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Foras na Mara

The Labadie, Jones and Cockburn Banks *Nephrops* Grounds (FU20-21) 2019 UWTV Survey Report and catch scenarios for 2020.

Jonathan White[1], Mikel Aristegui[1], Marci Blaszkowski[1], Dermot Fee[1], Séan O' Connor[1], John Power[1], Dean Anthony Notaro[2], Sinéad O' Brien[1] and Jennifer Doyle[1].

[1] Fisheries Ecosystems Advisory Services, Marine Institute, Renville, Oranmore, Galway, Ireland.
[2] University College Cork, College Road, Cork, Ireland.

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Abstract

This report provides the main results of the 2019 underwater television survey on the 'Labadie, Jones and Cockburn Banks' ICES assessment area; Functional Unit 20-21. The 2019 survey was multi-disciplinary in nature collecting UWTV, and other ecosystem data. A total of 95 UWTV stations were completed at 6 nm intervals over a randomised isometric grid design. The mean burrow density was 0.06 burrows/m^2 compared with 0.27 burrows/m^2 in 2018. The 2019 geostatistical abundance estimate was 617 million, a 77% decrease on the abundance for 2018, with a CV of 5% which is well below the upper limit of 20% recommended by SGNEPS 2012. Low densities were observed throughout the ground. Using the 2019 estimate of abundance and updated stock data implies catch in 2020 that correspond to the F ranges in the EU multi annual plan for Western Waters are between 1131 and 1150 tonnes (assuming that discard rates and fishery selection patterns do not change from the average of 2016–2018). One species of sea-pen (*Virgularia mirabilis*) were recorded as present at the stations surveyed*.* Trawl marks were observed at 32% of the stations surveyed.

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

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Introduction

The prawn (*Nephrops norvegicus*) are common in the Celtic Sea occurring in geographically distinct sandy/muddy areas were the sediment is suitable for them to construct their burrows. The *Nephrops* fishery in ICES sub-area 7 is extremely valuable with Irish landings in 2018 worth around €56 million at first sale. The Celtic Sea area (Functional Units 19-22; Figure 1) 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 (ICES, 2018). The 2018 reported landings from FU20-21 were ~1,997 t and estimated to be worth in the region of €8.5 m at first sale. This ground has become increasingly important to the Irish demersal fleet, which now accounts for around 65% of the total international FU20-21 *Nephrops* landings (ICES, 2018). 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 day, 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 & 2012a). This is the sixth UWTV survey in the Celtic Sea FU20-21 grounds carried out by the Marine Institute, Ireland.

The survey was multi-disciplinary in nature and the 2019 specific objectives are listed below :

1. To complete ~ 95 UWTV stations with 6.0 nautical mile (nm) spacing on the Labadie, Jones and Cockburn *Nephrops* ground (FU20-21).
2. To obtain 2019 quality assured estimates of *Nephrops* burrow distribution and abundance, and compare them with those from 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 for PSA analysis.

This report details: the survey design, the final UWTV results of the 2019 survey and also documents other data collected during the survey. Operational survey details are available in the form of a survey narrative from the scientist in charge (JW). The 2019 abundances are used to generate catch advice scenarios for 2020 in line with the recommendations and procedures outlined in the stock annex for FU20-21 (ICES, 2019).

Material and methods

The knowledge about the distribution of suitable *Nephrops* habitat in this area has been developing. Information so far suggests that *Nephrops* are found in complex channels, which are probably the remnants of fluvial channels related to the deglaciation of the Irish ice sheet at the end of the last ice age. The area of the ground was revised by WKCELT (ICES, 2014) with the inclusion of both French and Irish integrated logbook VMS data (Gerritsen & Lordan, 2011) and is now calculated at 10 014 km². This value is used for the survey.
INFOMAR seabed mapping programmes are now focussed in the Celtic Sea and the multibeam backscatter data from these surveys will aid in any area redefinition in time.

INFOMAR is the Department of Communications, Climate Action and Environment (DCCAE) funded national seabed mapping programme, jointly managed and delivered by Geological Survey Ireland and Marine Institute. Figure 2 shows the backscatter data to date relevant to this *Nephrops* survey area where light grey indicates soft sediment and darker grey harder ground.

The 2019 randomised isometric grid resulted in 95 planned stations and was generated using the "spsampl" function in the "sp" package (Pebesma & Bivand, 2005) in "R" (R Core Team, 2017). Stations depths varied from 78 m to 149 m and the completed stations ranged from 30 to 134 nm offshore (Figure 3). The 2019 survey took place on the RV. Celtic Voyager: from the 20th to 28th August.

In 2019 image data was collected by a custom built camera system recording High Definition still image data at 12 frames per second with a camera angle of 75 (°). The digital images were stored on a server and were reviewed onboard through an inhouse developed Image annotation R Shiny app (Aristegui, 2019). This app allows each reviewer to annotate burrows for each randomly assigned station in an efficient manner. The survey process is now paperless.

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. Time referenced high definition image data with field of view or 'FOV' of 1.01 metre. Vessel position (DGPS) and position of sledge (using a USBL transponder) were recorded every 3 seconds. The navigational data was quality controlled using an "R" script developed by the Marine Institute (ICES, 2009b). In 2019 USBL navigational data was used to calculate distance over ground or 'DOG' for 99% of stations and corrected ship navigation data used for 1 station.

In line with recommendations of the Study Group on *Nephrops* Surveys (SGNEPS), all scientists were trained/re-familiarised using training material and validated using reference footage for this area, prior to counting at sea (ICES, 2009b). This reference set was developed at the international workshop WKNEPS (ICES, 2018a). Individual's counting performance against the 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 the survey review process the numbers of *Nephrops* burrows systems (multiple burrows in close proximity which appear to be part of a single system and counted only once) by each scientist for each one-minute interval recorded. In addition *Nephrops* activity in and out of burrows were counted by each scientist for the full UWTV station. Following the recommendation of SGNEPS the time for verified recounts was 7 minutes (ICES, 2009b).

Presence / absence notes were also recorded on the occurrence of trawl marks, fish species and other species. Presence / absence of sea-pen species were also recorded due to an OSPAR Special Request (ICES 2011). Finally, if there was any time during the one-minute where counting was not possible, due to sediment clouds or other reasons, this was also estimated so that the time window could be removed from the distance over ground calculations. The "R" quality control tool allowed the quality of data for each station to be checked: navigation, speed, visual clarity and consistency in counts (Figure 4).

In 2019 the survey count data were 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). For those stations that did not pass the threshold it was deemed appropriate to carry out a third review. The paired count data that passed the threshold was used in the analysis. When the paired counts did not pass it was deemed acceptable to use the average of the three reviewers in the analysis. Lin's CCC quality control plots of count data for stations 176 to 178 are shown in Figure 5. There is moderate variability between counters but no obvious bias or excessive deviations. The moderate variability between counters is because burrow counting in this area is particularly difficult (see discussion).

