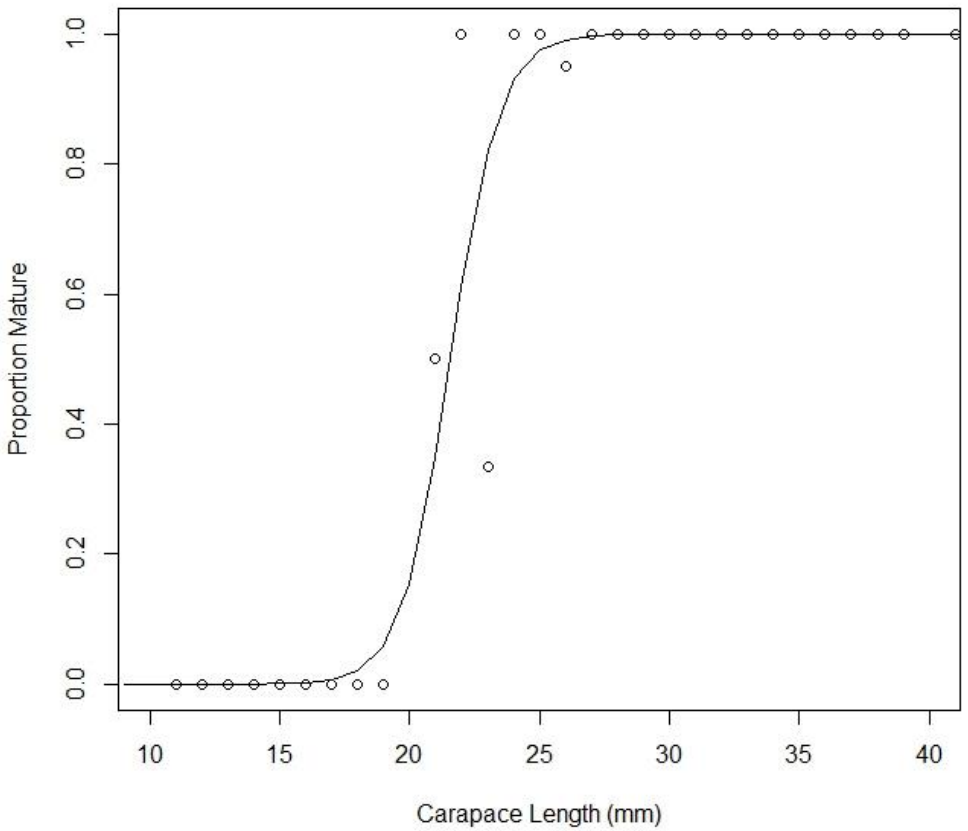

Figure 14: FU17 Aran grounds: Female *Nephrops* maturity ogive based on beam trawl catches in 2014 (L_{50} estimate ~ 22 CL mm).

