# FU19 *Nephrops* grounds 2018 UWTV survey report and catch scenarios for 2019.

**Mikel Aristegui[1], Sinéad O'Brien[1], Marcin Blaszkowski[1], Seán O'Connor[1], Ross Fitzgerald[1] and Jennifer Doyle[1].**

[1] Fisheries Ecosystems Advisory Services, Marine Institute, Renville, Oranmore, Galway, Ireland.

**Version October 2018**

Ireland's European Structural and Investment Funds Programmes 2014-2020
Co-funded by the Irish Government and the European Union

Department of Agriculture, Food and the Marine
An Roinn Talmhaíochta, Bia agus Mara

EUROPEAN MARITIME AND FISHERIES FUND

## Abstract

This report provides the main results of the ninth underwater television survey of the various *Nephrops* patches in Functional Unit 19. The survey was multi-disciplinary in nature collecting UWTV, multi-beam and other ecosystem data. In 2018 a total 42 UWTV stations were successfully completed. The mean density estimates varied considerably across the different patches. The 2018 raised abundance estimate was a 65% decrease from the 2017 estimate and at 176 million burrows is below the MSY $B_{trigger}$ (430 million). Using the 2018 estimate of abundance and updated stock data implies catch of 173 tonnes and landings of 130 tonnes in 2018 when MSY approach is applied (assuming that discard rates and fishery selection patterns do not change from the average of 2015–2017). One species of sea pen was observed; *Virgularia mirabilis,* which has been observed on previous surveys of FU19. Trawl marks were observed at 36% of the stations surveyed.

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

Suggested citation:

Aristegui, M., O'Brien, S., Blaszkowski, M., O'Connor, S., Fitzgerald, R., and Doyle, J. 2018. FU19 *Nephrops* Grounds (FU19) 2018 UWTV Survey Report and catch scenarios for 2019. Marine Institute UWTV Survey report.

## Introduction

*Nephrops norvegicus* are common in the Celtic Sea occurring in geographically distinct sandy/muddy areas were the sediment is suitable for them to construct their burrows. The *Nephrops* fishery in ICES sub-area 7 is extremely valuable with Irish landings in 2016 worth around €54 million at first sale. The Celtic Sea area (Functional Units 19-22) supports a large multi-national targeted *Nephrops* fishery mainly using otter trawls and yielding landings in the region of ~5,000 t annually. Over the last decade reported landings from FU19 have been at around 650 t (ICES, 2017). The 2017 landings of around 420 t are estimated to be worth €3.1 m at first sale. The *Nephrops* fishery in FU19 occurs on several spatially discrete patches of suitable habitat which are spread out over a large area (Figure 1).

*Nephrops* spend a great deal of time in their burrows and their emergence behaviour is influenced by many factors; time of year, light intensity and tidal strength. Underwater television surveys and assessment methodologies have been developed to provide a fishery independent estimate of stock size, exploitation status and catch advice for several *Nephrops* stocks around Ireland (ICES, 2009, 2011).

The 2018 survey was multi-disciplinary in nature and also covered TV stations in FU2021 the results of which are presented elsewhere (Doyle et. al., 2018). The specific objectives of 2018 survey are listed below:

1. To obtain 2018 quality assured estimates of *Nephrops* burrow densities from several of the discrete mud patches of *Nephrops* ground in FU19.
2. To compare burrow density estimates with those made by previous surveys.
3. 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.
4. To collect oceanographic data using a sledge mounted CTD.
5. To collect sediment samples.

This report details the final UWTV results of the 2018 FU19 survey and also documents other data collected during the survey. Operational survey details are available in the form of a survey narrative from the scientists in charge (JD). The 2018 abundances are used to generate catch scenarios for 2019 in line with the recommendations and procedures outlined in the stock annex for FU19 (ICES, 2018).

## Material and methods

The spatial extent of the *Nephrops* grounds in FU19 has been defined using 2006-2014 integrated VMS-logbook data using the methods described in Gerritsen and Lordan (2011) along with using multi-beam backscatter data from seabed mapping programmes (ICES, 2014). The discrete patches have been named as: Bantry Bay, Galley Ground 1-4, Cork Channels and Helvick 1 & 2 (Figure 1). The area of each ground polygon is shown in Table 1 as defined by WKCELT (ICES, 2015). *Nephrops*

also occur outside these defined polygons in areas such as Kenmare Bay which was surveyed for the fourth time this year (2 stations completed).

In 2018 UWTV stations were randomly picked within each patch using the "spsample" function from the "R" library "sp" (Pebesma & Bivand, 2005) of "R" (R Core Team, 2017). The planned stations are shown in Figure 2. Previously stations were randomly chosen using the "Create Random Points" tool in ArcToolbox of ArcGIS10. The sampling effort, i.e. the numbers of stations, on each ground were determined relative to the spatial extent of each patch, as in previous years.

The 2018 FU19 survey took place on RV. Celtic Voyager from 2nd to 12th July 2018. Surveys in other years were generally between June to September. The operational protocols used were those reviewed by WKNEPHTV 2007 (ICES, 2007) and used in all other grounds surveyed by Ireland. These can be summarised as follows: At each station the UWTV sledge was deployed and once stable on the seabed a 10 minute tow was recorded onto DVD. Vessel position (DGPS) and position of sledge using a USBL transponder were recorded every 2 - 5 seconds. The navigational data were quality controlled using an "R" script developed by the Marine Institute (ICES, 2009b). In 2018 the USBL navigational data was used to calculate distance over ground for all of the stations. Station depths ranged from 28 metres on Helvick grounds to 108 metres on the Galley Grounds.

In line with recommendations of the Study Group on *Nephrops* Surveys (SGNEPS; ICES, 2012) all scientists were trained/re-familiarised using reference training material from FU22, and counts validated, prior to recounting at sea (ICES, 2009b). There is no FU19 specific reference footage available yet. Individual's counting performance in 2018 against the FU22 reference counts was measured by Lin's concordance correlation coefficient (CCC). A threshold of 0.5 was used to identify counters who needed further training. Once this process had been undertaken, all recounts were conducted by two trained "burrow identifying" scientists independent of each other on board the research vessel during the survey.

During this review process the visibility, ground type and speed of the sledge during one-minute intervals were subjectively classified using a classification key. In addition to the numbers of *Nephrops* burrows complexes (multiple burrows in close proximity to one another, which appear to be part of a single complex and were counted once), *Nephrops* activity in and out of burrows was also counted by each scientist for each one-minute interval. Following the recommendation of SGNEPS the time for verified recounts was 7 minutes (ICES, 2009b).

Notes were also recorded each minute on the occurrence of trawl marks, fish species and other species. Abundance categories of sea-pen species were also recorded to fulfil an OSPAR Special Request (ICES 2011). A key was devised to categorise the densities of sea-pens based on the SACFOR abundance scale (Table 2) after ICES (2011).

Finally, if there was any time during each minute where counting was not possible, due to sediment clouds or other reasons, this was recorded and removed from the distance over ground calculations. The "R" quality control tool allowed for the data quality of navigation, speed, visual clarity and consistency in counts to be checked (an example is given in Figure 3).

In 2018 the survey count data was screened to check for any unusual discrepancies using Lin's Concordance Correlation Coefficient (CCC) with a threshold of 0.5. 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 plots of count data for stations 273, 274 and 275 are shown in Figure 4. Consistency and bias between individual counters was also examined (Figure 5). Some variability between counters was evident, but with no obvious bias or excessive deviation.

Mean density was calculated by dividing the total number of burrow systems by the survey area observed. The USBL positional data was used to calculate distance over ground of the sledge. The field of view of the camera at the bottom of the screen was estimated at 75cm assuming that the sledge was flat on the seabed (i.e. no sinking). This field of view was confirmed using lasers during the 2018 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.

Due to technical problems CTD data were not collected on this survey.

Sediment samples were collected using the Shipex grab after completion of TV station and if survey time allowed. A photograph of the sediment was logged and 1 kg of sediment was taken for PSA analysis. 17 samples were taken and the data will be processed at a later stage. This data will be used to generate sediment maps for this area and also to ground truth any sea-bed mapping programmes.

A global mean density and summary statistics (number of stations, standard deviation, standard error, 95% confidence intervals and CV) were estimated for all stations. Mean Density was multiplied by the total area given in Table 1 to estimate the raised abundance estimate along with confidence intervals. All analysis was carried out using "R" (R Core Team, 2017). The same approach has been used since 2015. Prior to 2013 some other adjustments were made to account for incomplete survey coverage. Details of these are given in previous survey reports (Lordan, *et al.*, 2013).