Mean density was calculated by dividing the total number of burrow systems by the survey area observed. The USBL data were used to calculate distance over ground of the sledge. The field of view of the camera at the bottom of the screen was estimated by extrapolation at 1.01 metre assuming that the sledge was flat on the seabed (i.e. no sinking). 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.

For each UWTV station a temperature and depth profile was logged for the duration of each tow using a sled mounted and calibrated Seabird SBE39plus. This data will be processed at a later stage inhouse and is considered an emerging time series

Seven sediment samples were collected using the Shipex grab after completion of a TV station and when survey time allowed. This data will be used to generate sediment maps for this area and also to ground truth INFOMAR sea-bed mapping programmes in this area.

The approach to work up the abundance estimates each year has been documented in previous survey reports. Since 2015 the geostatistical analysis was carried out using the "RGeostats" package (Renard D., *et al*, 2015) and is available as an "R" markdown document. The same steps were carried out as in previous years; construction of experimental variogram, a model variogram produced with an exponential model, create krigged grid file using all data points as neighbours, same boundary used to estimate the domain area, mean density, total burrow abundance and calculate survey precision.

Results

All 95 stations were completed successfully on the FU20-21 *Nephrops* grounds (Figure 2). Figure 6 shows bubble plots of the variability between minutes and operators. These show that the burrow estimates are fairly consistent between minutes and counters. The variability is slightly higher between minutes.

The adjusted burrow densities from 2013 to 2019 are shown in Figure 7 as a combined violin and box plot. These show that density has decreased in 2019 from 2018. The highest station density observed in 2019 was 0.22/ m^2 while the majority were in the lower range of < 0.1/m^2. The 2019 mean adjusted[1] density of 0.06 burrows/m^2 is the lowest in the time series to date and was 77% lower than the 2018 estimate of 0.27 burrows/m^2.

Combined bubble and contour plots of the krigged densities from 2013 to 2019 are presented in Figure 8. Highest densities were towards the centre of the ground in years 2013 - 2014 while for 2015 - 2016 high densities were found in the northern and south-western area. In 2017 high densities were generally observed throughout the ground but the highest were to the northwest. In 2018 high densities were observed throughout the ground. There were also high densities observed close to boundaries in several areas. There was a general decrease in densities observed in 2019.

The summary empirical and geo-statistical results are given in Table 1. Stations surveyed in 2006 and 2012 should be viewed as exploratory and have not been used to extrapolate total abundance. The 2013 survey had partial coverage of the area (<60%) scaling the mean density to the total area (10,014 km^2) resulted in an abundance estimate of 1.6±0.3 billion. The 2018 geo-statistical abundance estimate is 2.7±0.006 billion which is 39% lower than in 2017. The 2019 geostatistical abundance estimate was 617 million a 77% decrease on the abundance for 2018 with a CV of 5% (Figure 9). The geo-statistical CVs were in the order of 3 to 5 %. These are well below the upper limit recommended of 20% (ICES, 2012).

The UWTV abundance data together with data from the fishery; landings, discards and removals in number are used to calculate the harvest rate (dead removals/TV abundance) in 2018 this was 3.0%. The mean weight in the landings and the discards and the proportions of removal retained are also shown (Table 2). The mean weights are variable between 2012 - 2018 and are based on available sampling data (ICES, 2019). The basis to the catch scenarios is given in Table 3. The catch scenarios and associated harvest rates are presented in Table 4. When the EU multiannual plan (MAP) for Western Waters and adjacent waters is applied (EU, 2019), catches in 2020 that correspond to the F ranges in the MAP are between 1131 and 1150 t (Table 4). This assumes that discard rates and fishery selection patterns do not change from the average of 2016–2018.

Sea-pen distribution across the *Nephrops* grounds is mapped in Figure 10. All sea-pens were identified from the image data as *Virgularia mirabilis*. Trawl marks were noted at 32% of the stations surveyed.

[1] Note the “adjusted” density estimates in this report are adjusted by dividing by 1.3 (Table 2) to take account of edge effect over estimation of area viewed during UWTV transects (see Campbell et al 2009).

Discussion

The 2019 survey achieved full coverage of the stock area for the sixth time. The density estimates in 2013 - 2016 are relatively similar and would be considered low (mainly ~0.2m^2). In 2017 there was a large increase in the densities across the whole ground, with a large increase also observed in FU22 also in the Celtic Sea (O'Brien *et al.,* 2017). In 2018 density across FU20-21 decreased. There was also a general decrease in density in the Celtic Sea *Nephrops* grounds in FU19 and FU22 (Aristegui, 2018).
Fluctuations in density has also been observed in the adjacent FU22 and FU19 this year (Doyle *et. al,* 2019). Sudden declines followed by large increases in abundance have also been observed in other *Nephrops* stocks in the past (e.g. FU12 and FU13 in 2012-2013).

A partial review of historical survey data was undertaken given the large fluctuations observed in the short time series to date for this survey, that is, to randomly check 20% of UWTV stations in years 2016 and 2017 as recommended by the working group for the Celtic Seas Ecoregion WGCSE (ICES, 2018b). This process was conducted in July 2018 during the FU20-21 UWTV survey. The analysis was presented to WGNEPS where full details are available in R-markdown (ICES, 2018c; Annex 7). This process was also followed in 2019 given the steep decrease in abundance estimate and following guidelines set out in the Manual for the *Nephrops* Underwater TV Surveys (SISP) (ICES, in prep). The analysis showed that the 2019 observed densities observed are robust (ICES, 2019).

It is likely that the recruitment to *Nephrops* populations in the Celtic Sea are linked through oceanographic process (O'Sullivan *et. al*, 2015). It may well be that oceanographic conditions have resulted in the observed density decreases in the Celtic Sea.

Nephrops fisheries in this area have been covered under the landings obligation since 2016 with several exemptions. Discard rates in weight for this FU have been around 19% in recent years.

The provision of catch advice and scenarios for 2020 based on the EU multiannual plan (MAP) for Western Waters assumes that discard rates and fishery selection patterns do not change from the average of 2016–2018.

The introduction of the landings obligation to *Nephrops* fisheries in 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 various ancillary information. The occurrence of trawl marks on the footage is notable for two reasons. Firstly, it makes identification of *Nephrops* burrows more difficult as the trawl marks remove some signature features making accurate burrow identification more difficult. Secondly, only occupied *Nephrops* burrows will persist in heavily trawled grounds and it is assumed that each burrow is occupied by one individual *Nephrops* (ICES 2008).

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 2019 have been observed on previous surveys of FU20-21. Monitoring *Nephrops* stock 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 sixth 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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References

Aristegui, M. 2019. Image annotation R Shiny app. Marine Institute. ttp://doi.org/c8jt

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.

