Aran, Galway Bay and Slyne Head *Nephrops* Grounds (FU17) 2017 UWTV Survey Report and catch options for 2018.

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Abstract

This report provides the main results and findings of the fifteenth 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 2017 a total of 40 UWTV stations were successfully completed, 31 on the Aran Grounds, 5 on Galway Bay and 4 on Slyne Head patches. The mean burrow density observed in 2017, adjusted for edge effect, was medium at 0.31 burrows/m². The final krigged burrow abundance estimate for the Aran Grounds was 377 million burrows with a CV (or relative standard error) of 4 %. The final abundance estimate for Galway Bay and Slyne Head was 16 and 11 million burrows with CVs of 4% and 4% respectively. The total abundance estimates have fluctuated considerably over the time series. The 2017 combined abundance estimate was a 6% increase compared to 2016 and at 404 million and is below the MSY $B_{trigger}$ (540 million). Using the 2017 abundance estimate and updated stock data implies catch of 551 tonnes and landings of 513 tonnes in 2018 when MSY approach is applied (assuming that discard rates and fishery selection patterns do not change from the average of 2014–2016). *Virgilaria mirabilis* was the only sea-pen species observed on the UWTV footage. Trawl marks were present at 20% of the Aran stations surveyed.

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

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Introduction

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 ICES sub-area 7 is extremely valuable with landings in 2016 worth around € 107 million 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 641 t in 2016 were worth approximately €5.8 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 fifteenth 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 (Figure 1). The 2017 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 2017 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.

This report details the final UWTV results of the 2017 survey and also documents other data collected during the survey. Operational survey details are available in form of a survey narrative from the scientist in charge (CL). The 2017 abundance are used to generate catch options for 2018 in line with the recommendations and procedures outlined in the stock annex for FU17 (ICES, 2015).

Material and methods

Since 2012 the Aran survey design has been based a randomised isometric grid with stations every 3.5 Nmi 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 randomised grid and random stations on the Galway Bay and Slyne grounds

were generated using the spsampl function in the sp package (Pebesma & Bivand, 2005) of r (R Core Team, 2017). The ground boundary used for the Aran, Galway Bay and Slyne grounds was revised by an ICES inter-benchmark process (ICES, 2015). In the past 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). Not all stations completed in 2017 and in previous years fell within the new ground polygons and these were excluded from the analysis.

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 2015 the Galway Bay and 14 Aran stations were surveyed on June 10th and 11th on RV Celtic Voyager. The vessel then broke down and the remaining stations (20 Aran and 5 Slyne) were carried out on RV Prince Madog on the 1st and 2nd of July. This year's survey took place between the 18th and 28th of June.

The operational protocols used were those reviewed by WKNEPHTV 2007 (ICES, 2007) and employed on other UWTV surveys in Irish waters. They 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 2017 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 2017 against the reference footage 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 2) after ICES (2011). Finally, if there was any time during the one-minute where counting was not possible, due to sediment clouds or other reasons, this

was also estimated so that the time window could be removed from the distance over ground calculations.

In 2017 the survey count data was screened to check for any unusual discrepancies using Lin's Concordance Correlation Coefficient (CCC) with a threshold of 0.6. Lin's CCC (Lin, 1989) measures the ability of counters to exactly reproduce each other's counts on a scale of 1 to –1 where 1 is perfect concordance (i.e. a pairwise plot will have all points lying along the 1:1 line. A value of –1 would be generated by all points lying on the –1:1 line and a value of 0 indicates no correspondence at all. Lin's CCC quality control plot of survey count data for stations 1 to 3 is shown in Figure 5. Consistency and bias between individual counters was also examined using Figure 6. There is some variability between counters but no obvious bias or excessive deviations.

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 2017 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 the RGeostats 10.0.8 (Renard D. et al., 2015). The procedure used is fully documented in the stock annex.

To estimate the abundance for Galway Bay and Slyne Head grounds, the area of each ground polygon was calculated in ArcGIS10 and an average value used (Table 1). 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.

Ten 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. 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 10 valid beam trawl tows are shown in Figure 2.

Results

The station positions for the 31 stations on the Aran grounds, 5 in Galway Bay and 4 at Slyne head are shown in Figure 2. One further station was carried out in Galway Bay on the zero grounds and is not used in the analysis. A combined violin and box plot of the observed burrow densities from 2006 to 2017 is presented in Figure 7. 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 mean and median density has increased slightly in 2017. It has been very noticeable since 2011 that there was a substantial reduction in density throughout the ground with no high density (> 0.7/m^2) observed. 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.

A combined krigged contour plot and bubble plot of the density data are shown in Figure 9. These show that 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 often high densities close to the boundary. In this area there is a sharp transition from mud to rocky substrate. The densities in 2017 were fairly homogenous throughout the ground.

The summary statistics from this geo-statistical analysis for the Aran Grounds are given in Table 3 and Figure 10. The 2017 abundance estimate of 377 million burrows is a 10% higher than in 2016. The estimation variance of the surveys is relatively low (CVs in the order <6%).

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 10. The Galway Bay estimates fluctuate widely but appear to 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 ~8% and ~2% respectively. The 2017 combined abundance estimate was 7% higher than in 2016 and at 404 million but is still below MSY $B_{trigger}$ value of 540 million shown in Figure 10.

Figure 11 shows the standardised length frequency distributions (LFDs) by sex of *Nephrops* caught using a beam trawl on the Aran grounds between 2006 and 2017 surveys. No fishing was carried out on surveys prior to 2006 or in 2008 and 2015 (due to time constraints as a result of poor weather conditions). For plotting purposes the individuals <10 CL mm caught in 2010 and 2017 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 show and increasing trend over time but have declined in 2017 compared with 2016 which was the highest in the time series.

A summary of the benthic taxa by tow is presented in Figure 12. This heatmap combined with a dendrogram which shows the proportional counts of benthic species. A threshold was used which removed those species with less than 1% as their maximum relative abundance. Hierarchical clustering using the complete linkage method with Euclidean distance measure identifies stations which have similar benthic compositions. *Lunatia*

species (necklace shell) was the most abundant species and was recorded in all tows. *Goneplax rhomboids,* a burrowing crab species was recorded at three tows. *Eledone cirrhosa* (curled octopus) was also recorded where this species is a noted predator of crustaceans and has been observed lying close to the *Nephrops* burrow entrances on the Smalls ground (FU22). *Virgularia miriabilis* was also present in all tows. Table 5 summarises the fish catches. The most abundant fish species recorded were; *Lepidorhombus whiffiagonis* (megrim), *Lophius budegassa* (black-bellied monkfish), *Glyptocephalus cynoglossus* (witch) and *Merlangius merlangus* (whiting).

The sea-pen presence-absence observations across the *Nephrops* grounds are mapped in Figure 13 using the key described in Table 2. All of sea-pens were identified from the video footage as *Virgularia mirabilis* and was also present at stations where trawl marks were recorded. This sea-pen species was recorded as frequently present at 66%, occasionally present at 31% and commonly present at 16% of total stations. Trawl marks were noted at 20% of the Aran stations surveyed. Trawl marks were also present at one station at Slyne Head. No trawl marks were noted at the Galway Bay stations.

The results of the CTD data collection are presented in Figure 14. The bottom temperature on the Aran grounds was mainly between 10-11^{o}C. In Galway Bay bottom temperatures were a couple of degrees warmer.

The UWTV abundance data together with data from the fishery; landings, discards and removals in number are used to calculate the harvest ratio in 2016 of 9.2%. The mean weight in the landings and the discards and the proportions of removal retained are also shown (Table 6).

The basis to the catch options table is given in Table 7. The catch and landings options at various different fishing mortalities are calculated in line with the stock annex using the 2017 survey abundance are presented in Table 8. The latest estimate of stock abundance (value from June 2017 survey, 404 million) is below the MSY $B_{trigger}$ value (540 million). The ICES MSY approach states that under such conditions the F_{MSY} harvest rate (8.5 % for FU17 Norway lobster) should be reduced by multiplying it by the ratio of current abundance to MSY $B_{trigger.}$ This corresponds to a harvest rate of 8.5 x 404 ÷ 540 = 6.4 % for the catch advice in 2018. Fishing at MSY approach in 2018 would result in catches of 551 tonnes and landings of 513 t assuming that discard rates and fishery selection patterns do not change from the average of 2014–2016.

Discussion

Observed burrow densities have fluctuated a lot over time in this area. The abundance shows an overall decreasing trend over time and has been at or below MSY $B_{trigger}$ since 2012. This is in contrast to the more stable burrow abundance estimates in most other areas in 7 over similar time frames. Because the burrow abundance decreased significantly in 2017 below MSY $B_{trigger}$ the ICES MSY approach states that under such conditions the F_{MSY} harvest rate (8.5 % for FU17 Norway lobster) should be reduced by multiplying it by the ratio of current abundance to MSY $B_{trigger.}$

Discard rates for this FU are estimated to have reduced significantly in the in the last five years and are now around 7%. Because harvest rates are calculated on the basis of numbers and 25% of the *Nephrops* in this area are assumed to have survived discarding up to now this presents a problem in calculating catch options for 2018. *Nephrops* fisheries in this area have been covered under the landings obligation since 2016 by a *de minimus* is also in place allowing up to 7% of the catch to be discarded. Under the Landings Obligation scenario in Table 8 it is assumed that all catches will be landed in 2018 so the discards that would have survived up to now are also removed from the fishery. In this scenario fishing at MSY approach in 2017 would imply total catches of 533 t which implies; landings or in ICES terminology "wanted catch" of 496 t and discards or "unwanted catch" of 37 t. The difference between this scenario and the scenario where discards continue at current rates is minimal.