## Results

The summary statistics for the various discrete *Nephrops* patches within FU19 are given in Table 3. Figure 6 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 2018 mean adjusted[1] burrow density estimates vary considerably, from the lowest observed at Bantry, Galley Grounds 1, and Helvick 2 of 0.06 (burrows/m²) to the highest of 0.19 (burrows/m²) at Galley Grounds 2. The mean density for most patches showed a decrease compared with 2017. Bubble plots of densities over the time-series by discrete patch show variability across the grounds and years (Figure 7). The adjusted burrow densities for each *Nephrops* patch from 2006 to 2018 are shown in Figure 8 as a violin and box plot. For the most grounds the observed densities were lower in 2018 than in previous years.

The adjusted burrow densities for the combined FU19 grounds from 2006 to 2018 are shown in Figure 9. The 2018 mean density of 0.09 burrows/$m^2$ was 65% lower than 2017, and is the lowest observed in the time-series

The time series of summary statistics for FU19 are given in Table 4. The 2018 raised abundance estimate of 176 million burrows is a 65% decrease from the 2017 estimate (Figure 10), and below the MSY $B_{trigger}$ reference point (430 million). The CV or RSE (relative standard error) for the 2018 survey was 15% which is below the upper limit of 20% recommended by SGNEPS (ICES, 2012).

Sea-pen distribution across the FU19 *Nephrops* grounds is mapped in Figure 11. *Virgularia mirabilis* was identified from the video. Trawl marks were noted at 36% of the stations surveyed.

The UWTV abundance data together with data from the fishery; landings, discards and removals in number are used to calculate the harvest rate in 2017 of 4.4%. The mean weight in the landings and the discards and the proportions of removal retained are also shown (Table 5). The basis to the catch scenarios is given in Table 6.

The catch and landings scenarios at various different fishing mortalities were calculated in line with the stock annex of the Report of the Working Group on Celtic Seas Ecoregion (ICES, 2018) using the 2018 survey abundance (Table 7). The latest estimate of stock abundance is below the MSY $B_{trigger}$ (value 430 million). The ICES MSY approach states that under such conditions the $F_{MSY}$ harvest rate (9.3% for FU 19 Norway lobster) should be reduced by multiplying it by the ratio of the current abundance to MSY $B_{trigger.}$ This corresponds to a harvest rate of 9.3 x 176 ÷ 430 = 3.8% for the catch advice in 2019. Fishing at the MSY approach level in 2019 would result in catches of 173 t and landings of 130 t assuming that discard rates and fishery selection patterns do not change from the average of 2015–2017.

[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).

## Discussion

The time series of UWTV survey information is developing for this Functional Unit. Several discrete mud patches with fished *Nephrops* populations have been identified and the survey coverage and precision since 2011 has been reasonable. It is clear that there are consistent differences in density in the different patches but most patches seem to vary annually in a similar way. Scientific knowledge of the spatial distribution of the *Nephrops* habitat in this area is developing thanks to new multi-beam data (www.infomar.ie), more extensive VMS data and information from the fishing industry particularly for inshore areas.

*Nephrops* fisheries in this area have been covered under the landings obligation since 2016. Discard rates for this FU are estimated to be relatively high at approximately 50% by number and 25% by weight in the last three years. This was well above the 2018 Landing Obligation *de minimis* of 6%. The provision of catch advice and scenarios for 2019 based on the MSY approach assumes that discarding will continue at the average rate estimated between 2015 and 2017.

In reality we should not expect the fishery in FU19 to be able to adapt to reduce discards to 6% so quickly. However, the imposition of the landings obligation on *Nephrops* fisheries since 2016 should result in changes in selectivity in the fisheries with high discard rates like FU19. 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 should 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 2008).

Monitoring the occurrence and frequency of sea-pens observed on these *Nephrops* patches is important in the context of OSPAR's designation of sea-pen and burrowing megafauna communities as threatened. The sea-pen *Virgularia mirabilis* which was seen in 2018 has been observed on previous surveys of FU19. Monitoring *Nephrops* stocks and the benthic habitat is also important in the context of the MFSD indicators (e.g. sea floor integrity).

The sediment sample data collected during the survey will increase the knowledge base on habitat mapping in time.

The main objectives of the survey were successfully met for the ninth time. The UWTV footage quality was excellent and in 2018 and all of the *Nephrops* patches within FU19 were successfully surveyed. 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 sincere thanks and gratitude to Colin McBrearty (Master) and crew of the RV. Celtic Voyager. Thanks to the onboard P&O technican Lukasz Pawlikowski who maintained the UWTV system throughout the survey. Thanks to Aodhán Fitzgerald, Rosemarie Butler (RVOPs) and Rob Bunn and Dave Tully (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.

## References


Campbell, N., Dobby, H., and Bailey, N. 2009. Investigating and mitigating uncertainties in the assessment of Scottish *Nephrops norvegicus* populations using simulated underwater television data. ICES Journal of Marine Science 66: 646–655. doi: 10.1093/icesjms/fsp046.

Doyle, J., Aristegui, M., Hanniffy, O., White, J., Fee, D., and McCorriston, P. 2018. The Labadie, Jones and Cockburn Banks *Nephrops* Grounds (FU20-21) 2018 UWTV Survey Report and catch scenarios for 2019. Marine Institute UWTV Survey report.

Gerritsen HD and Lordan C, (2011). Integrating Vessel Monitoring Systems (VMS) data with daily catch data from logbooks to explore the spatial distribution of catch and effort at high resolution. ICES J Mar Sci 68 (1): 245-252.

ICES 2007. Report of the Workshop on the use of UWTV surveys for determining abundance in *Nephrops* stocks throughout European waters (WKNEPHTV). ICES CM: 2007/ACFM: 14 Ref: LRC, PGCCDBS.

ICES 2009a. Report of the Benchmark Workshop on *Nephrops* assessment (WKNEPH). ICES CM: 2009/ACOM:33

ICES 2009b. Report of the Study Group on *Nephrops* Surveys (SGNEPS). ICES CM 2009/LRC: 15. Ref: TGISUR.

ICES 2011. Report of the ICES Advisory Committee 2011. ICES Advice.2011. Book 1: Introduction, Overviews and Special Requests. Protocols for assessing the status of sea-pen and burrowing megafauna communities, section 1.5.5.3.

ICES 2012. Report of the Study Group on *Nephrops* Surveys (SGNEPS). ICES CM 2012/SSGESST: 19. Ref: SCICOM, ACOM

ICES 2014. Report of the Benchmark Workshop on Celtic Sea stocks (WKCELT), 3–7 February 2014, ICES Headquarters, Copenhagen, Denmark. ICES CM 2014\ACOM:42. 194 pp.

ICES 2016. EU request to ICES to provide FMSY ranges for selected stocks in ICES subareas 5 to 10. *In* Report of the ICES Advisory Committee, 2016. ICES Advice 2016, Book 5, Section 5.2.3.1.

ICES. 2018. Report of the Working Group on Celtic Seas Ecoregion (WGCSE), 9–18 May 2018, Copenhagen, Denmark. ICES CM 2018/ACOM:13. 1887 pp.

Lin, L, I. 1989. A concordance correlation coefficient to evaluate reproducibility. Biometrics 45, pp255-268.

Lordan, C., Doyle, J., Hehir, I., O'Sullivan, D., Allsop, C., O'Connor, S., Blaszkowski, M., Butler, R., Burke, C., and Stewart, P. 2013. FU19 *Nephrops* Grounds 2013 UWTV Survey and catch options for 2014. Marine Institute UWTV Survey report.