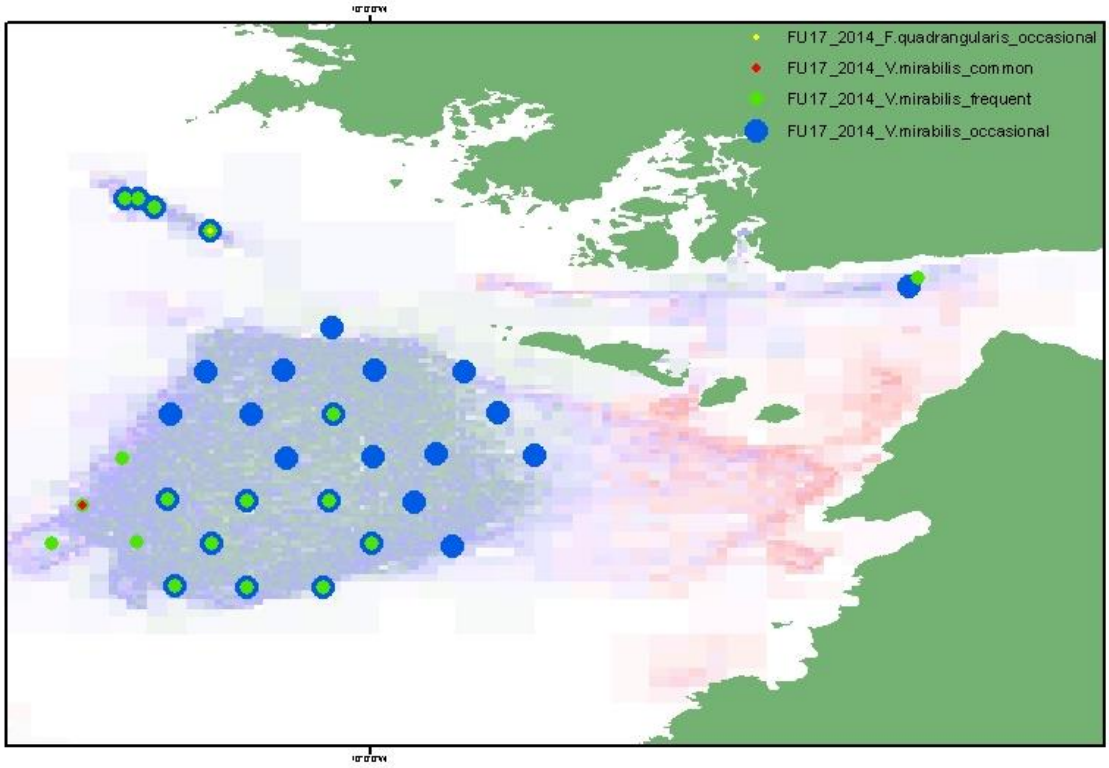

Figure 15: FU17 Aran grounds: Stations where *Virgilaria mirabilis* and *Funiculina quadrangularis* were identified during 2014 overlaid on a heat map *Nephrops* directed fishing activity.