The imposition of the landings obligation on *Nephrops* fisheries since 2016 should result in changes in selectivity. This is not taken into account in any of the catch advice because it is not possible to predict exactly what might happen. The main message is that any improvements in selectivity in the fishery and reductions in discards will result in increased mean weight in the catches. This will in turn reduce overall mortality on the stocks and allow for catch increases in the future.

An important objective of this UWTV survey is to collect 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.

Monitoring the occurrence and frequency of sea-pens observed on these *Nephrops* patches is important in the context of OSPAR's designations of sea-pen and burrowing megafauna communities as threatened. The sea-pen species *Virgularia mirabilis* which was seen in 2017 have been observed on previous surveys of FU17. Monitoring *Nephrops* stock and the benthic habitat is also important in the context of the MFSD indicators (e.g. sea floor integrity).

The main objectives of the survey were successfully met for the sixteenth successive year. The UWTV coverage and footage quality was excellent throughout the survey. The multi-disciplinary nature of the survey means that the information collected is highly relevant for a number of research and advisory applications.

Acknowledgments

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onboard technical difficulties. Thanks to Aodhan Fitzgerald (RVOPs) and Rob Bunn and Dave Tully (FEAS) at the Marine Institute for organising survey logistics. Thanks to Gordon Furey, Barry Kavanagh, John Barry and Tom O'Leary P&O Maritime for shore side support.

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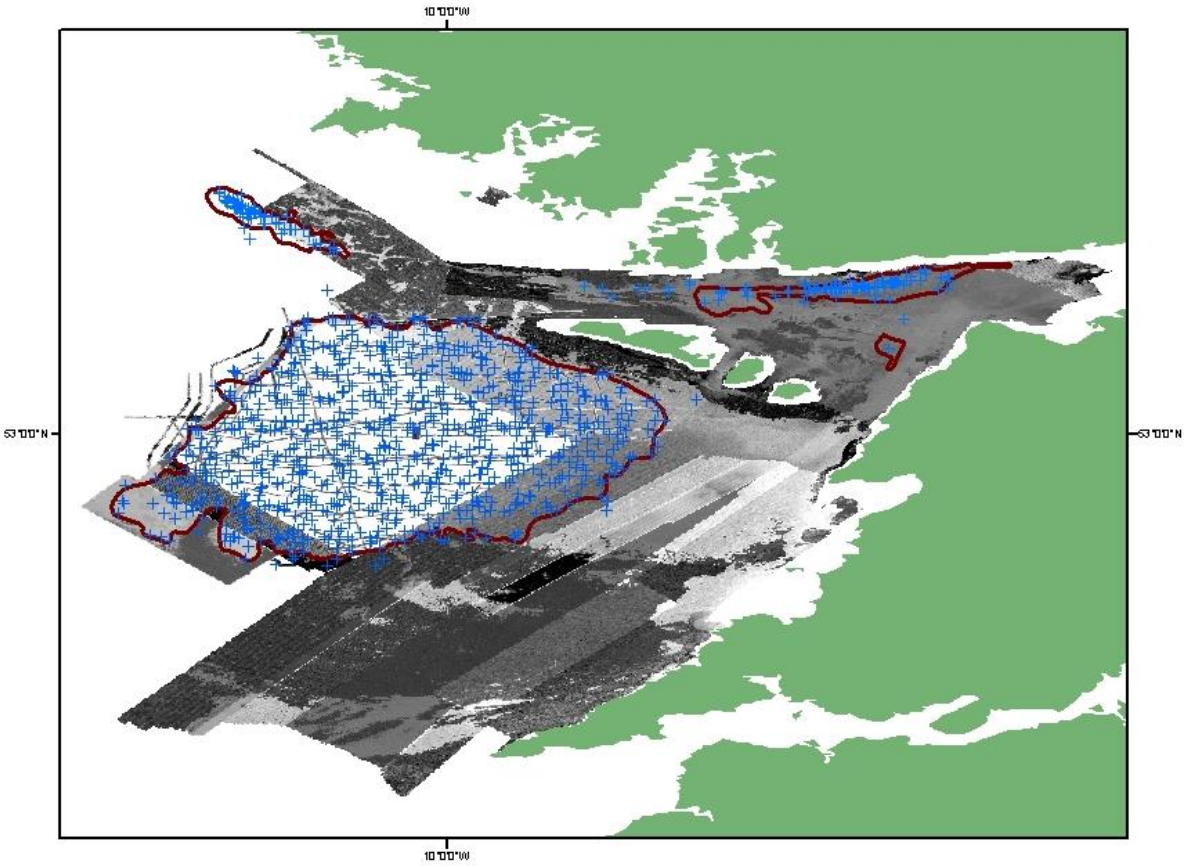

Figure 1: The spatial distribution of all UWTV survey stations from 2002-2017 in Functional Unit 17 overlaid on multibeam backscatter data (source: INFOMAR 2005-2016). Darker grey backscatter indicates harder seabed substrate.

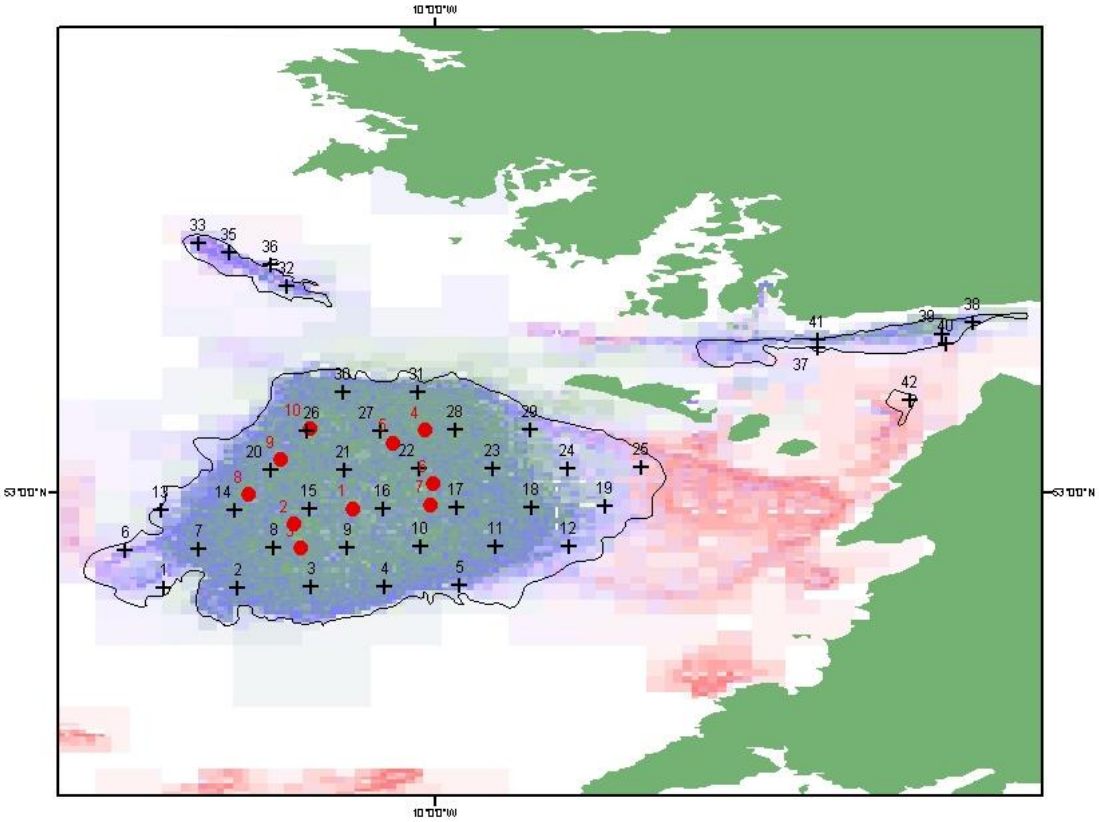

Figure 2: FU17 Aran grounds: UWTV Stations completed in 2017 overlaid on a heat map of *Nephrops* directed fishing activity between 2006 -2017.
(+) denotes TV stations and red dots beam trawl stations.

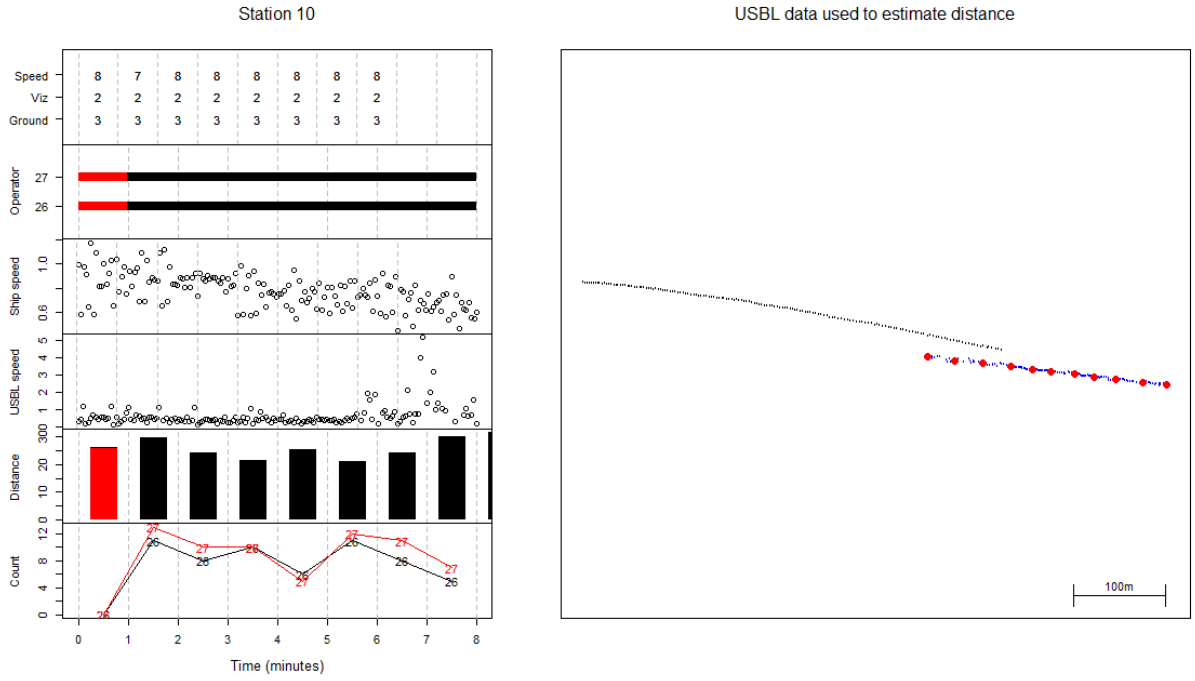

Figure 3 : FU17 Aran grounds: r - tool quality control plot of station 10 of the 2017 survey.