Aristegui, M., O'Brien, S., Blaszkowski, M., O'Connor, S., Fitzgerald, R., and Doyle, J. 2018. The "Smalls" *Nephrops* Grounds (FU22) 2018 UWTV Survey Report and catch scenarios for 2019. Marine Institute UWTV Survey report.

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., O'Brien, S., Lynch, D., Vacherot, JP., and Fitzgerald, R. 2019. FU19 *Nephrops* Grounds (FU19) 2019 UWTV Survey Report and catch scenarios for 2020. Marine Institute UWTV Survey report.

Doyle, J., O'Brien, S., Fitzgerald, R., Vacherot, JP., Sugrue, S., and Quinn M. 2019. The "Smalls" *Nephrops* Grounds (FU22) 2019 UWTV Survey Report and catch scenarios for 2020. Marine Institute UWTV Survey report.

EU. 2019. Regulation (EU) 2019/472 of the European Parliament and of the Council of 19 March 2019 establishing a multiannual plan for stocks fished in the Western Waters and adjacent waters, and for fisheries exploiting those stocks, amending Regulations (EU)

2016/1139 and (EU) 2018/973, and repealing Council Regulations (EC) No 811/2004, (EC) No 2166/2005, (EC) No 388/2006, (EC) No 509/2007 and (EC) No 1300/2008. Official Journal of the European Union, L 83: 1–17. http://data.europa.eu/eli/reg/2019/472/oj

Gerritsen, H., 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 Journal of Marine Science: Journal du Conseil 68: 245–252. doi: http://dx.doi.org/10.1093/icesjms/fsq137.

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 2008. Report of the Workshop and training course on *Nephrops* burrow identification (WKNEPHBID). ICES CM: 2008/LRC: 3 Ref: LRC, ACOM.

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

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

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 2016b. 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. 2018a. Report of the Workshop on *Nephrops* burrow counting, 2-5 October 2018, Aberdeen, UK. ICES CM 2018/ EOSG:25.47 pp.

ICES 2018b. Report of the Working Group for Celtic Seas Ecoregion (WGCSE). ICES CM: 2018/ ACOM:13 in draft.

ICES. 2018c. Report of the Working Group on *Nephrops* Surveys (WGNEPS), 6–8 November 2018. Lorient, France. ICES CM 2018/ EOSG:18.227 pp.

ICES (in prep.). Manual for the Nephrops Underwater TV Surveys. Series of ICES Survey Protocols (SISP).

ICES. 2019. Working Group for the Celtic Seas Ecoregion (WGCSE). ICES Scientific Reports. 1:29. 1078 pp. http://doi.org/10/17895/ices.pub.7982.

O'Sullivan D, Lordan C, Doyle J, Berry A, Lyons K. 2015. Metapopulation connectivity via larval transport of the Norway lobster *Nephrops norvegicus* in waters around Ireland: a modelled approach. Mar Ecol Prog Ser 534:95-106.

O'Brien, S., Blaszkowski, M., Butler, R., Fee, D., Hernon, P., Santana, C., Lordan, C. and Doyle, J. 2017. The "Smalls" *Nephrops* Grounds (FU22) 2017 UWTV Survey Report and catch options for 2018. 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/

Renard D., Bez N., Desassis N., Beucher H., Ors F., Laporte F. 2015. RGeostats: The Geostatistical package [version:11.1.1]. MINES ParisTech. Free download from: http://cg.ensmp.fr/rgeostats

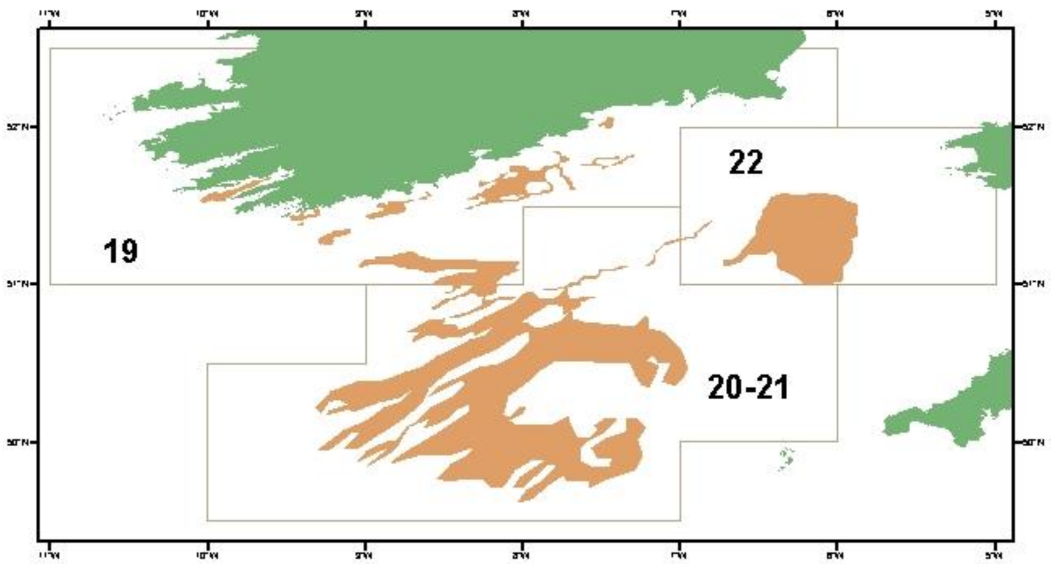


Figure 1: FU20-21 grounds: *Nephrops* Functional Units (FUs) and *Nephrops* survey area polygons in the greater Celtic Sea.