Pebesma, E.J., R.S. Bivand, 2005. Classes and methods for spatial data in R. R News 5 (2), https://cran.r-project.org/doc/Rnews/

R Core Team (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/

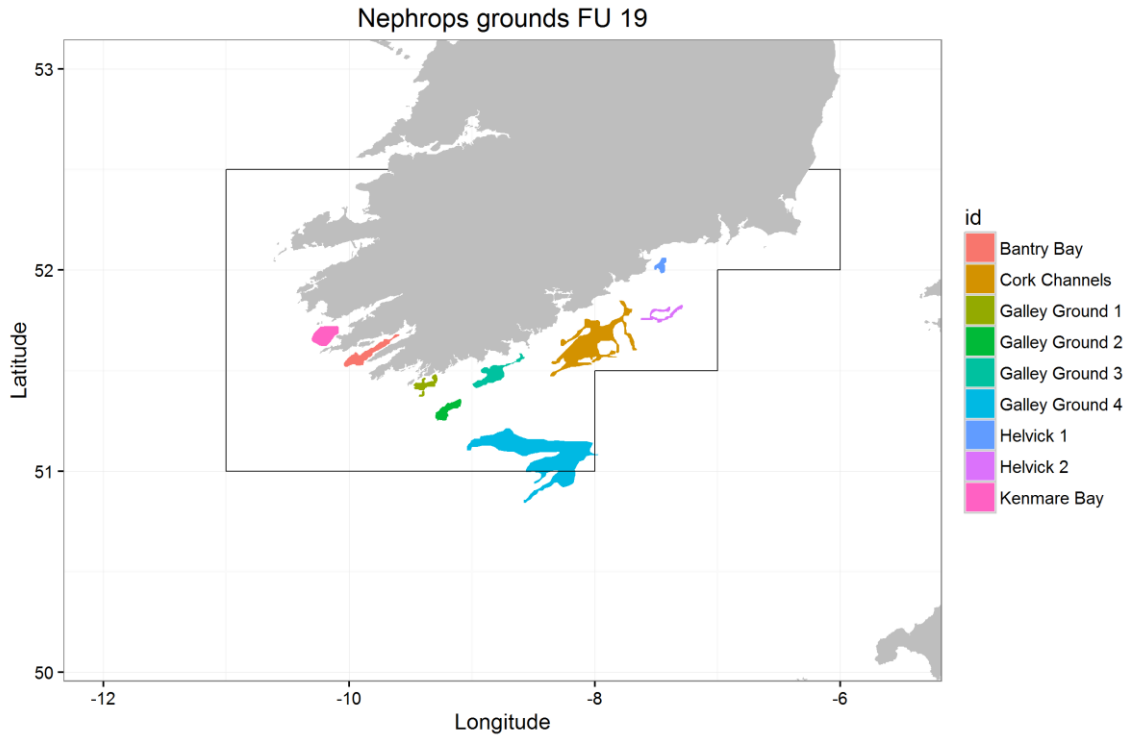


**Figure 1**: FU19 grounds: Individual *Nephrops* ground area polygons in Functional Unit 19.

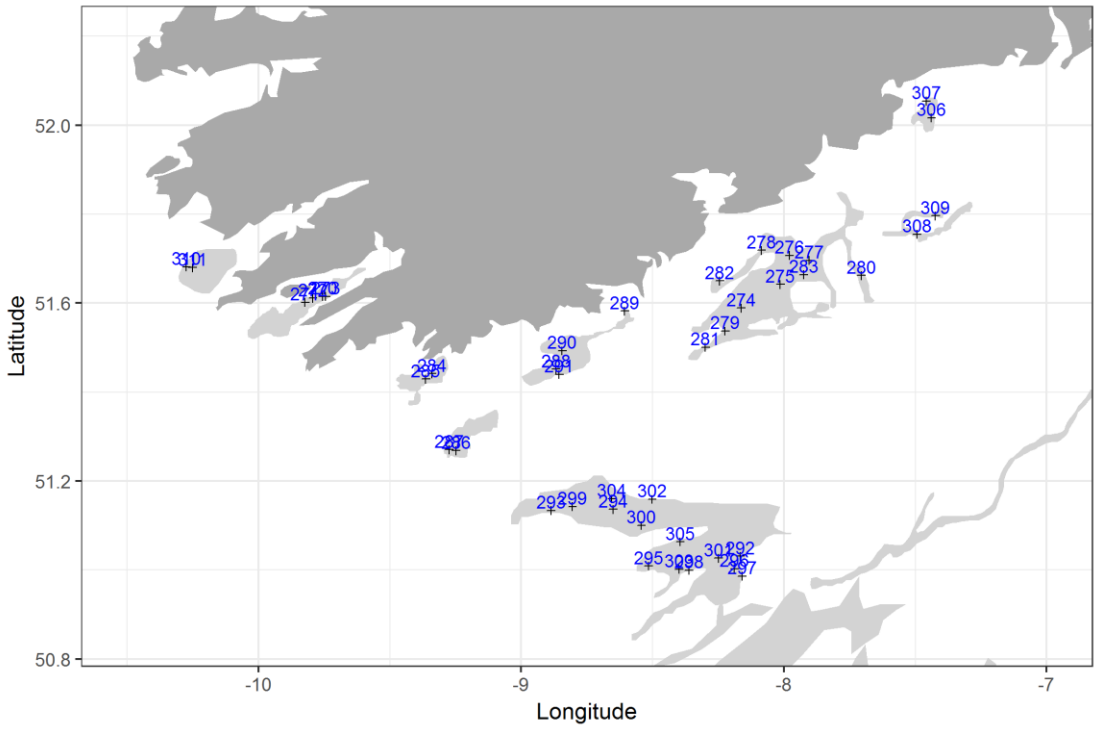


**Figure 2**: FU19 grounds: Stations completed on the 2018 FU19 *Nephrops* UWTV survey.

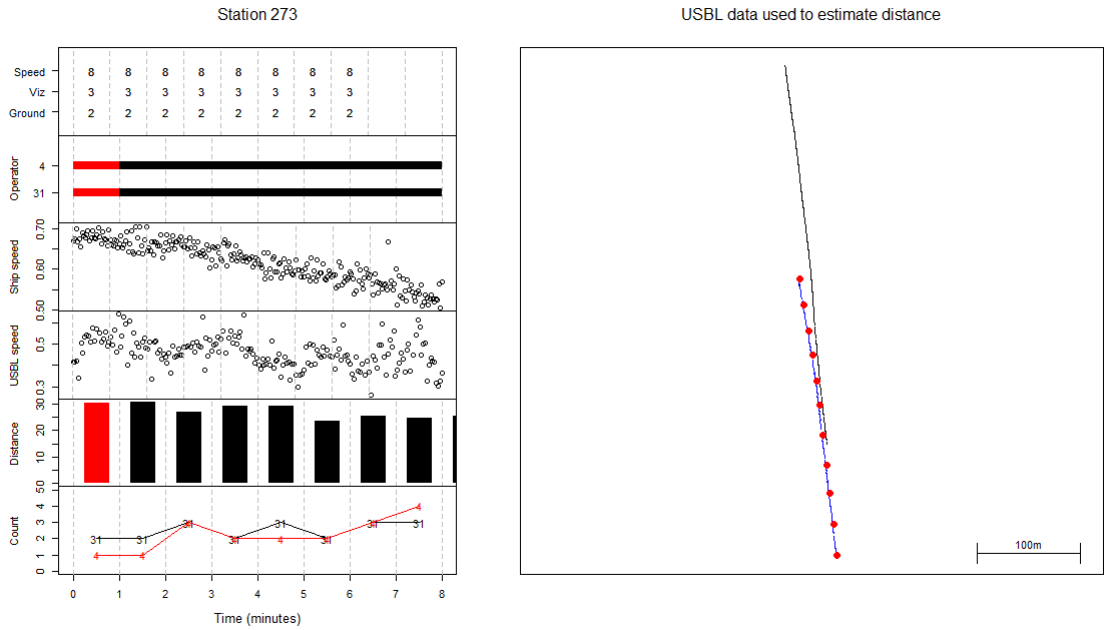


**Figure 3**: FU19 grounds: R - tool quality control plot for station 273 of the FU19 2018 UWTV survey.

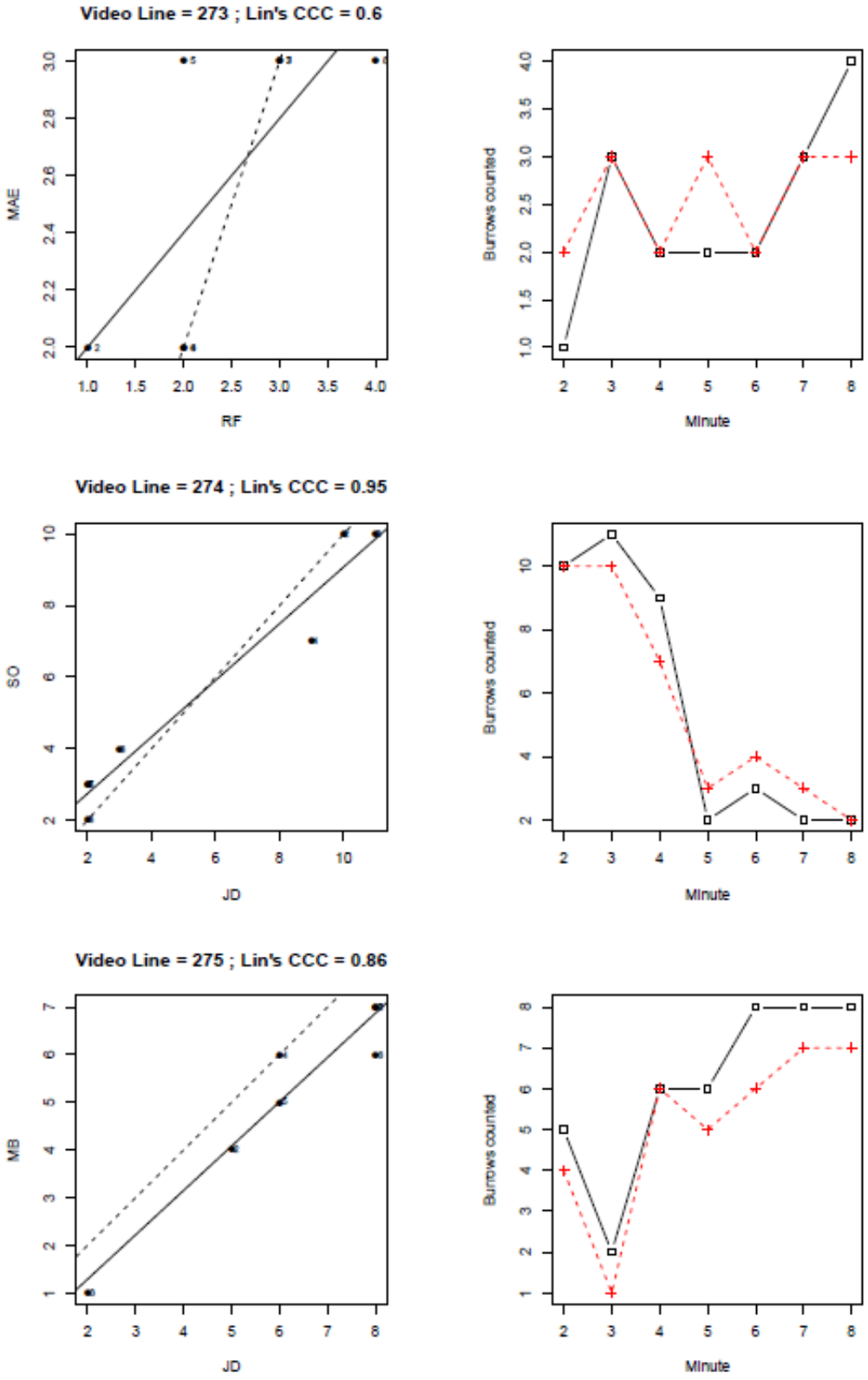


**Figure 4**: FU19 grounds: Lin's CCC quality control plot of count data for stations 273, 274 and 275 of the 2018 survey.