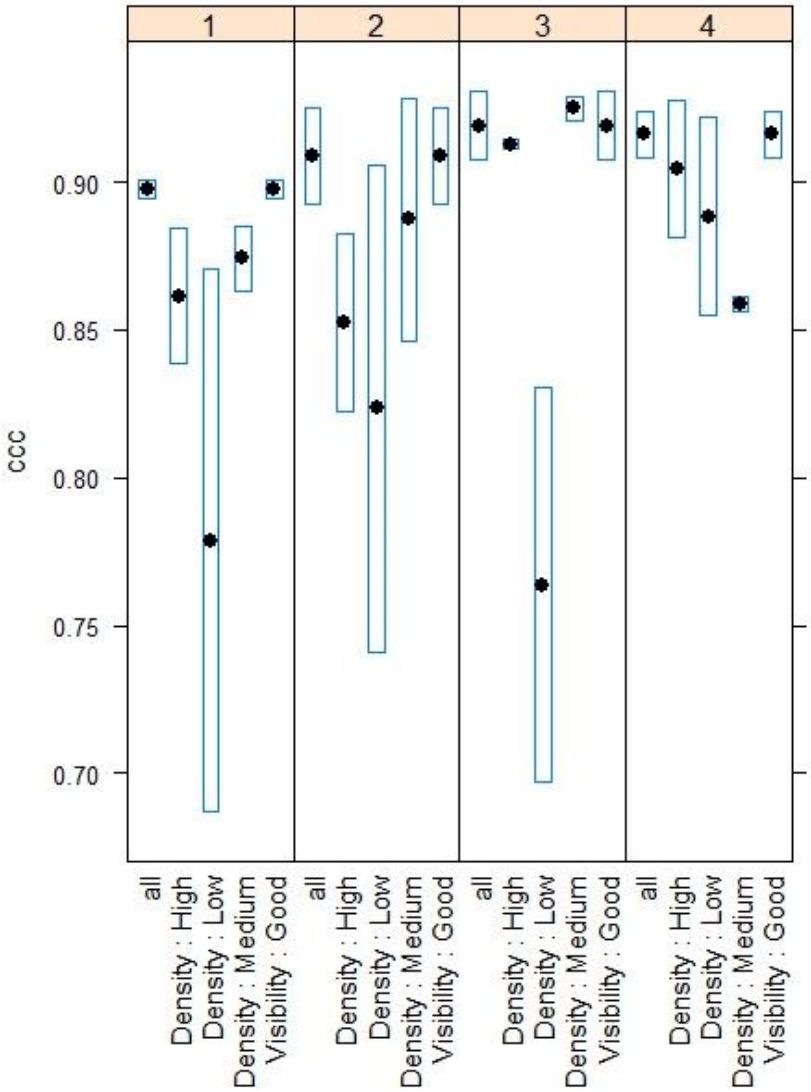

Figure 4: FU17 Aran grounds: 2017 Counting performance against the reference counts as measured by Lin's CCC for FU17 "Aran grounds". Each panel represents an individual. The x-axis (from left to right), all stations pooled, high density, low density, moderate density and visibility good.

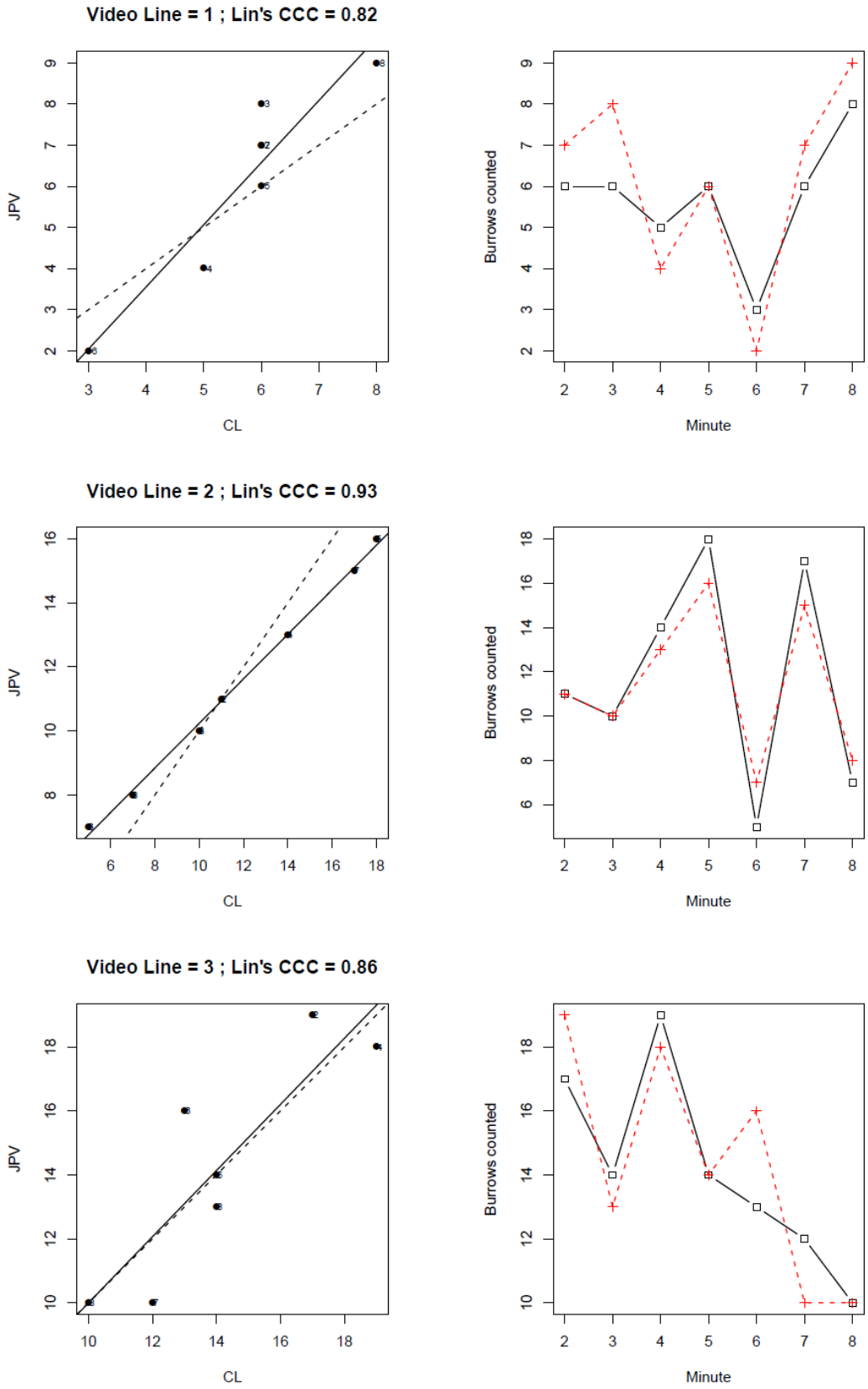

Figure 5: FU17 Aran grounds: Lin's CCC quality control plot of count data for stations 1 – 3 of the 2017 survey.