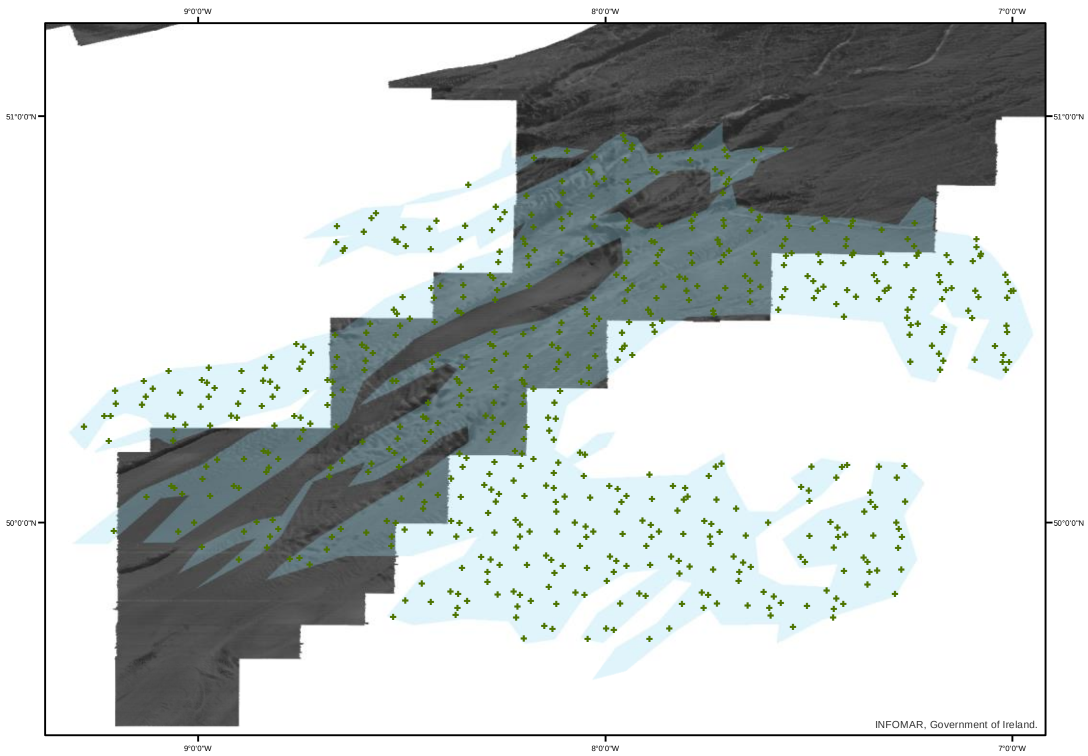


Figure 2: FU20-21 grounds: Multibeam backscatter data from INFOMAR mapping programme to date. Green (+) are UWTV stations completed to date and blue shading is the extent of UWTV survey area.

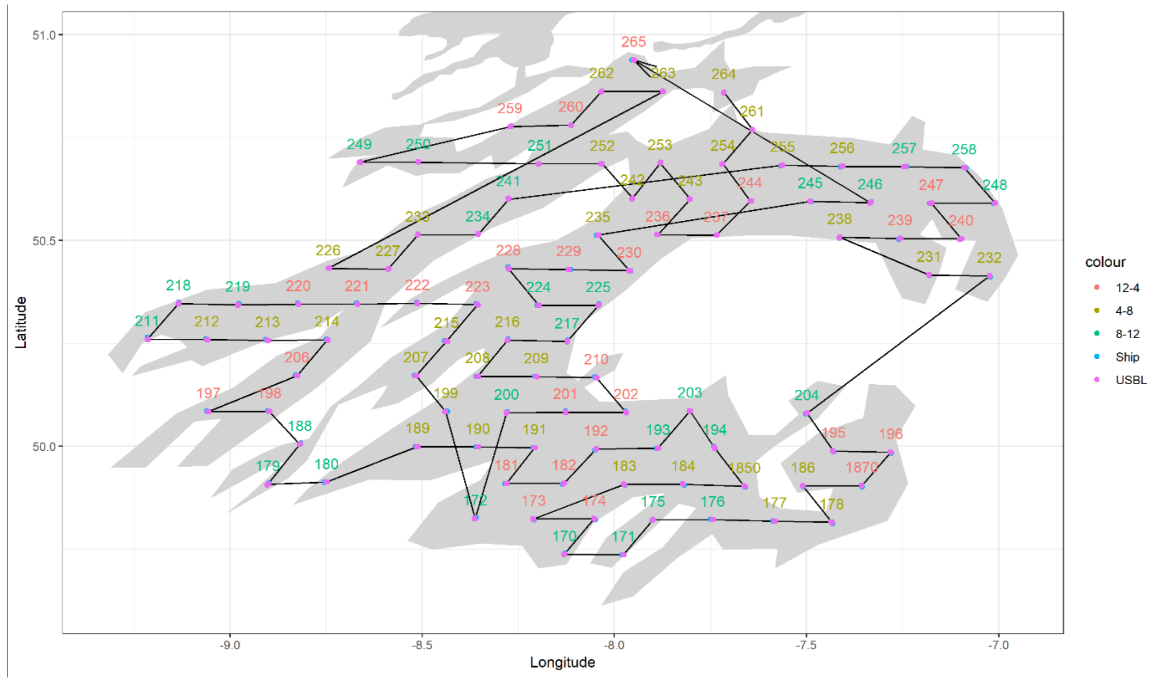


Figure 3: FU20-21 grounds: TV stations completed and navigation data recorded on the 2019 survey on each survey watch.

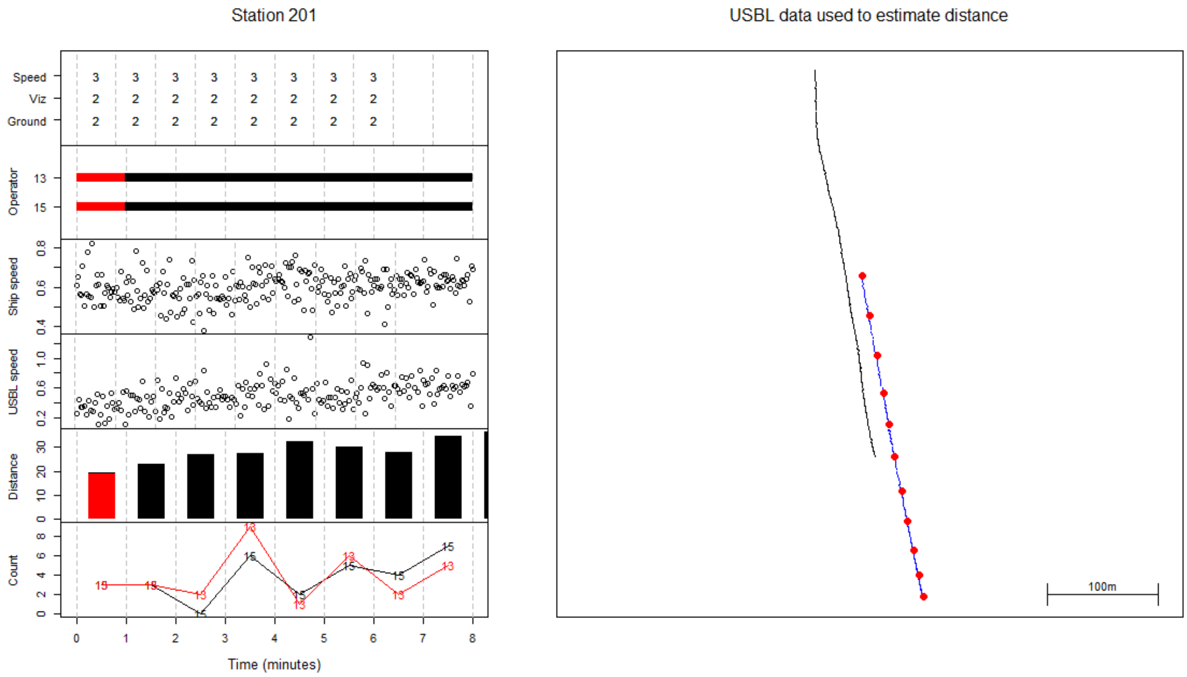


Figure 4: FU20-21 grounds: R - tool quality control plot for station 201 of the 2019 survey.