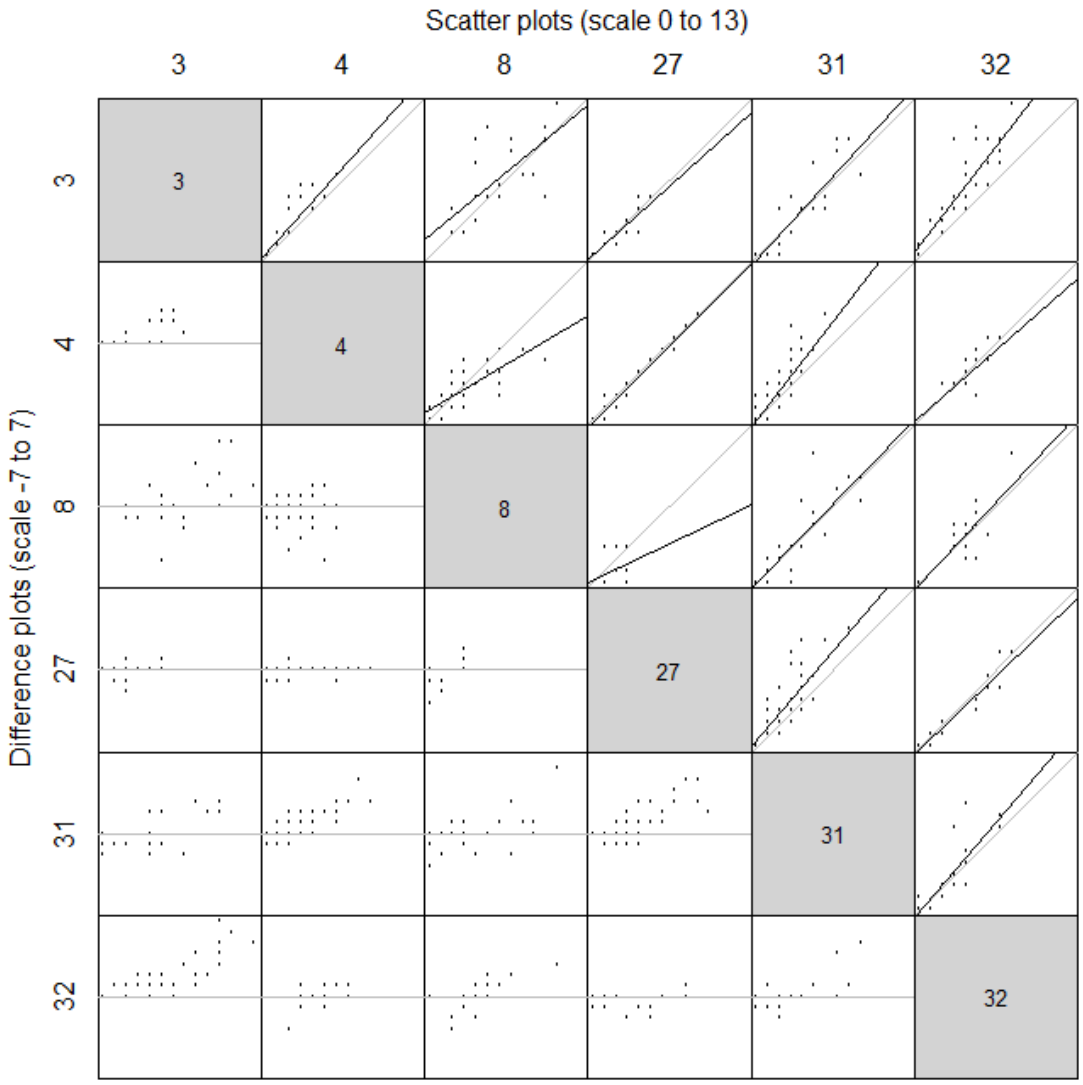


**Figure 5**: FU19 grounds: Scatter plot analysis of counter trends during FU19 2018 UWTV survey.

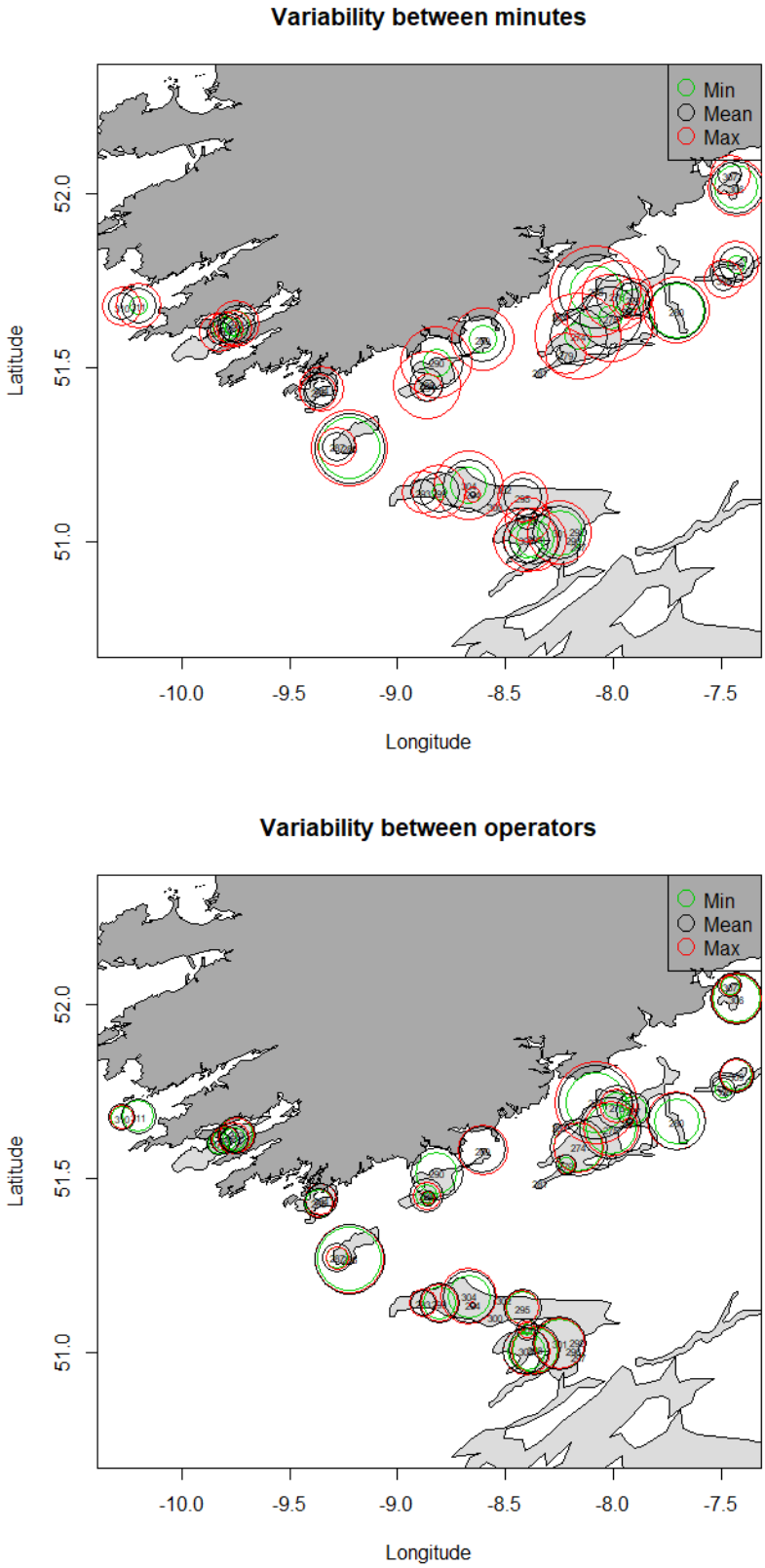


**Figure 6:** FU19 grounds: Plot of the variability in density between minutes (top panel) and between operators (counters) (bottom panel) for each station in 2018.