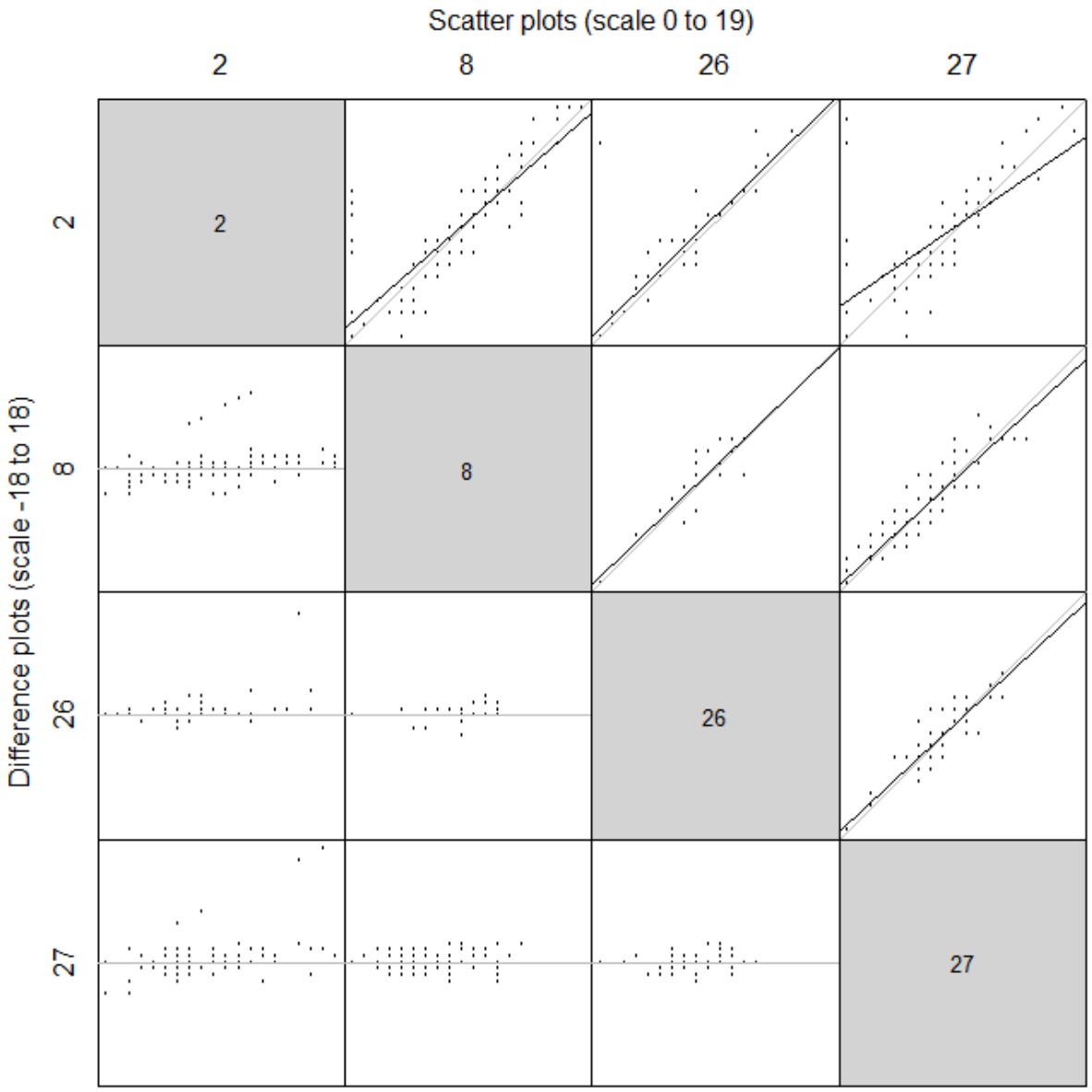

Figure 6: FU17 Aran grounds: Scatter plot analysis of counter correlations for the 2017 survey.

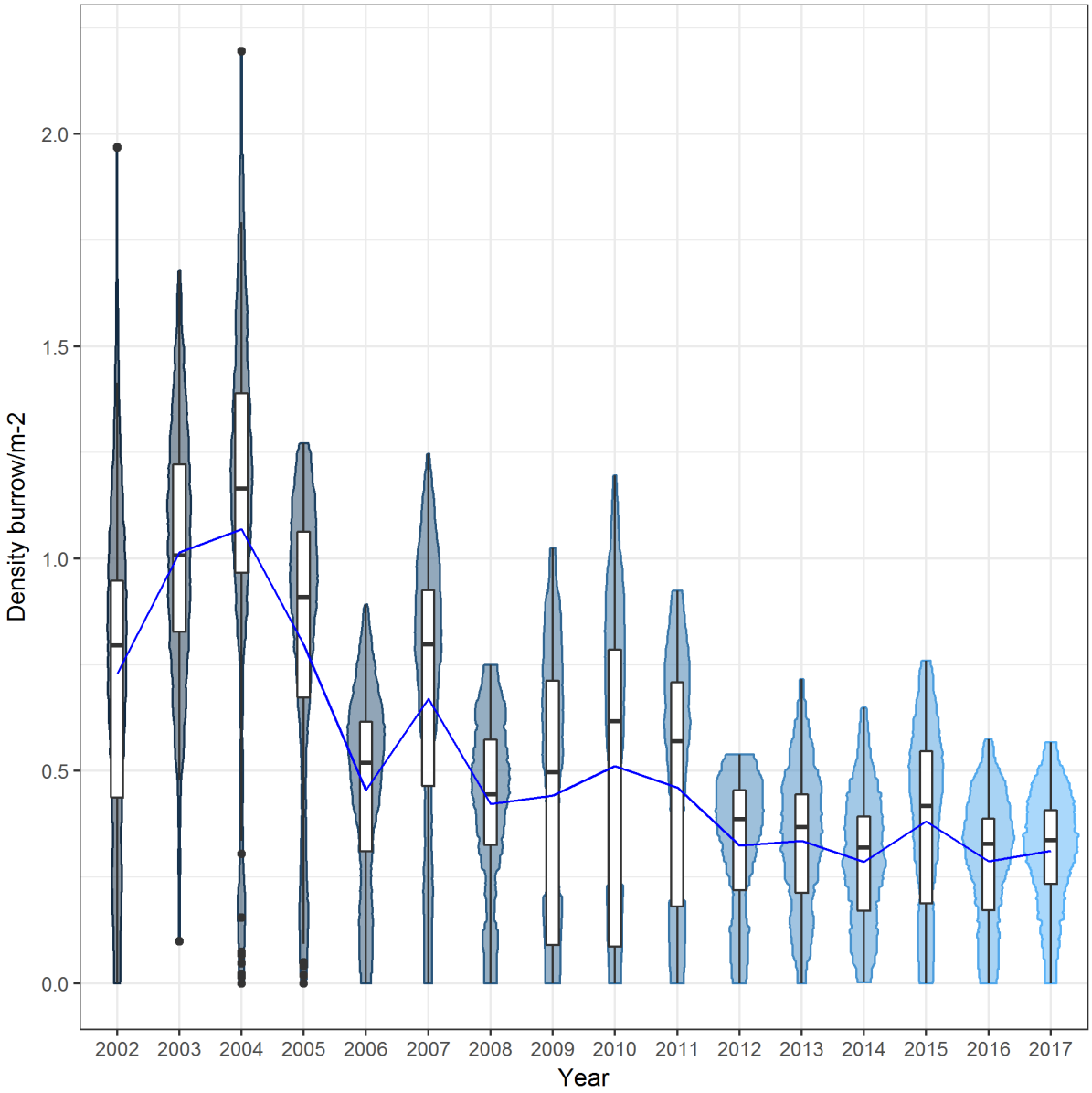

Figure 7: FU17 Aran grounds: Violin and box plot a of adjusted burrow density distributions by year from 2006-2017. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers.

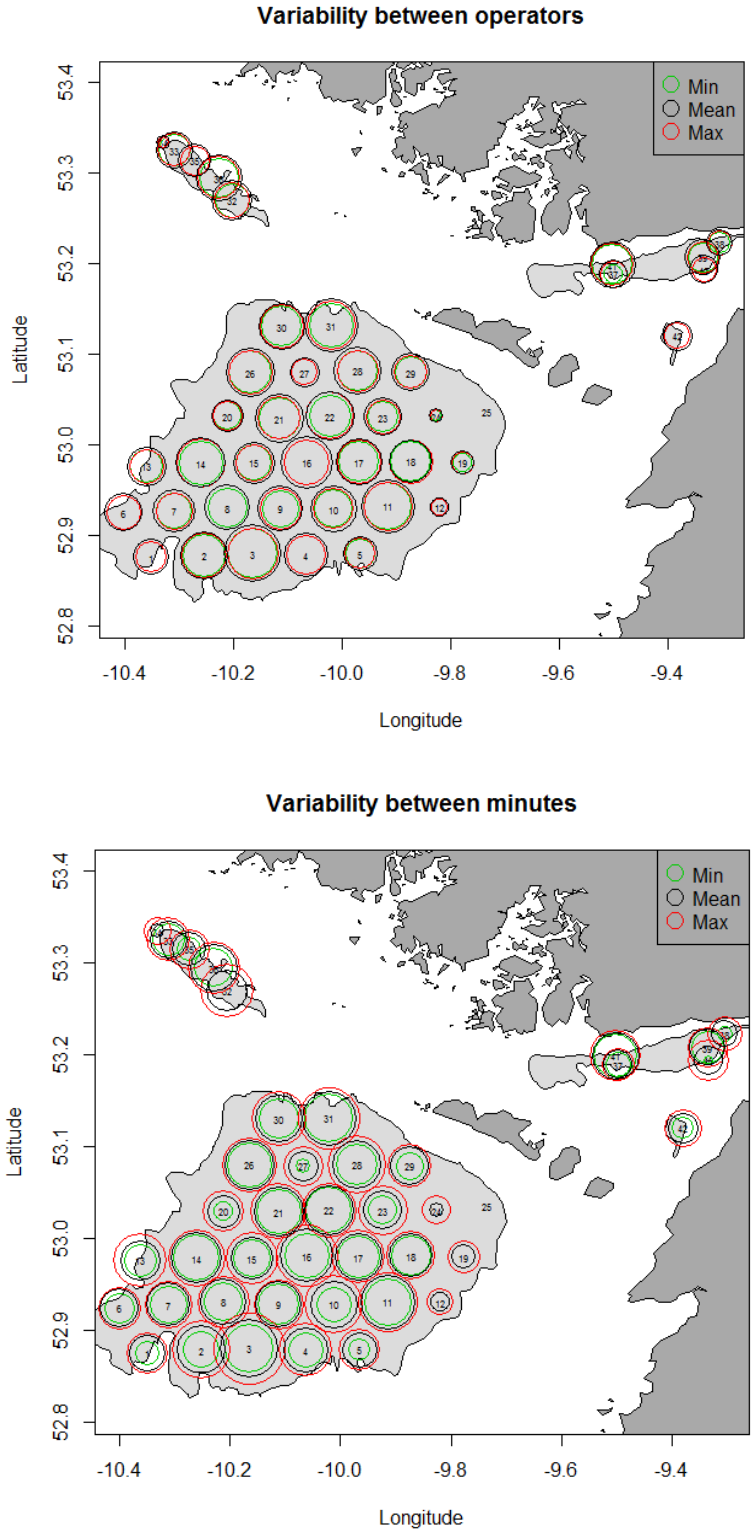

Figure 8: FU17 Aran grounds: Plot of the variability in density between minutes (top panel) and between operators (counters) (bottom panel) for each station in 2017.