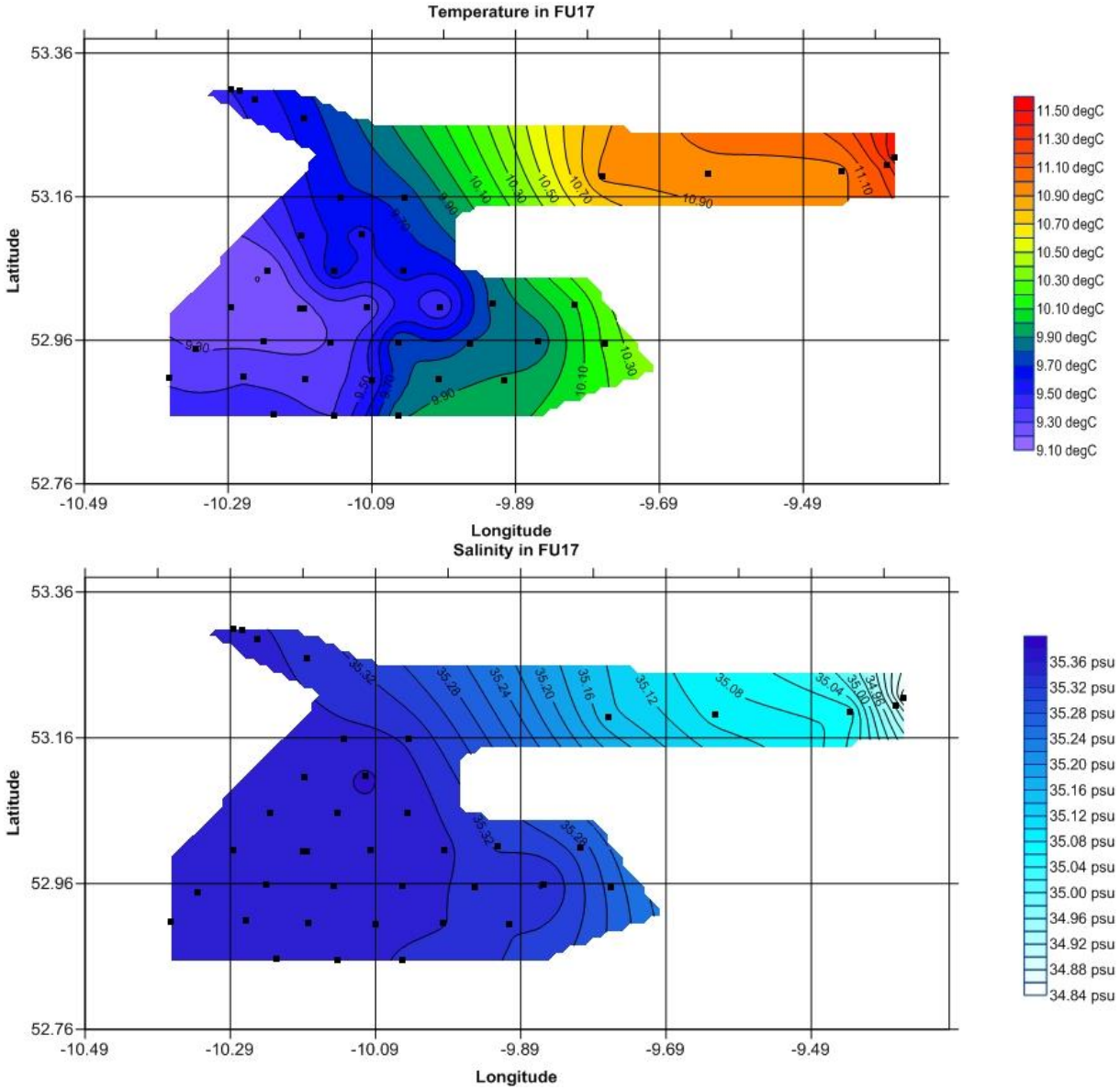

Figure 16: FU17 Aran grounds: Bottom temperature and salinity collected by CTD during the 2014 survey.