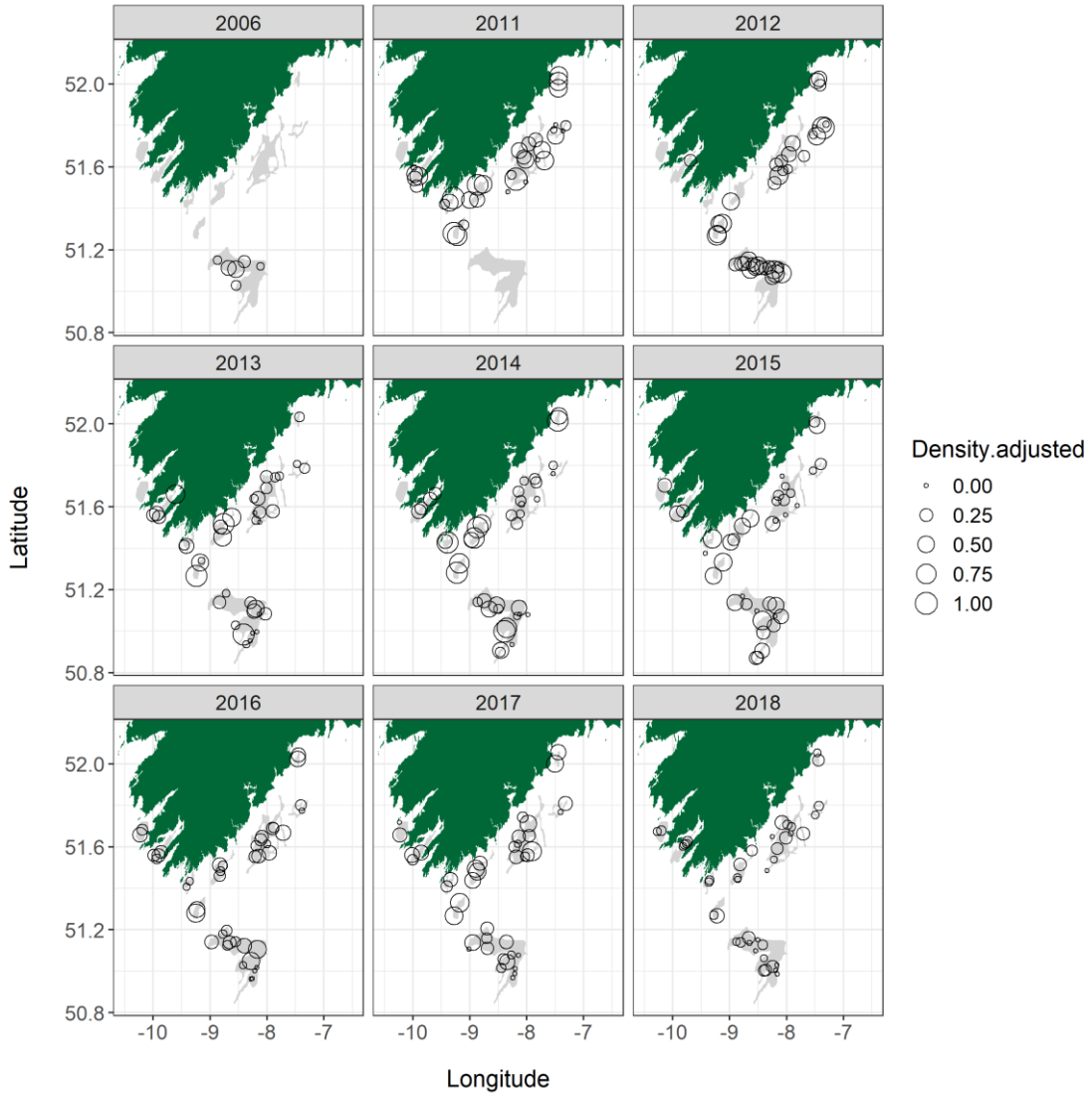


**Figure 7:** FU19 grounds: Bubble plot of the adjusted density (burrows/m²) from 2006 to 2018.

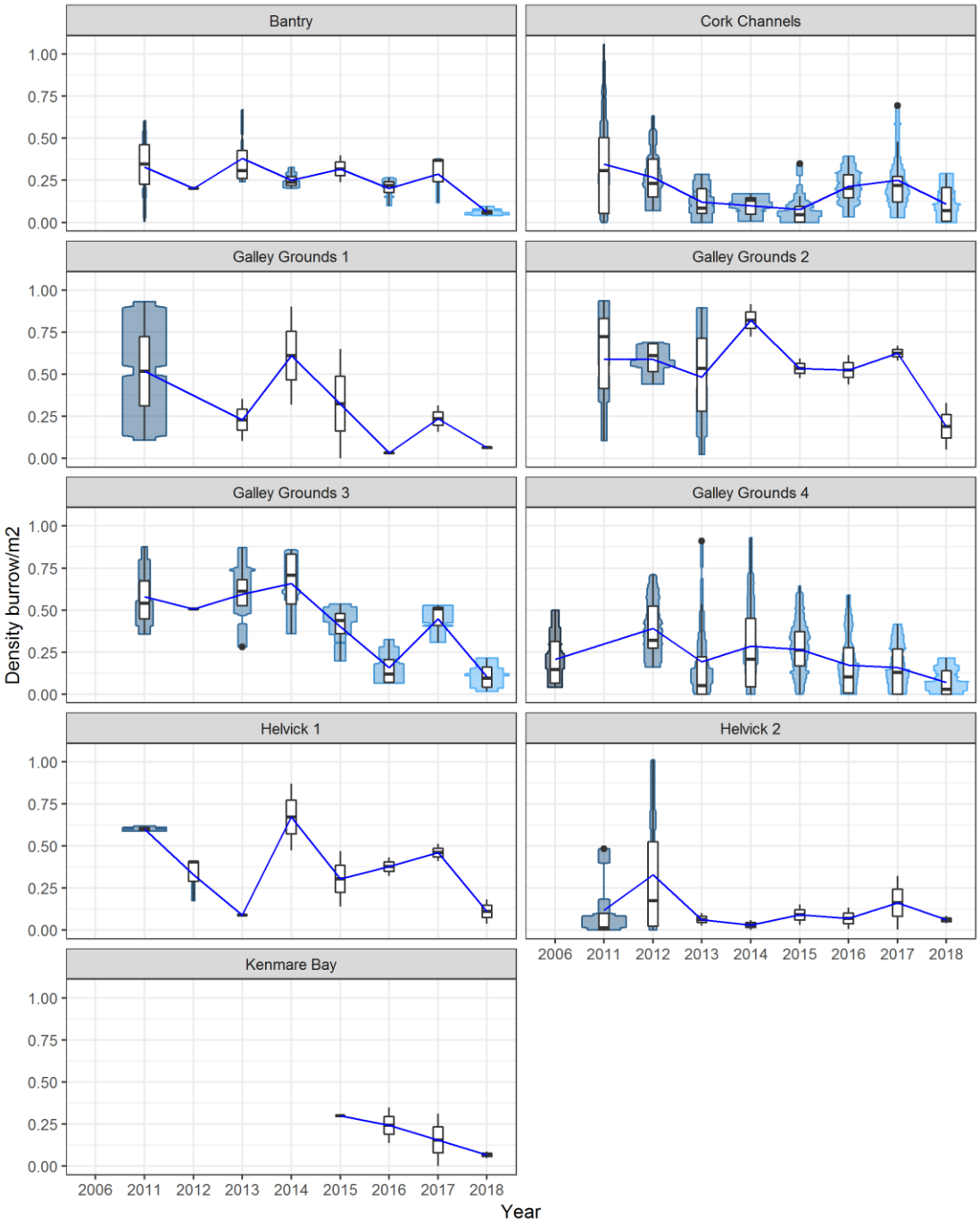


**Figure 8**: FU19 grounds: Violin and box plots of adjusted burrow density distributions by year for 2006-2018 for each ground. The blue line indicates the mean density over time. The horizontal black line represents the median, white box is the inter quartile range, the black vertical line is the range and the black dots are outliers. No TV survey from 2007 – 2010.

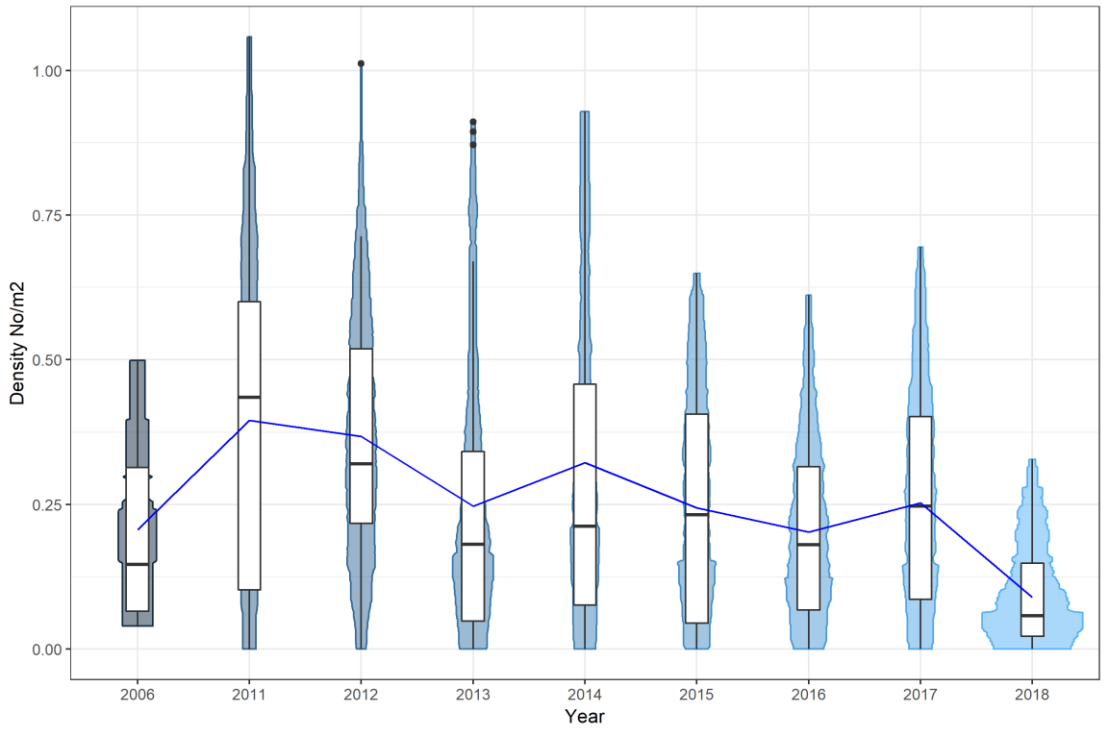