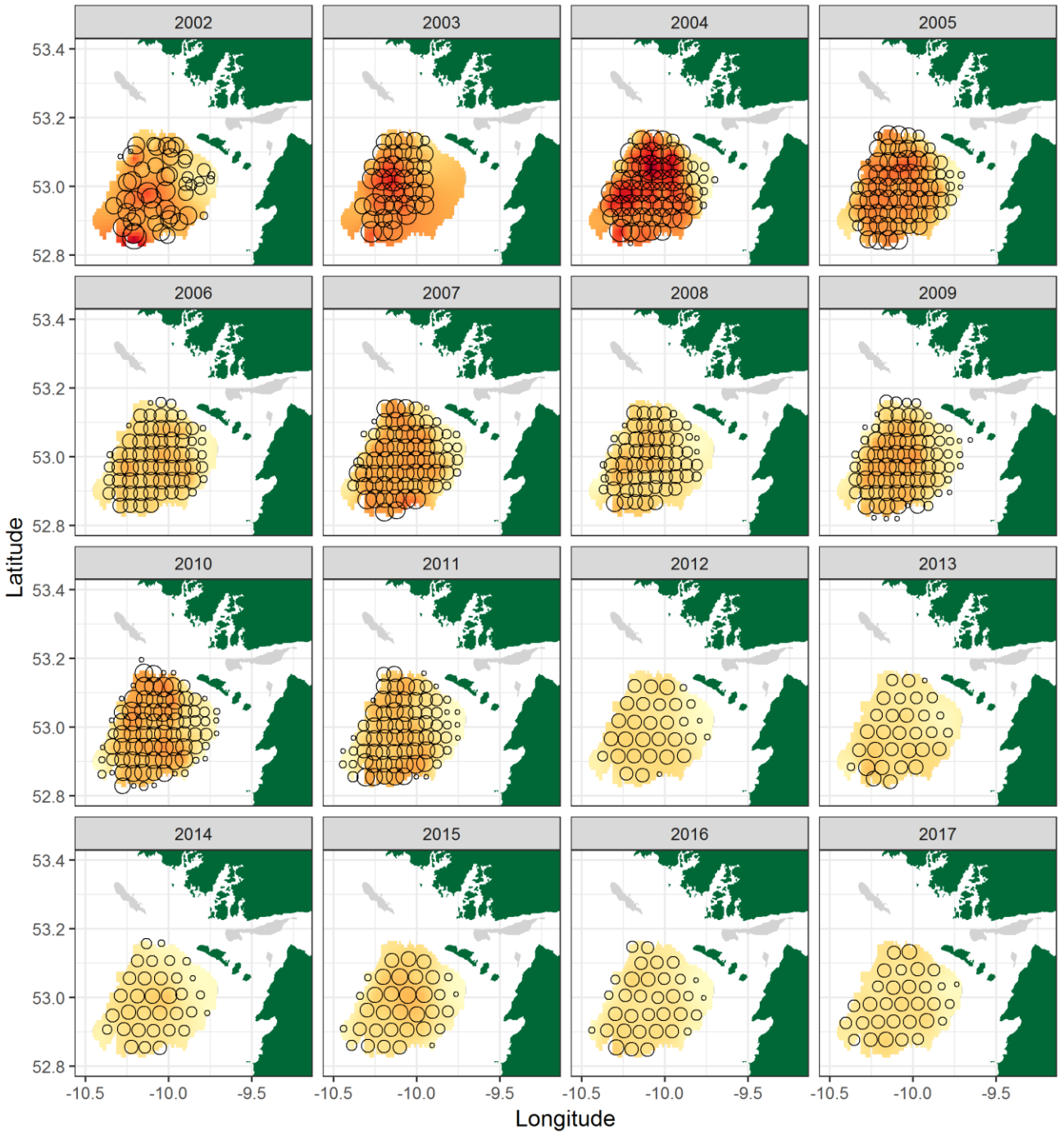

Figure 9: FU17 Aran grounds: Contour plots of the krigged density estimates by year from 2002 (top left) - 2017 (bottom left).

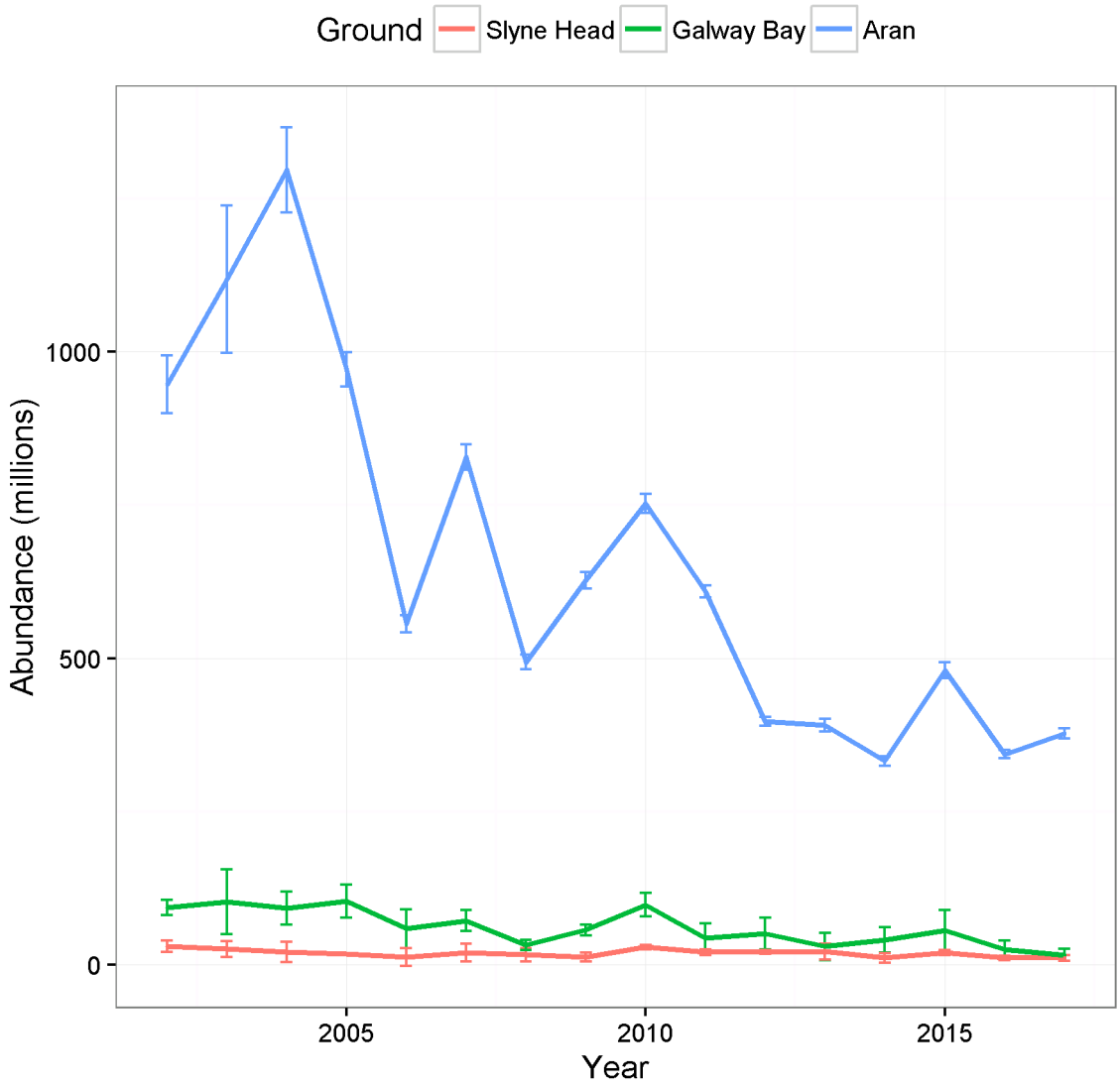

Figure 10: FU17 Aran grounds: Time series of abundance estimates for the Aran Grounds, Galway Bay and Slyne Head (error bars indicate 95% confidence intervals).