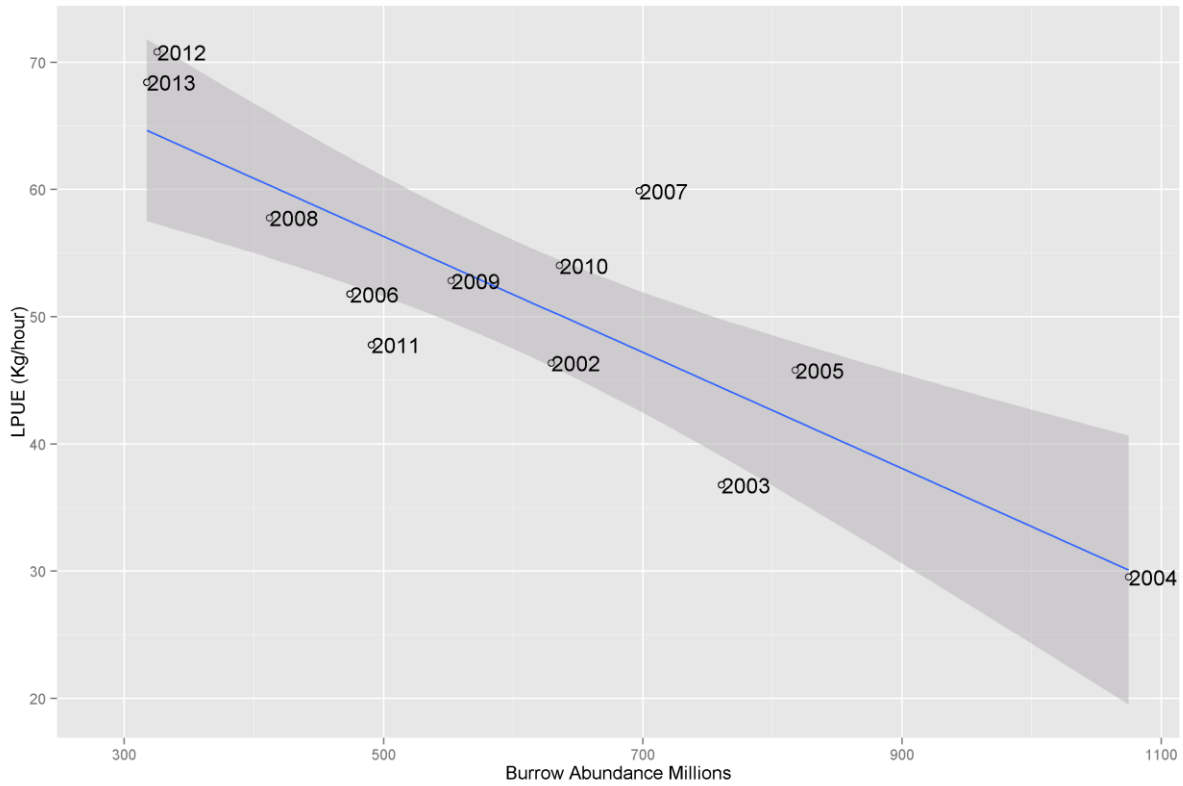

Figure 17: FU17 Aran grounds: Plot of LPUE versus burrow abundance over the time series. The blue line is a linear model (Adjusted R-squared: 0.69), the grey shaded are is the 95% confidence region.

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: FU17 Aran grounds: Area calculations for Galway Bay and Slyne Head *Nephrops* grounds in ArcGIS10.

		ArcGIS Projections			
FU	VMS grounds Polygons	Eckert VI (world) (km2)	Irish National Grid (km2)	Cylindrical Equal Area (km2)	Average (km2)
17	SlyneHead	39.3	39.4	39.3	39.3
17	GalwayBay	74.2	74.0	74.0	74.1

Table 3: FU17 Aran grounds: Overview Aran of geostatistical results from 2002-2014.

FU	Ground	Year	Number of stations	Burrow Count	Mean Density adjusted (burrows/m²)	Estimation Standard Deviation	Domain Area (km²)	Geostatistical abundance estimate adjusted (millions of Burrows)	CV on Burrow estimate
		2002	49	7,036	0.65	0.04	943	629	4%
		2003	41	9,814	0.78	0.06	943	761	5%
		2004	64	10,687	1.10	0.05	943	1075	3%
		2005	70	8,774	0.84	0.03	936	818	3%
		2006	67	6,928	0.49	0.02	932	474	3%
		2007	71	10,272	0.71	0.03	942	697	3%
17	**Aran**	2008	63	7,617	0.43	0.02	906	412	3%
		2009	82	6,585	0.56	0.02	940	552	2%
		2010	91	8,091	0.65	0.01	937	636	2%
		2011	76	7,365	0.51	0.02	909	491	3%
		2012	31*	1,271	0.34	0.02	942	325	5%
		2013	31*	1,937	0.32	0.02	941	317	4%
		2014	33*	2,041	0.29	0.01	939	287	4%

* reduced isometric grid 3.5nmi

Table 4: FU17 Aran grounds: Summary statistics for the Galway Bay and Slyne Head *Nephrops* grounds from 2002-2014.

Ground	Year	Number of stations	Mean Adjusted Density (burrow/m²)	CViid (Relative SE)	Raised abundance estimate (million burrows)	Upper CI on abundance	Lower CI on abundance
Galway Bay	2002	7	1.17	6%	86.5	76.2	96.7
	2003	3	1.29	12%	95.3	72.6	118.0
	2004	9	1.02	16%	75.7	51.9	99.5
	2005	4	1.30	8%	96.7	80.8	112.6
	2006	3	0.74	12%	55.2	41.4	69.0
	2007	5	0.91	9%	67.3	55.7	79.0
	2008	9	0.35	21%	26.2	15.0	37.5
	2009	8	0.71	6%	52.7	46.2	59.3
	2010	10	1.24	9%	91.5	75.9	107.2
	2011	10	0.39	33%	29.2	10.1	48.4
	2012	4	0.64	16%	47.8	32.4	63.1
	2013	5	0.37	27%	27.8	12.6	43.0
	2014	5	0.33	34%	24.6	7.8	41.3
Slyne Grounds	2002	5	0.75	10%	29.5	23.5	35.5
	2003						
	2004	3	0.51	22%	20.1	11.4	28.9
	2005	3	0.44	2%	17.5	16.9	18.0
	2006	3	0.30	28%	11.9	5.2	18.6
	2007	4	0.51	23%	19.9	10.7	29.0
	2008						
	2009	6	0.31	22%	12.2	6.7	17.7
	2010	9	0.57	20%	22.4	13.6	31.2
	2011	7	0.51	14%	20.1	14.6	25.6
	2012	3	0.52	3%	20.6	19.3	21.9
	2013	4	0.54	19%	21.2	13.1	29.2
	2014	4	0.28	22%	11.0	6.1	15.9

Table 5. FU17 Aran grounds: Length-weight parameters by sex estimated for *Nephrops* caught during the 2014 survey together with those currently used to raise the sampling data.