**Figure 9**: FU19 grounds: Combined violin and box plot of adjusted burrow density distributions by year for 2006-2018. The blue line indicates the mean density over time. The horizontal black lines represent medians, white boxes the inter quartile ranges, the black vertical lines the range and the black dots are outliers. No TV survey from 2007 – 2010.

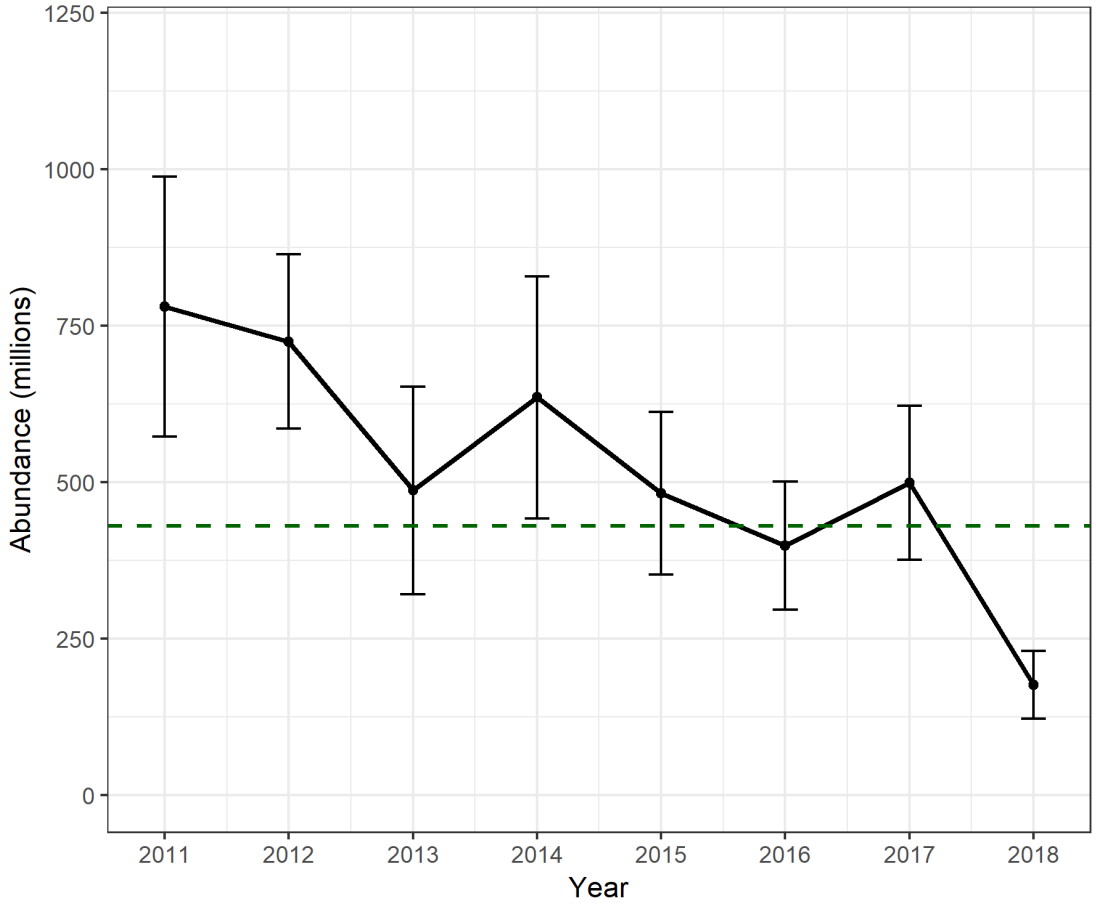


**Figure 10:** FU19 grounds: Time series of raised abundance estimates (in millions of burrows) for FU19. No survey data from 2007 to 2010. The error bars indicate the 95% confidence intervals and and $B_{trigger}$ is dashed green line.