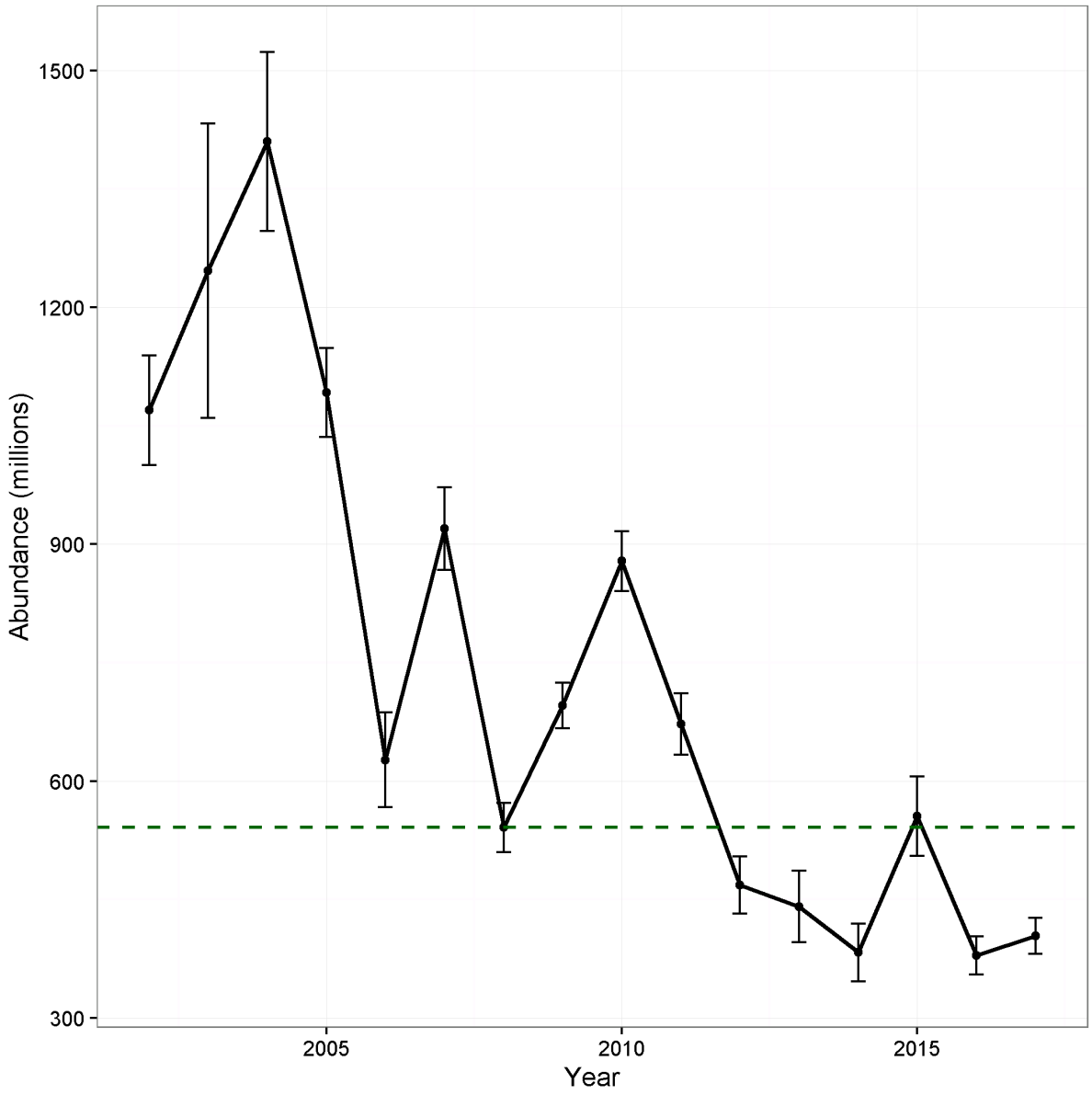

Figure 11: FU17 Aran grounds: Time series of total abundance estimates for FU17 (error bars indicate 95% confidence intervals) and $B_{trigger}$ (540 million) is dashed green line.

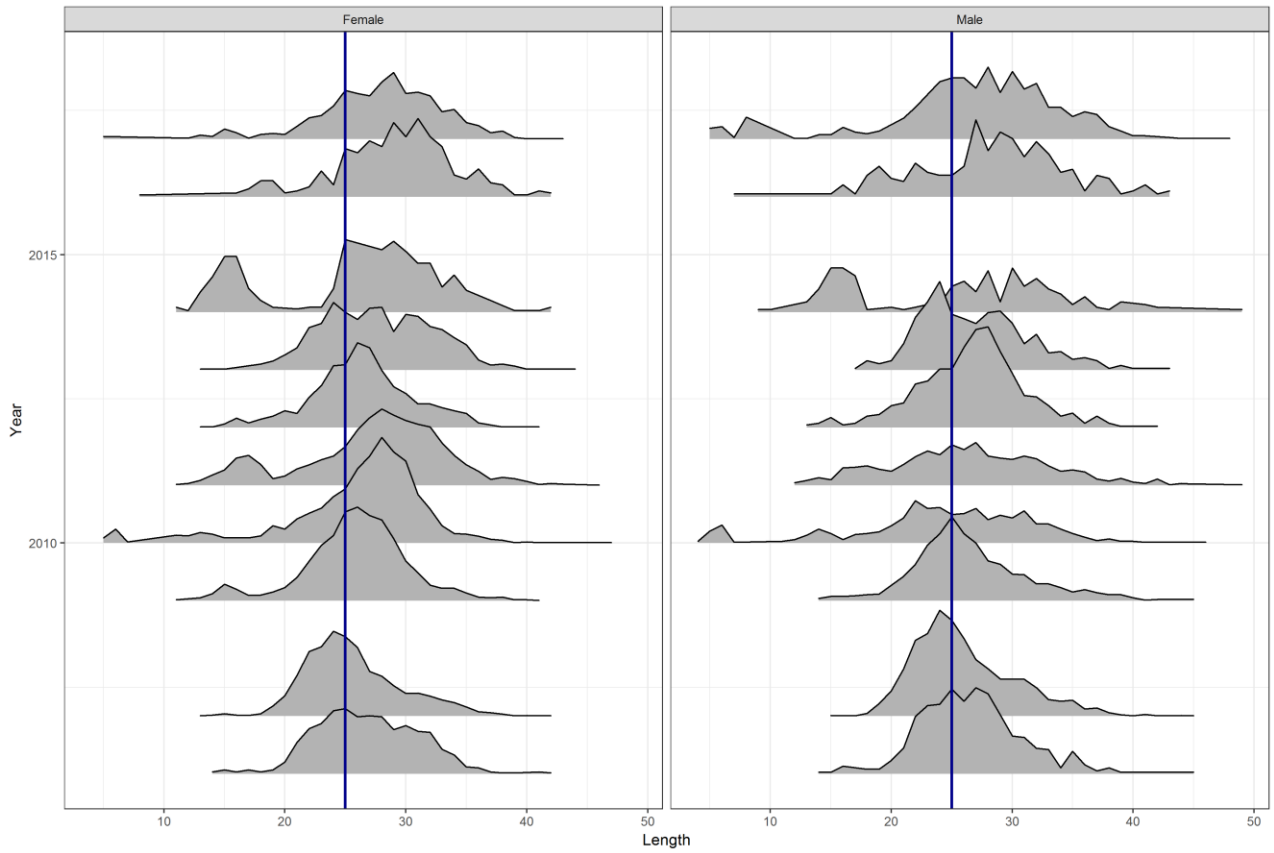

Figure 11: FU17 Aran grounds: Standardised length frequency distributions for male and female *Nephrops* caught using beam trawl during 2006 to 2017 UWTV surveys on the "Aran Grounds" except years 2008 and 2015. Minimum conservation reference size (MCRS) 25 mm carapace length shown as blue line.

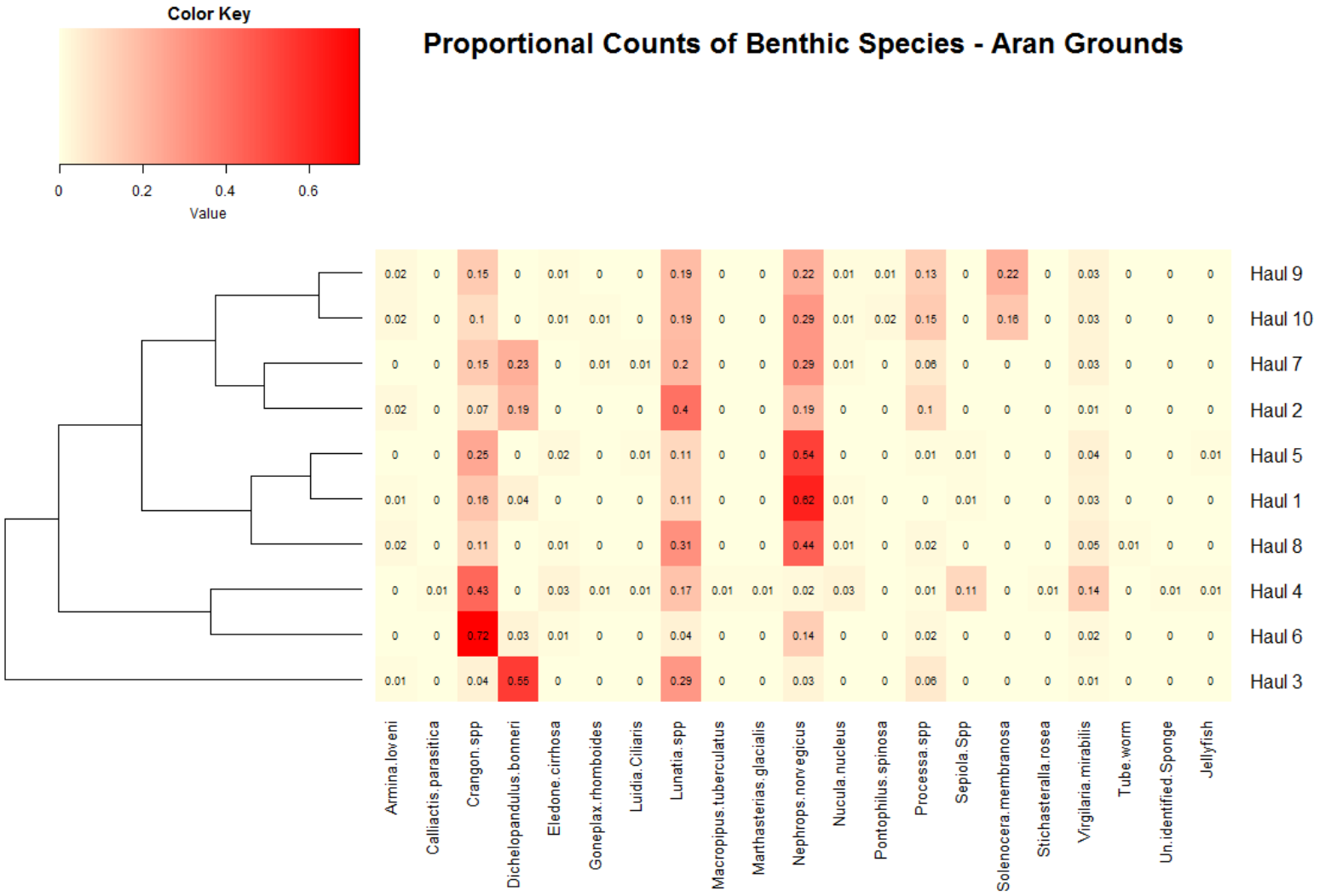

Figure 12: FU17 Aran grounds: Heat map and dendrogram of benthic catches from 2017 beam tows.