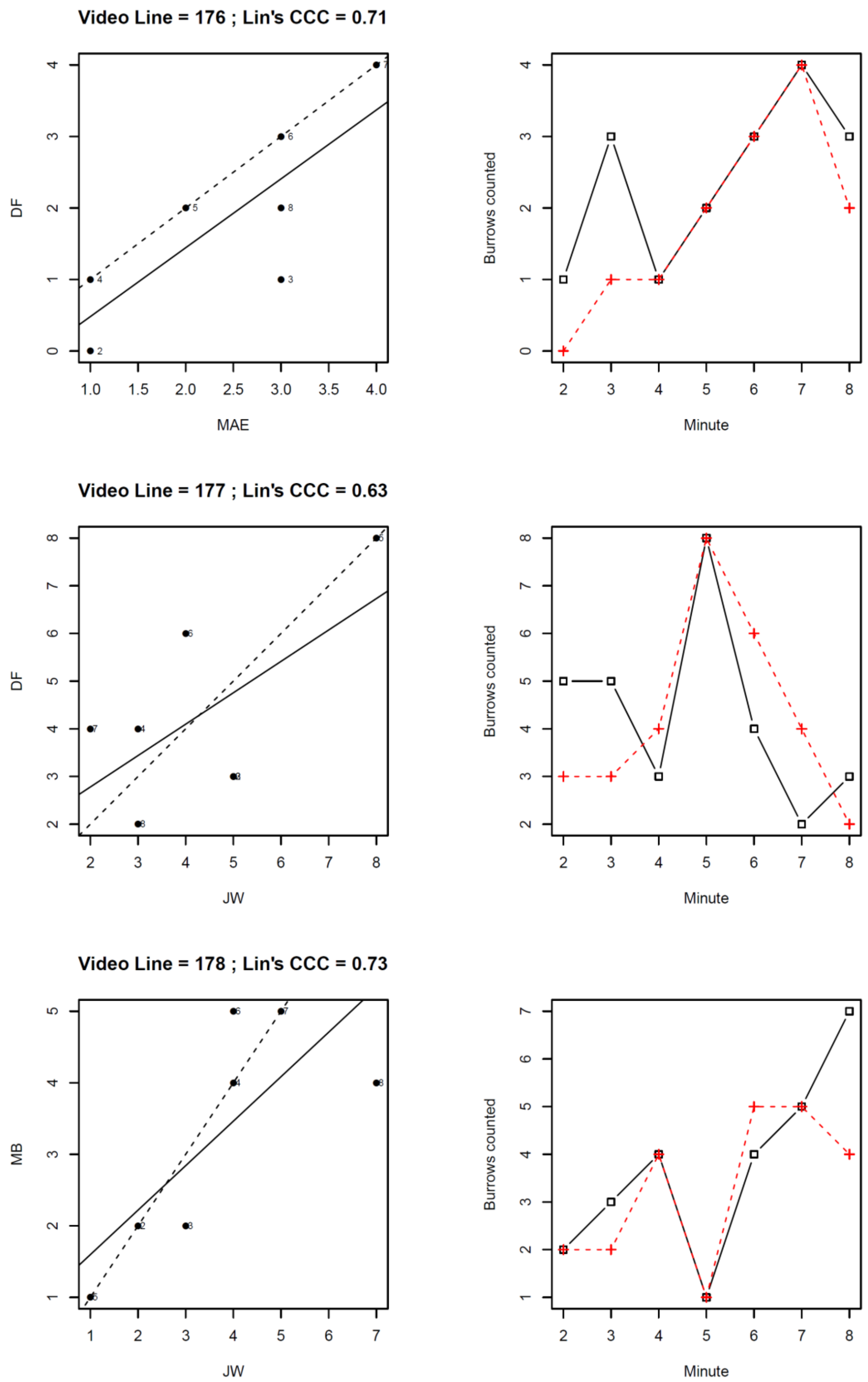
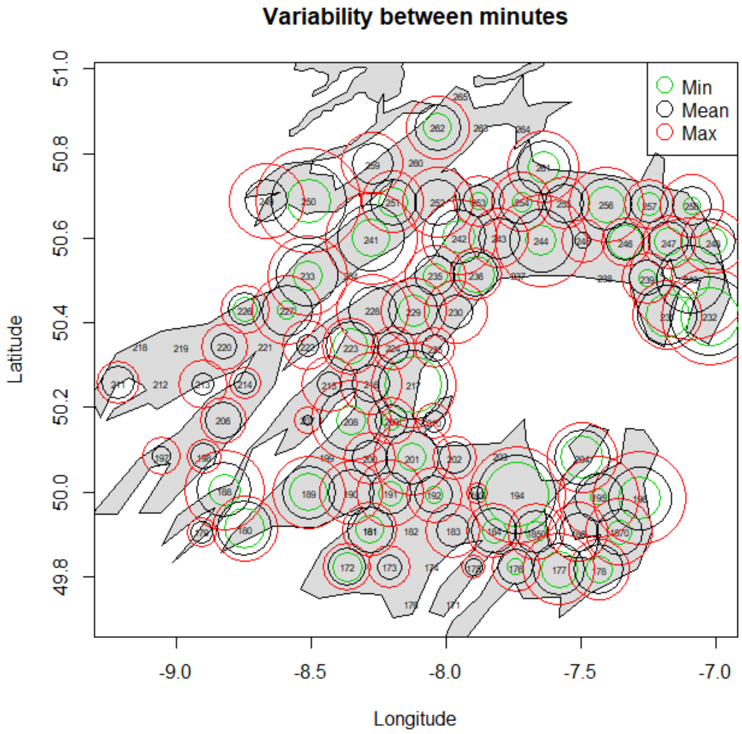


Figure 5: FU20-21 grounds: Lin's CCC quality control plots of count data for stations 176-178 from the 2019 survey.