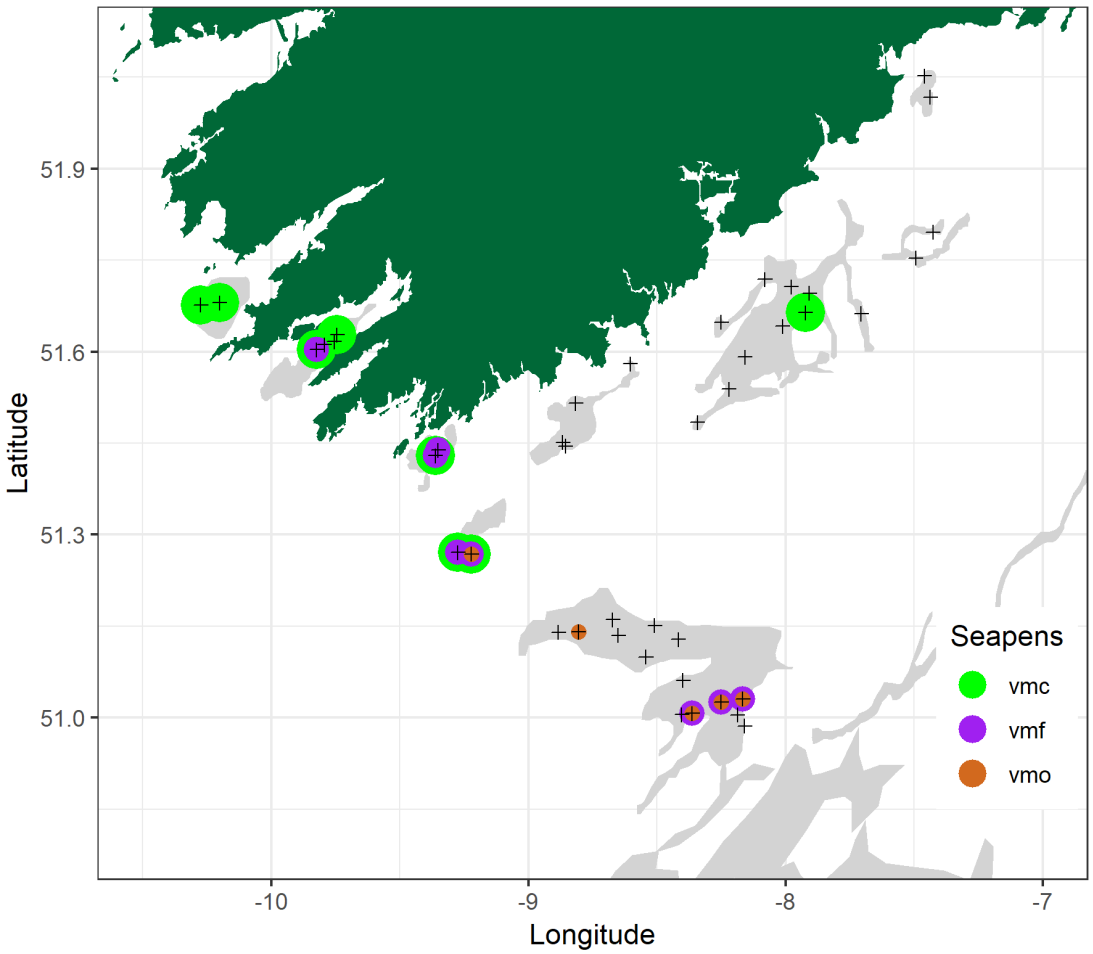


**Figure 11:** FU19 grounds: 2018 stations where *Virgularia mirabilis* (vm) was identified and classified according to abundance key - occasional (o), frequent (f), common (c). Single (+) denotes TV stations with no sea-pen observations.

**Table 1:** FU19 grounds: Area calculations for the various *Nephrops* grounds in FU19 (ICES, 2014).

| Ground Name | Area (km²) |
|---|---|
| Bantry | 121.52 |
| Cork Channels | 562.01 |
| Galley Grounds 1 | 60.86 |
| Galley Grounds 2 | 76.74 |
| Galley Grounds 3 | 133.94 |
| Galley Grounds 4 | 925.10 |
| Helvick 1 | 33.09 |
| Helvick 2 | 59.52 |
| Total | 1,972.78 |

**Table 2:** FU19 grounds: Key for classification of sea-pen 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:** FU19 grounds: Detailed summary statistics for the various *Nephrops* patches in FU19 over the time series. (N = number of stations, Mean Density ($N/m^2$) is adjusted for the bias correction factor, sd, se and ci are the standard deviation, standard error and 95% confidence intervals on the mean density).

| Year | Ground | N | Mean Density ($N/m^2$) | sd | se | ci |
|---|---|---|---|---|---|---|
| 2006 | Galley Grounds 4 | 6 | 0.21 | 0.18 | 0.08 | 0.19 |
| 2011 | Bantry | 5 | 0.33 | 0.23 | 0.1 | 0.28 |
| 2011 | Cork Channels | 12 | 0.35 | 0.32 | 0.09 | 0.2 |
| 2011 | Galley Grounds 1 | 3 | 0.52 | 0.41 | 0.24 | 1.02 |
| 2011 | Galley Grounds 2 | 3 | 0.59 | 0.43 | 0.25 | 1.07 |
| 2011 | Galley Grounds 3 | 4 | 0.58 | 0.22 | 0.11 | 0.35 |
| 2011 | Helvick 1 | 3 | 0.6 | 0.01 | 0.01 | 0.04 |
| 2011 | Helvick 2 | 5 | 0.12 | 0.21 | 0.09 | 0.26 |
| 2012 | Bantry | 1 | 0.2 | NA | NA | NA |
| 2012 | Cork Channels | 9 | 0.27 | 0.17 | 0.06 | 0.13 |
| 2012 | Galley Grounds 2 | 4 | 0.59 | 0.12 | 0.06 | 0.19 |
| 2012 | Galley Grounds 3 | 1 | 0.51 | NA | NA | NA |
| 2012 | Galley Grounds 4 | 16 | 0.39 | 0.16 | 0.04 | 0.09 |
| 2012 | Helvick 1 | 3 | 0.33 | 0.13 | 0.08 | 0.33 |
| 2012 | Helvick 2 | 6 | 0.33 | 0.41 | 0.17 | 0.43 |
| 2013 | Bantry | 4 | 0.38 | 0.2 | 0.1 | 0.31 |
| 2013 | Cork Channels | 11 | 0.12 | 0.1 | 0.03 | 0.07 |
| 2013 | Galley Grounds 1 | 2 | 0.23 | 0.18 | 0.13 | 1.59 |
| 2013 | Galley Grounds 2 | 3 | 0.48 | 0.44 | 0.25 | 1.09 |
| 2013 | Galley Grounds 3 | 4 | 0.59 | 0.24 | 0.12 | 0.38 |
| 2013 | Galley Grounds 4 | 13 | 0.19 | 0.27 | 0.07 | 0.16 |
| 2013 | Helvick 1 | 1 | 0.09 | NA | NA | NA |
| 2013 | Helvick 2 | 2 | 0.06 | 0.05 | 0.04 | 0.48 |
| 2014 | Bantry | 4 | 0.25 | 0.05 | 0.03 | 0.09 |
| 2014 | Cork Channels | 10 | 0.1 | 0.06 | 0.02 | 0.04 |
| 2014 | Galley Grounds 1 | 2 | 0.61 | 0.41 | 0.29 | 3.69 |
| 2014 | Galley Grounds 2 | 2 | 0.82 | 0.14 | 0.1 | 1.23 |
| 2014 | Galley Grounds 3 | 4 | 0.66 | 0.23 | 0.12 | 0.37 |
| 2014 | Galley Grounds 4 | 14 | 0.29 | 0.29 | 0.08 | 0.17 |
| 2014 | Helvick 1 | 2 | 0.67 | 0.28 | 0.2 | 2.53 |
| 2014 | Helvick 2 | 2 | 0.03 | 0.04 | 0.03 | 0.39 |
| 2015 | Bantry | 2 | 0.32 | 0.11 | 0.08 | 1.02 |
| 2015 | Cork Channels | 10 | 0.08 | 0.11 | 0.03 | 0.08 |
| 2015 | Galley Grounds 1 | 2 | 0.32 | 0.46 | 0.32 | 4.12 |
| 2015 | Galley Grounds 2 | 2 | 0.53 | 0.08 | 0.06 | 0.74 |

**Table 3 (cont.):** FU19 grounds: Detailed summary statistics for the various *Nephrops* patches in FU19 over the time series. (N = number of stations, Mean Density (N/m²) is adjusted for the bias correction factor, sd, se and ci are the standard deviation, standard error and 95% confidence intervals on the mean density).