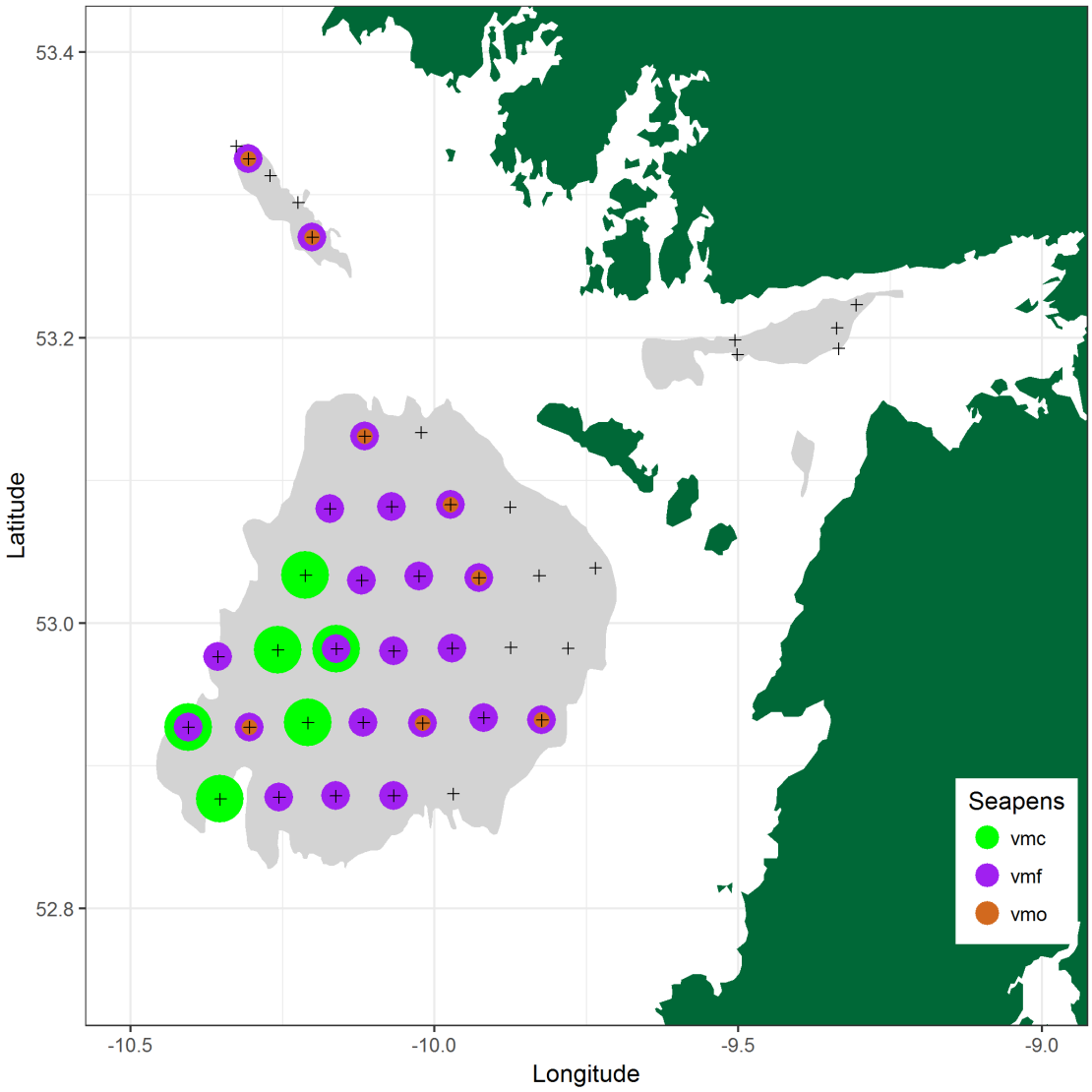

Figure 13: FU17 Aran grounds: 2017 stations where *Virgilaria mirabilis* (vm) were identified from video footage and classified according to abundance key - occasional (o), frequent (f), common (c). (+) denotes TV stations with no sea-pen observations.

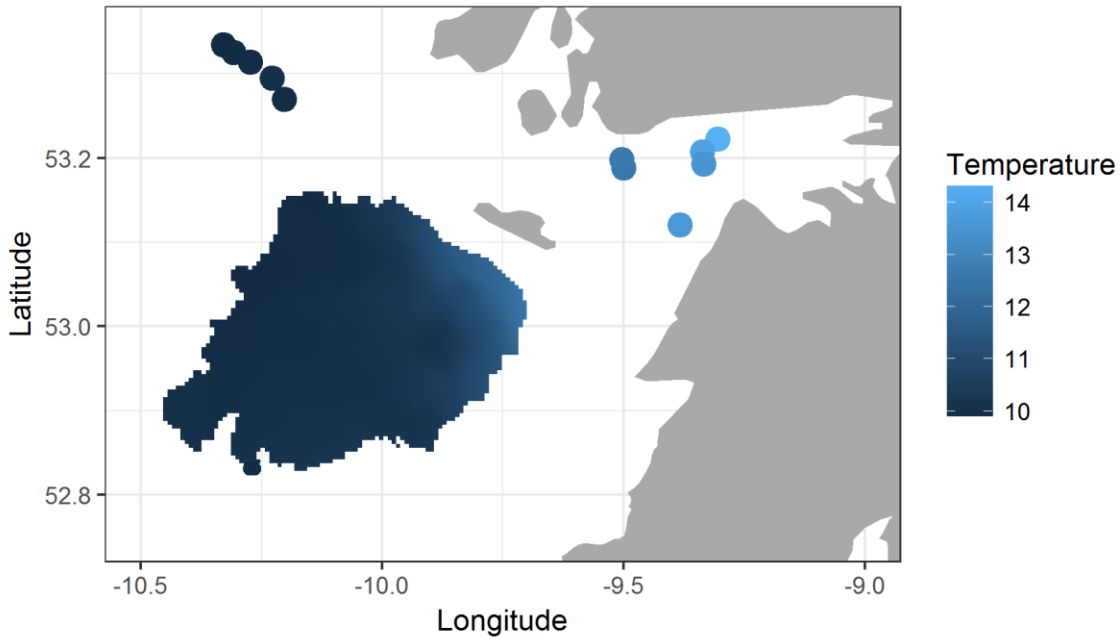

Figure 14: FU17 Aran grounds: Bottom temperature as recorded during the survey.

Table 1: FU17 Aran grounds: Area calculations for Aran grounds, Galway Bay and Slyne Head *Nephrops* grounds in ArcGIS10.

Ground	Area (km²)
Aran	1202
Galway Bay	79
Slyne Head	39.1
Total	1320.1

Table 2: 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 3: FU17 Aran grounds: Overview Aran of geostatistical results from 2002-2017.

Year	Number of Stations	Mean Density (burrows/m²)	Estimation Standard Deviation	Area (km²)	Geostatistical abundance estimate (millions of Burrows)	CV on Burrow estimate
2002	49	0.79	0.17	1196	947	3%
2003	41	0.94	0.09	1196	1118	6%
2004	64	1.08	0.27	1196	1297	3%
2005	70	0.81	0.12	1196	972	2%
2006	67	0.46	0.06	1196	556	3%
2007	71	0.69	0.12	1196	828	2%
2008	63	0.41	0.05	1196	494	3%
2009	82	0.52	0.1	1196	627	2%
2010	87	0.63	0.1	1196	752	2%
2011	76	0.51	0.09	1196	609	2%
2012	31*	0.33	0.03	1196	397	3%
2013	31*	0.33	0.03	1196	390	4%
2014	33*	0.28	0.03	1196	332	4%
2015	34*	0.40	0.06	1197	480	4%
2016	34*	0.29	0.03	1196	343	3%
2017	31*	0.31	0.02	1196	377	4%

- Reduced isometric grid

Table 4: FU17 Aran grounds: Summary statistics for the Galway Bay and Slyne Head *Nephrops* grounds from 2002-2017.