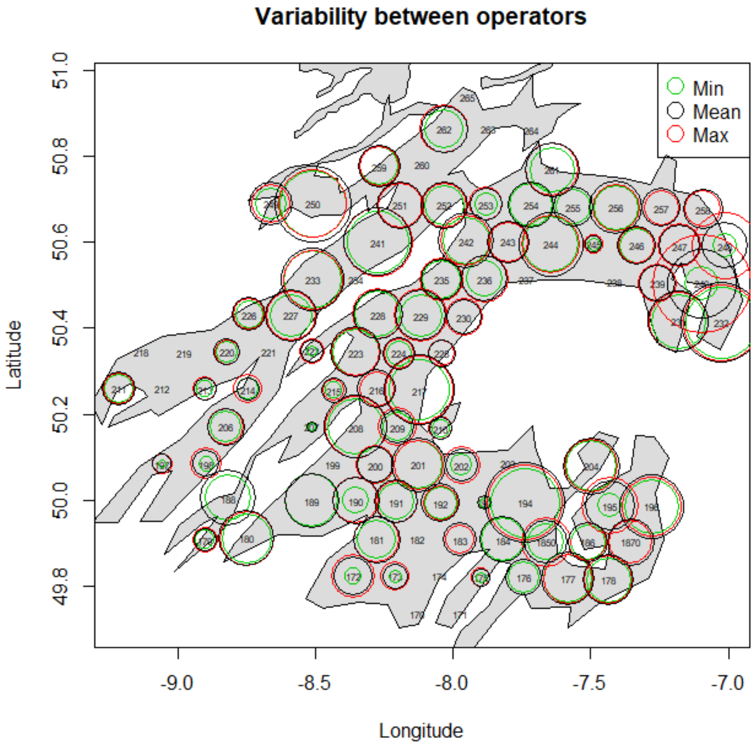


Figure 6: FU20-21 grounds: Plots of the variability in density between minutes (top panel) and between operators (counters) (bottom panel) for each station in 2019.

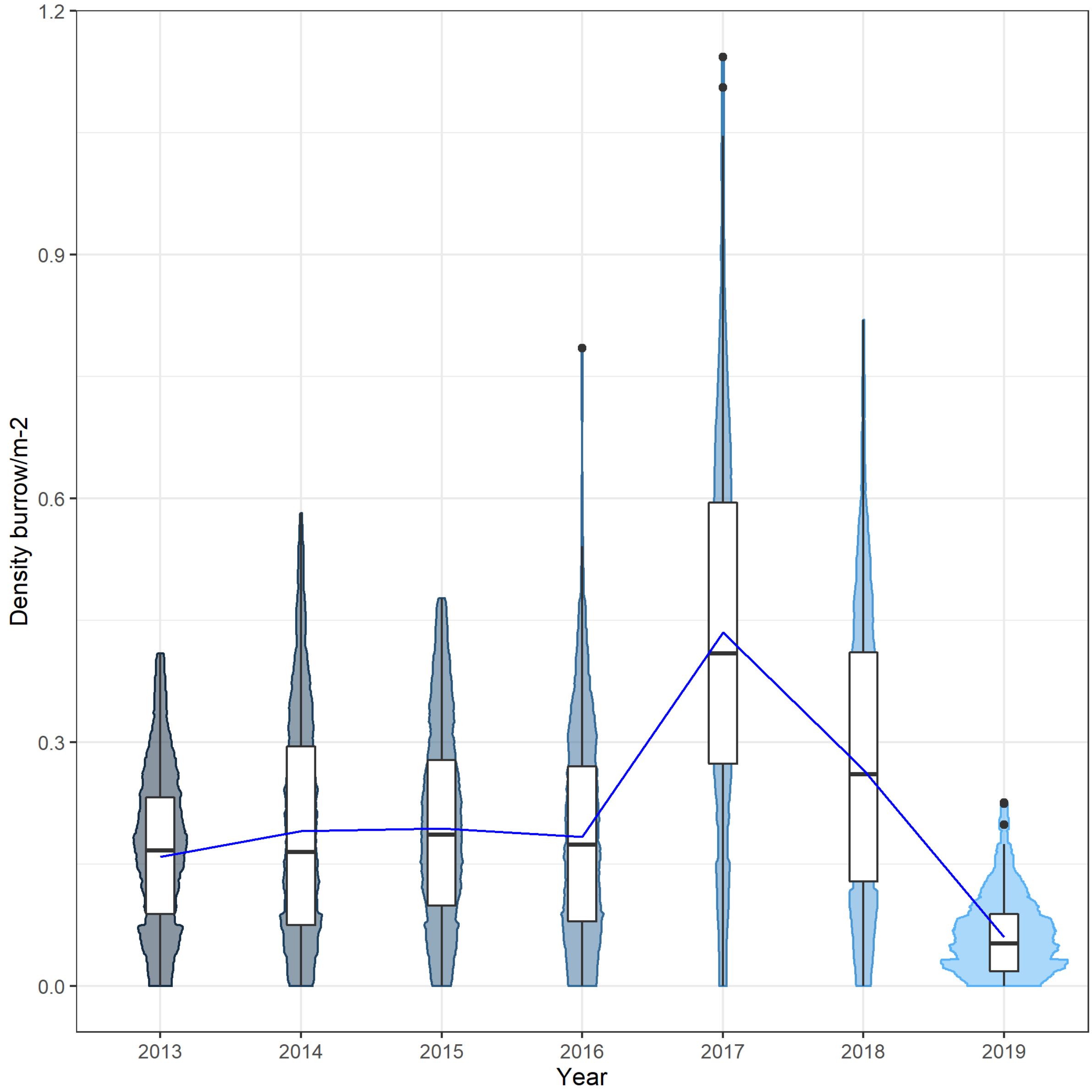


Figure 7: FU20-21 grounds: Violin and box plot of adjusted burrow density distributions by year from 2013-2019. The blue line indicates the mean density over time. The horizontal blacks line represents medians, white boxes the inter quartile ranges, the black vertical lines are the range and the black dots are outliers.