| Year | Ground | N | Mean Density (N/m²) | sd | se | ci |
|---|---|---|---|---|---|---|
| 2015 | Galley Grounds 3 | 4 | 0.4 | 0.14 | 0.07 | 0.23 |
| 2015 | Galley Grounds 4 | 14 | 0.27 | 0.19 | 0.05 | 0.11 |
| 2015 | Helvick 1 | 2 | 0.3 | 0.23 | 0.16 | 2.08 |
| 2015 | Helvick 2 | 2 | 0.09 | 0.09 | 0.06 | 0.79 |
| 2015 | Kenmare Bay | 1 | 0.3 | NA | NA | NA |
| 2016 | Bantry | 4 | 0.2 | 0.07 | 0.04 | 0.12 |
| 2016 | Cork Channels | 10 | 0.21 | 0.11 | 0.03 | 0.08 |
| 2016 | Galley Grounds 1 | 2 | 0.03 | 0.01 | 0.01 | 0.08 |
| 2016 | Galley Grounds 2 | 2 | 0.53 | 0.12 | 0.09 | 1.11 |
| 2016 | Galley Grounds 3 | 4 | 0.16 | 0.12 | 0.06 | 0.19 |
| 2016 | Galley Grounds 4 | 14 | 0.17 | 0.2 | 0.05 | 0.12 |
| 2016 | Helvick 1 | 2 | 0.38 | 0.08 | 0.06 | 0.7 |
| 2016 | Helvick 2 | 2 | 0.07 | 0.09 | 0.06 | 0.81 |
| 2016 | Kenmare Bay | 2 | 0.24 | 0.15 | 0.11 | 1.33 |
| 2017 | Bantry | 3 | 0.29 | 0.15 | 0.09 | 0.37 |
| 2017 | Cork Channels | 10 | 0.25 | 0.20 | 0.06 | 0.14 |
| 2017 | Galley Grounds 1 | 2 | 0.24 | 0.11 | 0.08 | 1.00 |
| 2017 | Galley Grounds 2 | 2 | 0.63 | 0.06 | 0.04 | 0.55 |
| 2017 | Galley Grounds 3 | 3 | 0.45 | 0.12 | 0.07 | 0.30 |
| 2017 | Galley Grounds 4 | 15 | 0.16 | 0.16 | 0.04 | 0.09 |
| 2017 | Helvick 1 | 2 | 0.46 | 0.07 | 0.05 | 0.66 |
| 2017 | Helvick 2 | 2 | 0.16 | 0.23 | 0.16 | 2.03 |
| 2017 | Kenmare Bay | 2 | 0.16 | 0.22 | 0.16 | 1.97 |
| 2018 | Bantry | 4 | 0.06 | 0.02 | 0.01 | 0.04 |
| 2018 | Cork Channels | 10 | 0.11 | 0.11 | 0.04 | 0.08 |
| 2018 | Galley Grounds 1 | 2 | 0.06 | 0.01 | 0.01 | 0.10 |
| 2018 | Galley Grounds 2 | 2 | 0.19 | 0.19 | 0.14 | 1.75 |
| 2018 | Galley Grounds 3 | 4 | 0.11 | 0.09 | 0.05 | 0.14 |
| 2018 | Galley Grounds 4 | 14 | 0.07 | 0.08 | 0.02 | 0.05 |
| 2018 | Helvick 1 | 2 | 0.11 | 0.10 | 0.07 | 0.92 |
| 2018 | Helvick 2 | 2 | 0.06 | 0.03 | 0.02 | 0.28 |
| 2018 | Kenmare Bay | 2 | 0.07 | 0.03 | 0.02 | 0.25 |

**Table 4:** FU19 grounds: Final of results for UWTV surveys in FU19 for 2006-2018. No UWTV survey in years 2007 to 2010.

| FU | Year | Number of stations | Mean Density adjusted (burrow /m²) | Standard Deviation | Raised abundance estimate adjusted (million burrows) | Upper 95%CI on Abundance | Lower 95%CI on Abundance | CVs |
|---|---|---|---|---|---|---|---|---|
| FU19 | 2006 | 6 | 0.21 | 0.18 | 408 | 789 | 26 | 36% |
| | 2007 | No Survey Data | | | | | | |
| | 2008 | | | | | | | |
| | 2009 | | | | | | | |
| | 2010 | | | | | | | |
| | 2011 | 35 | 0.34 | 0.26 | 665 | 842 | 488 | 13% |
| | 2012 | 40 | 0.3 | 0.18 | 594 | 708 | 480 | 9% |
| | 2013 | 40 | 0.25 | 0.26 | 487 | 653 | 320 | 17% |
| | 2014 | 40 | 0.32 | 0.31 | 636 | 829 | 442 | 15% |
| | 2015 | 39 | 0.24 | 0.2 | 482 | 612 | 352 | 13% |
| | 2016 | 42 | 0.2 | 0.17 | 399 | 501 | 296 | 13% |
| | 2017 | 41 | 0.25 | 0.20 | 499 | 622 | 376 | 12% |
| | 2018 | 42 | 0.09 | 0.09 | 176 | 230 | 122 | 15% |

**Table 5:** FU19 grounds: Inputs to catch scenarios 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 | % | % |
| 2006 | 26 | 3 | 28 | | | | 28.3 | 14.4 | 9 | 7 |
| 2007 | 31 | 2 | 32 | | | | 31.1 | 17.0 | 5 | 4 |
| 2008 | 26 | 6 | 30 | | | | 33.8 | 19.3 | 18 | 14 |
| 2009 | 27 | 18 | 41 | | | | 30.5 | 14.5 | 39 | 33 |
| 2010 | 24 | 20 | 39 | | | | 29.6 | 13.5 | 45 | 38 |
| 2011 | 24 | 31 | 47 | 665 | 171 | 7.1 | 25.0 | 12.6 | 56 | 49 |
| 2012 | 29 | 33 | 54 | 594 | 111 | 9.1 | 26.4 | 12.7 | 53 | 46 |
| 2013 | 29 | 33 | 54 | 487 | 161 | 11.0 | 27.4 | 12.1 | 54 | 47 |
| 2014 | 16 | 11 | 25 | 636 | 188 | 3.9 | 28.6 | 14.1 | 41 | 34 |
| 2015 | 17 | 13 | 27 | 482 | 126 | 5.5 | 29.8 | 13.8 | 43 | 36 |
| 2016 | 20 | 14 | 30 | 399 | 100 | 7.5 | 29.9 | 14.2 | 41 | 34 |
| 2017 | 15 | 10 | 22 | 499 | 120 | 4.4 | 28.8 | 14.4 | 40 | 33 |
| 2018 | | | | 176 | 53 | | | | | |

**Table 6:** FU19 grounds: The basis for the catch scenarios.

| Variable | Value | Notes |
|---|---|---|
| Stock abundance (2019) | 176 | UWTV 2018 |
| Mean weight in wanted catch | 29.5 g | Average 2015–2017 |
| Mean weight in unwanted catch | 14.1 g | Average 2015–2017 |
| Unwanted catch | 41.2% | Average 2015–2017 (proportion by number). |
| Discards survival | 25% | Proportion by number |
| Dead unwanted catch | 34.4% | Average 2015–2017 (proportion by number). |

**Table 7:** Catch advice and scenarios for 2019. Discarding assumed to continue at recent average. All weights are in tonnes.

| Basis | Total catch | Dead removals | Wanted catch | Dead unwanted catch | Surviving unwanted catch | Harvest rate* % | % advice change ** |
|---|---|---|---|---|---|---|---|
| | WC+DUC+SUC | WC+DUC | WC | DUC | SUC | for WC+DUC | |
| ICES advice basis | | | | | | | |
| MSY approach; $F = F_{MSY} \times$ (Stock Abundance 2019)/MSY $B_{trigger}$ | 173 | 162 | 130 | 33 | 11 | 3.8 | -85 |
| Other options | | | | | | | |
| $F_{MSY}$ | 423 | 397 | 317 | 80 | 27 | 9.3 | -64 |
| $F_{MSY\ lower}$ | 378 | 354 | 283 | 71 | 24 | 8.3 | -68 |
| $F_{MSY\ lower} \times$ (Stock Abundance 2019)/MSY $B_{trigger}$ | 155 | 145 | 116 | 29 | 10 | 3.4 | -87 |
| $F_{MSY\ upper}$*** | 423 | 397 | 317 | 80 | 27 | 9.3 | -64 |
| $F_{MSY\ upper} \times$ (Stock Abundance 2019)/MSY $B_{trigger}$ | 173 | 162 | 130 | 33 | 11 | 3.8 | -85 |
| $F_{2017}$ | 198 | 186 | 149 | 37 | 12 | 4.4 | -83 |

* Calculated for dead removals and applied to total catch.

** Advice value 2019 relative to advice value 2018.