Year	Ground	Number of stations	Mean Adjusted Density (burrow/m²)	CViid (Relative SE)	Area (km²)	Raised abundance estimate (million burrows)	Upper CI on abundance	Lower CI on abundance
2002	Galway Bay	7	1.18	7%	78.966	93.1	105.9	80.3
2003	Galway Bay	3	1.3	16%	78.966	102.6	155.7	49.6
2004	Galway Bay	8	1.17	14%	78.966	92.2	119.1	65.3
2005	Galway Bay	4	1.3	11%	78.966	103	130	76
2006	Galway Bay	3	0.74	9%	78.966	58.8	90.4	27.2
2007	Galway Bay	5	0.91	8%	78.966	71.8	89	54.6
2008	Galway Bay	5	0.4	4%	78.966	31.6	39.9	23.3
2009	Galway Bay	8	0.71	4%	78.966	56.3	64.6	48
2010	Galway Bay	10	1.24	11%	78.966	97.6	116.5	78.7
2011	Galway Bay	6	0.55	12%	78.966	43.2	67.1	19.4
2012	Galway Bay	4	0.64	10%	78.966	50.9	76.9	24.9
2013	Galway Bay	5	0.37	10%	78.966	29.6	52	7.2
2014	Galway Bay	3	0.5	6%	78.966	39.8	60.6	19
2015	Galway Bay	5	0.71	15%	78.966	55.8	88.8	22.8
2016	Galway Bay	7	0.32	7%	78.966	25.1	41.8	8.4
2017	Galway Bay	5	0.20	4%	78.966	15.8	25.4	6.1
2002	Slyne Head	5	0.76	8%	39.146	29.8	38.9	20.7
2003*	Slyne Head	0	0.65	0%	39.146	25.3	38.1	12.4
2004	Slyne Head	3	0.53	10%	39.146	20.8	37.4	4.2
2005	Slyne Head	3	0.44	1%	39.146	17.4	18.6	16.2
2006	Slyne Head	3	0.3	9%	39.146	11.8	26.3	-2.6
2007	Slyne Head	4	0.51	12%	39.146	19.8	34.3	5.3
2008*	Slyne Head	0	0.41	0%	39.146	16	26.7	5.2
2009	Slyne Head	6	0.31	7%	39.146	12.2	19.2	5.1
2010	Slyne Head	7	0.73	4%	39.146	28.7	32.3	25.1
2011	Slyne Head	7	0.51	5%	39.146	20	25.1	14.8
2012	Slyne Head	3	0.52	2%	39.146	20.5	23.3	17.7
2013	Slyne Head	4	0.54	10%	39.146	21.1	33.8	8.3
2014	Slyne Head	4	0.28	6%	39.146	11	18.8	3.2
2015	Slyne Head	5	0.5	4%	39.146	19.6	24	15.2
2016	Slyne Head	4	0.3	3%	39.146	10.8	16.0	5.5
2017	Slyne Head	4	0.24	4%	39.146	10.7	15.3	6.7

* mean density estimated

Table 5: FU17 Aran grounds: Summary of fish catches by tow in weight (kg) from 2017 fishing operations.

Species	Weight (kg)									
	Tow1	**Tow2**	**Tow3**	**Tow4**	**Tow5**	**Tow6**	**Tow7**	**Tow8**	**Tow9**	**Tow10**
ARGENTINA SPHYRAENA	0.014	0.104	0.064	0.018	0.05	0.03	0	0.015	0.015	0
ARNOGLOSSUS LATERNA	0.01	0	0	0	0	0	0	0	0	0
CALLIONYMUS LYRA	0.11	0.386	0.074	0.472	0.272	0.08	0.07	0.09	0.88	0.158
CALLIONYMUS MACULATUS	0	0.084	0.242	0.036	0.156	0.64	0.35	0.465	0.144	0.44
CARPOS APER	0.004	0.004	0.018	0.004	0.006	0.012	0.004	0.005	0	0
CONGER CONGER	0	0	0.174	0	0	0.056	0.0186	0	0	0.082
CEPOLA RUBESCENS (C. MACROPHTHALMA)	0	0	0.26	0	0	0.18	0.15	0	0.01	0.04
ENCHELYOPUS CIMBRIUS	0	0	0	0	0.02	0.016	0.01	0	0.008	0.01
EUTRIGLA (CHELIDONICTHYS) GURNARDUS	0.032	0	0.048	0.001	0.001	0.001	0.001	0.015	0	0.028
GAIDROPSARUS VULGARIS	0.012	0.014	0.01	0	0	0	0	0.015	0.01	0.01
GLYPTOCEPHALUS CYNOGLOSSUS	0.275	0.385	0.584	1.298	0.66	0.766	1.116	0.755	2.874	1.024
GOBIES	0.015	0	0	0	0	0	0	0.01	0.006	0.002
HIPPOGLOSSOIDES PLATESSOIDES	0.334	0.0365	0.432	0.132	0.07	0.208	0.158	0.305	0.414	0.214
LEPIDORHOMBUS WHIFFIAGONIS	1.606	4.058	1.43	1.28	1.116	1.022	1.074	4.105	3.535	5.14
LEUCORAJA NAEVUS	0	0	0	0	0	0	0	0	0	0.746
LIMINDA LIMANDA	0	0.23	0	0.058	0	0.184	0	0	0	0
LOPHIUS BUDEGASSA	0.685	1.4	3.39	0.612	1.545	1.64	0.835	1.598	2.008	0.0934
LOPHIUS PISCATORIUS	1.204	3.075	0.276	0	0.072	0.044	0.246	0.42	1.39	0.2
MELANOGRAMMUS AEGLEFINUS	0.176	0.292	0.41	0	0.14	0.006	0.01	0	0	0
MERLANGIUS MERLANGUS	1.276	1.06	2.75	0	1.22	0.72	1.14	0.118	0.078	0.008
MERLUCCIUS MERLUCCIUS	0	0.132	0.414	0	0.374	0.274	0.634	0.068	0.72	0.142
MICROCHIRUS VARIEGATUS	0.048	0.095	0.122	0.126	0.062	0.094	0.026	0.038	0.102	0.026
MICROSTOMUS KITT	0.348	0.184	0.09	0.106	0.116	0.094	0.436	0.11	0.154	0.304
MICROMESISTIUS POUTASSOU	0.022	0.148	1.122	0.003	0.032	0	0	0	0.02	0.026
PLEURONECTES PLATESSA	0	0.205	0	0	0	0	0	0	0	0
RAJA MONTAGUI	1.074	0	0	0	0	0	0	0	0	0
SCYLIORHINUS CANICULA	0	0.85	0.79	0	0	0	0	0	0	0.8
SCOPHTHALMUS MAXIMUS (PSETTA MAXIMA)	0	0	0	0	0	1.702	0	0	0	0
SOLEA SOLEA	0	0	0.23	0	0	0	0	0	0	0.19
SPRATTUS SPRATTUS	0.03	0.016	0	0	0.01	0.008	0	0	0.032	0.002
TRISOPTERUS MINUTUS	0	0	0	0.008	0.006	0	0	0	0	0
Total Weight (kg)	7.275	12.759	12.930	4.154	5.928	7.777	6.279	8.132	12.400	9.685

Table 6: Inputs to short-term catch option table.

Year	Landings in number	Total discards in number *	Removals in number	UWTV abundance estimates	95% conf. intervals	Harvest rate	Mean weight in landings	Mean weight in discards	Discard rate	Dead discard rate
	millions	millions	millions	millions	millions	%	grammes	grammes	%	%
2002	55	18	68	1070	69	6.3	21.2	10.8	25%	20%
2003	44	18	58	1246	186	4.6	21.2	10.0	29%	24%
2004	29	11	38	1410	113	2.7	18.1	9.9	28%	23%
2005	42	20	57	1092	56	5.2	18.4	9.2	32%	26%
2006	NA	NA	50	627	60	7.9	NA	NA	NA	NA
2007	NA	NA	57	920	52	6.2	NA	NA	NA	NA
2008	48	22	65	541	31	12.0	21.9	11.2	31%	26%
2009	25	9	32	696	29	4.6	25.1	13.6	28%	22%
2010	37	15	49	879	38	5.6	25.2	14.7	29%	23%
2011	32	9	38	672	39	5.7	20.6	10.8	21%	17%
2012	60	8	66	468	36	14.4	20.9	10.4	11%	9%
2013	60	12	69	441	46	15.7	21.6	10.7	17%	13%
2014	34	5	38	383	37	9.8	22.6	9.6	13%	10%
2015	18	2	19	556	50	3.4	20.9	9.1	8%	6%
2016	30	6	35	379	24	9.2	21.2	10.9	17%	14%
2017				404	23					

Table 7: FU17 Aran grounds: The basis for the catch options for 2018.

Variable	Value	Notes
Stock abundance	404 million individuals	UWTV Survey 2017
Mean weight in landings	22.2 g	Average 2008–2016.
Mean weight in discards	11.2 g	Average 2008–2016.
Discard rate	12.9%	Average 2014–2016 (proportion by number). Calculated as discards/(landings + discards).
Discard survival rate	25%	Only applies in scenarios where discarding is allowed.
Dead discard rate	10.0%	Average 2014–2016 (proportion by number). Calculated as dead discards divided by dead removals (landings + dead discards). Only applies in scenarios where discarding is allowed.

Table 8: FU17 Aran grounds: Short-term management option table giving catch options for 2018 using the 2017 UWTV survey estimate.

a) Catch options for 2018 assuming zero discards.

Basis	Total catch	Wanted catch*	Unwanted catch*	Harvest rate**
ICES advice basis				
MSY approach; F = F_{MSY}*(Stock Abundance 2018)/MSY $B_{trigger}$	533	496	37	6.4%
Other options				
F_{MSY}	713	663	50	8.5%
F_{2016}	772	718	54	9.2%

* "Wanted" and "unwanted" catch are used to describe *Nephrops* that would be landed and discarded in the absence of the EU landing obligation, based on the average estimated discard rates for 2014–2016.
** Calculated for dead removals and applied to total catch.

b) Catch options for 2018 assuming discarding to continue at recent average.

Basis	Total catch	Dead removals	Landings	Dead discards	Surviving discards	Harvest rate*
	L+DD+SD	L+DD	L	DD	SD	for L+DD
ICES advice basis						
MSY approach; F = F_{MSY}*(Stock Abundance 2018)/MSY $B_{trigger}$	551	541	513	29	10	6.4%
Other options						
F_{MSY}	737	724	685	39	13	8.5%
F_{2016}	797	783	741	42	14	9.2%

* Calculated for dead removals and applied to total catch.

All harvest rates are calculated in numbers and refer to the dead removals. The difference in catch weights between catch options with the same harvest rates is related to the fact that, in the scenario allowing for discarding, a proportion of the discards is assumed to survive (25%).