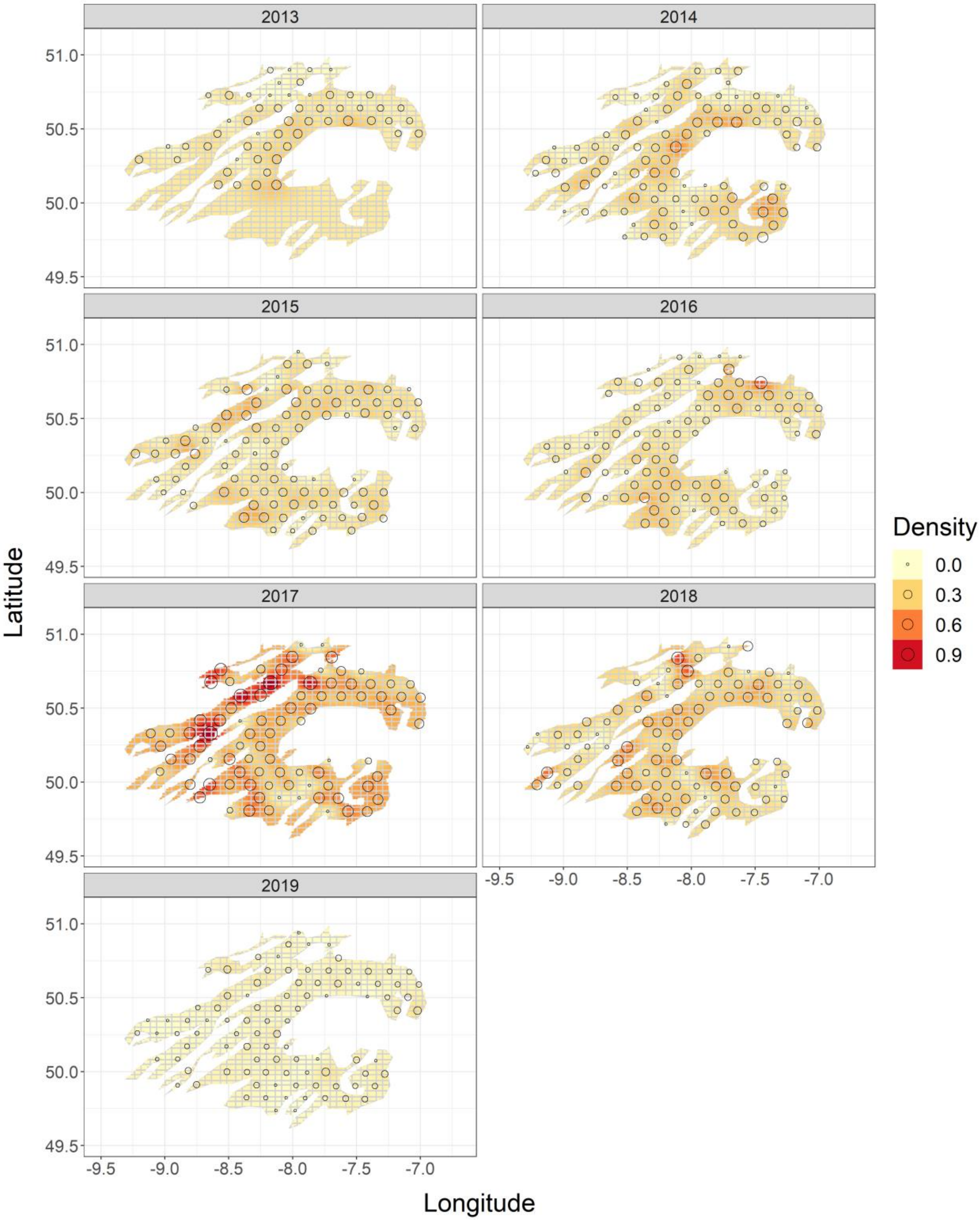


Figure 8: FU20-21 grounds: Contour plots of the krigged density estimates by year from 2013 (top) - 2019 (bottom).

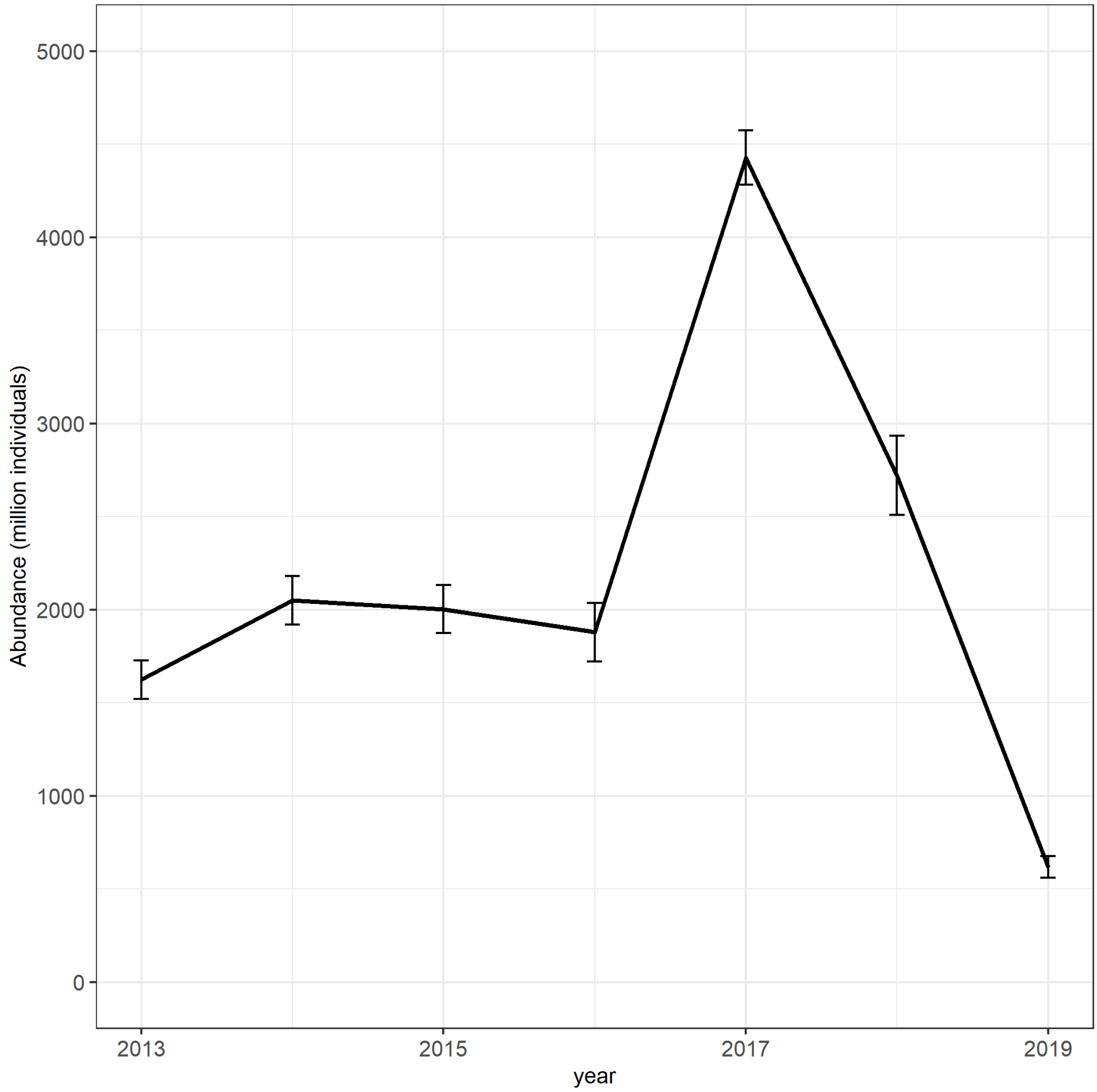


Figure 9: FU20-21 grounds: Time series of raised abundance estimates (in millions of burrows) for FU20-21. The error bars indicate the 95% confidence intervals.