FU	Year	Parameters	Female	Male
17	2014	a currently used for FU17	0.000684	0.000322
		b currently used for FU17	2.963	3.207
		a estimated	0.000417202	0.000270532
		a 2.5% Confidence Intervals	0.0003599511	0.0002199279
		a 97.5% Confidence Interval	0.0004835548	0.0003327787
		b estimated	3.10487	3.256782
		b 2.5% Confidence Intervals	3.060191	3.193670
		b 97.5% Confidence Interval	3.149548	3.319893
		Bias Correction Factor	1.003762	1.004669
		Number of Observations	157	73

Table 6: FU17 Aran grounds: Summary of benthic catch by tow in weight (kg) and number from 2014 fishing operations.

	Tow1		Tow2		Tow3		Tow4		Tow5	
Species	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)	Number
Actinuage richardii							0.048	1	0.12	1
Alpheus gaber					0.001	1	0.002	1		
Aphrodite aculeata			0.045	1	0.054	1				
Asterias rubens			0.009	1			0.043	1	0.0185	2
Astropecten irregularis	0.0007	1	0.186	2						
Aurelia aurtia	0.0075	1	0.184	4						
Cancer pagurus	0.538	1								
Crangon spp	0.038	56	0.058	79	0.214	248	0.083	105	0.145	51
Dichelopandulus bonneri	0.005	4	0.001	1					0.005	2
Eledone cirrhosa	0.084	1			0.0123	1	0.175	9	0.068	6
Goneplax rhomboides	0.002	2	0.033	8	0.191	17	0.019	8	0.027	14
Hirudinea spp			0.0006	1						
Liocarcinus depurator	**0.025**	**4**	**0.045**	**5**	**0.015**	**4**	**0.017**	**6**		
Liocarcinus holsatus	**0.007**	**1**	**0.052**	**10**	**0.0127**	**3**	**0.005**	**1**	**0.002**	**1**
Luidia spp			0.0079	1						
Lunatia spp	0.162	57	0.126	45	0.162	65	0.408	227	0.416	177
Macropodia spp					0.001	1	0.001	1	0.001	1
Macropipus tuberculata					0.0025	1	0.003	1		
Munida rugosa					0.001	1			0.001	2
Nephrops norvegicus	0.188		2.807		3.864		1.504		1.5	
Nucula nucleus	**0.004**	**5**	**0.002**	**3**			**0.007**	**8**	**0.003**	**4**
Pagurus spp			**0.002**	**1**	**0.023**	**3**	**0.004**	**1**	**0.013**	**2**
Pelagia			0.014	14	0.0054	1	0.008		0.006	
Pontophilus spinosa	0.01	19	0.026	49	0.175	101	0.036	52	0.031	51
Processa spp			0.02	24	0.1772	61	0.008	7	0.009	7
Rossia macrosoma									0.024	1
Scapellum scapellum					0.156	5	0.024	1	0.0201	1
Sepiola atlantica	0.002	1	0.001	1	0.0039	1	0.001	1	0.003	2
Solenocera membranosa							0.003	1	0.002	1
Stichastrella rosea			0.004	1					0.006	2
Turret Shells	0.001	1								
Virgilaria mirabilis	0.002	1			0.0012	1	0.001	1	0.001	1
Worm casings									0.001	1
Total	1.076	155	3.624	251	5.072	516	2.400	433	2.423	330

Table 7: FU17 Aran grounds: Summary of fish catches by tow in weight (kg) from 2014 fishing operations.