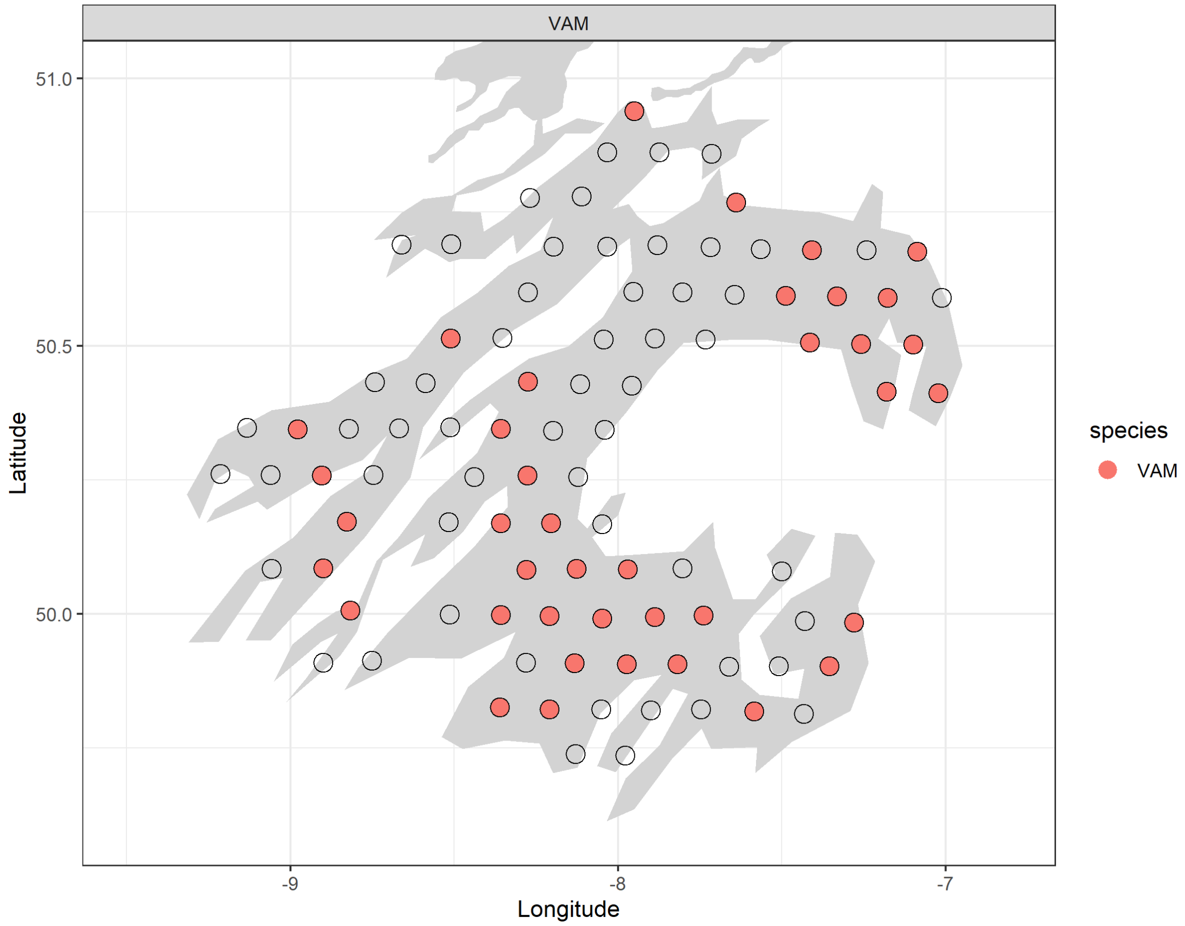


Figure 10: FU20-21 grounds: 2019 stations where *Virgularia mirabilis* (VAM) were identified. Pink circles indicated presence and open circles denotes TV stations with no sea-pen observations.

Table 1: Summary of UWTV results; number of stations, mean density observed, standard deviation, absolute abundance estimates with 95% confidence intervals, estimated area of the stock and coefficient of variation on the abundance.

Year	Number of stations	Mean Density adjusted (burrow /m²)	Standard Deviation	Absolute abundance estimate (million burrows)	95 % CI on Abundance	Domain area	CVs %
2006	9	0.44	0.31	nr			
2012	54	0.57	0.25	nr			
2013	55	0.16	0.11	942	60	5701	3
2013*				1624	103	9835,	
2014	98	0.19	0.14	2051	131	9835	3
2015	96	0.20	0.02	2003	118	9835	3
2016	93	0.18	0.02	1879	147	9835	5
2017	86	0.44	0.08	4428	347	9835	4
2018	96	0.27	0.04	2721	212	9835	4
2019	95	0.06	0.004	617	58	9835	5

* the 2013 survey achieved partial coverage ~60% of the total area. The abundance has been scaled up to the entire area since densities in the unsurveyed part of the ground were not significantly different in 2014.

nr= no reliable abundance estimate could be calculated because survey coverage was partial.

Table 2: The inputs for the catch scenarios.

Year	UWTV abundance estimate	95% Confidence Interval	Landings in number	Total discards in number*	Removals in number	Harvest rate (by number)	Landings	Total discards*	Discard proportion (by number)	Dead discard proportion (by number)	Mean weight in landings	Mean weight in discards
	Millions					%	tonnes		%		grammes	
2012			38.2	36.1	65.3		1189	542	48.5	41.4	31.1	15.0
2013	1624	103	34.8	19.2	49.2	3.0	1387	327	35.6	29.3	39.9	17.0
2014	2051	131	50.6	55.5	92.2	4.5	1836	834	52.3	45.2	36.3	15.0
2015	2003	129	59.4	28.1	80.5	4.0	2116	442	32.2	26.2	35.7	15.7
2016	1879	157	60.2	37.5	88.3	4.7	2453	801	38.4	31.8	40.7	21.4
2017	4428	145	60.1	19.2	74.5	1.7	1849	306	24.3	19.4	30.8	15.9
2018	2721	212	64.7	21.5	80.8	3.0	1803	381	25.0	20.0	27.9	17.7
2019	617	58										

Table 3: The basis for the catch scenarios.

Variable	Value	Notes
Stock abundance (2020)	617 million	UWTV survey 2019 (number of individuals).
Mean weight in wanted catch	33.1 g	Average 2016–2018.
Mean weight in unwanted catch	18.3 g	Average 2016–2018.
Unwanted catch	29.2%	Average 2016–2018 (proportion by number).
Discards survival	25.0%	Proportion by number
Dead unwanted catch	23.7%	Average 2016–2018.

Table 4: Catch advice and scenarios for 2020; Discarding assumed to continue at recent average. All weights are in tonnes.

Catch scenarios assuming recent discard rates 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							
EU MAP^ : F_{MSY}	1150	1096	935	161	54	6.0	-78
F = MAP $F_{MSY\ lower}$	1131	1078	920	158	53	5.9	-79
F = MAP $F_{MSY\ upper}$ ***	1150	1096	935	161	54	6.0	-78
Other options							
MSY approach	1150	1096	935	161	54	6.0	-78
F_{2018}	569	543	463	80	27	3.0	-89

^ EU multiannual plan (MAP) for Western Waters (EU, 2019).
* By number.
** Advice value for 2020 relative to the advice value for 2019 (5320 tonnes).
*** $F_{MSY\ upper}$ =F_{MSY} for this stock