Species	Weight (kg)				
	Tow1	Tow2	Tow3	Tow4	Tow5
GAIDROPSARUS VULGARIS			0.008	0.016	
LIMANDA LIMANDA			0.136		
CALLIONYMUS LYRA	0.246	0.366	0.156	0.128	0.074
EUTRIGLA (CHELIDONICTHYS) GURNARDUS		0.482	0.054	0.168	0.074
MELANOGRAMMUS AEGLEFINUS	0.102				
MERLUCCIUS MERLUCCIUS	0.674	0.608	0.112	0.024	0.016
MICROSTOMUS KITT	0.16				
SCYLIORHINUS CANICULA (f)	1.024				
ARGENTINA SPHYRAENA	0.006	0.001	0.034	0.002	
LEPIDORHOMBUS WHIFFIAGONIS	0.69	0.542	0.008	0.208	0.538
LOPHIUS PISCATORIUS	0.066	0.066	0.47	1.472	0.054
TRISOPTERUS ESMARKI	0.196	0.048	0.09		
HIPPOGLOSSOIDES PLATESSOIDES	0.256	0.186	0.346	0.05	0.1
GADICULUS ARGENTEUS					0.012
MICROCHIRUS VARIEGATUS	0.356	0.18		0.032	0.001
MICROMESISTIUS POUTASSOU			0.074		
MERLANGIUS MERLANGUS	0.276	0.94	0.352		
GLYPTOCEPHALUS CYNOGLOSSUS	0.022	0.916	0.268	0.378	0.046
GOBIES		0.001			0.001
TRACHYSCORPIA CRISTULATA			0.001		0.001
Total Weight (kg)	4.074	4.336	2.109	2.478	0.917

Table 8: FU17 Aran grounds: Inputs to management option table. Landings, discards, and removals by number, proportion retained, absolute UWTV survey abundance and 95% confidence intervals estimated harvest rate, and landings and discards mean weights.

Year	Landings in Number (millions)	Discards in Number (millions)	Removals in Number (millions)	Prop Removals Retained	Absolute Survey (millions)	95% Confidence Interval	Harvest Ratio	Landings (t)	Discards (t)	Mean Weight in landings (gr)	Mean Weight in discards (gr)
2001	48.7	25.4	71.6	0.68				912			
2002	54.5	17.7	70.4	0.77	629	48	11.2%	1 152	192	21.2	10.8
2003	44.1	18.3	60.6	0.73	761	71	8.0%	933	183	21.2	10.0
2004	29.0	11.4	39.3	0.74	1075	68	3.7%	525	112	18.1	9.9
2005	42.4	19.7	60.1	0.70	818	41	7.4%	778	182	18.4	9.2
2006	na	na	49.5*	na	474	25	10.4%	636	na	na	na
2007	na	na	57.3*	na	697	42	8.2%	913	na	na	na
2008	47.2	21.7	66.7	0.71	412	24	16.2%	1,057	246	22.4	11.3
2009	23.5	15.7	37.6	0.62	552	23	6.8%	625	256	26.6	16.3
2010	41.0	13.3	53.0	0.77	636	20	8.3%	1 000	194	24.4	14.5
2011	30.8	7.7	37.7	0.82	491	28	7.7%	600	83	19.5	10.8
2012	55.6	7.6	62.4	0.89	325	34	19.2%	1 135	85	20.4	11.3
2013	59.2	14.178	72.0	0.82	317	27	22.7%	1 295	170	21.9	12.0
2014					287	22					
Avg 11-13				**0.843**			**16.52%**			**20.6**	**11.4**

na= not available.

* No discard samples; an average discard rate was used to estimate removals (including dead discards).

Table 9: FU17 Aran grounds: Short-term management option table giving catch options for 2015 using the 2014 UWTV survey estimate.

Basis: Absolute survey abundance index 2015 = 287 million (2014 index); Mean individual weights in landings (2011–2013, 20.6 g), mean individual weights in discards (2011–2013, 11.4 g); Dead discard rate (by number) = 15.7% (average 2011–2013).

Basis	Total catches*	Landings	Dead discards**	Surviving discards**	Harvest rate
	L+DD+SD	L	DD	SD	for L+DD
MSY Approach	584	524	54	6	10.5%
$F_{2011\text{-}13}$	918	825	84	9	16.5%
$F_{0.1}$ Combined	400	359	37	4	7.2%
F_{max}	617	554	57	6	11.1%

Weights in tonnes.

* Total catches are the landings, plus dead and surviving discards.

** Total discard rate is assumed to be 16.8% of the catches (in number, last 3 years average, 2011-2013), discard survival is assumed 10%