The "Smalls" *Nephrops* Grounds (FU22) 2019 UWTV Survey Report and catch scenarios for 2020.

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Abstract

This report provides the main results and findings of the fourteenth annual underwater television survey on the 'Smalls grounds' ICES assessment area; Functional Unit 22. The survey was multi-disciplinary in nature collecting UWTV, CTD and other ecosystem data. A total of 41 UWTV stations were surveyed successfully (high quality image data), carried out over an isometric grid at 4.5nmi or 8.3km intervals. The precision, with a CV of 9%, was well below the upper limit of 20% recommended by SGNEPS (ICES, 2012). The 2019 abundance estimate was 30% higher than in 2018 and at 1121 million is below the MSY $B_{trigger}$ reference point (990 million). 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 2247 and 2820 tonnes (assuming that discard rates and fishery selection patterns do not change from the average of 2016–2018). One species of sea pens were recorded as present at the stations surveyed: *Virgularia mirabilis*. Trawl marks were observed at 57% of the stations surveyed.

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

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Introduction

The prawn (*Nephrops norvegicus*) are common in the Celtic Sea occurring in geographically distinct sandy/muddy areas where the sediment is suitable for them to construct their burrows (Figure 1). The *Nephrops* fishery in ICES sub-area 7 is extremely valuable with Irish landings in 2018 worth around €56 m at first sale. The Celtic Sea area (Functional Units 19-22, see 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, 2019). The 2018 reported landings from the Smalls (~1639 t) were estimated to be worth in the region of €11.5 million at first sale. The Smalls ground is particularly important to the Irish demersal fleet accounting for around 13% of the fishing effort by all demersal vessels >15m between 2006 and 2009 (Gerritsen, *et al*., 2012). The Irish demersal fleet now account for ~ 90% of the FU22 *Nephrops* landings (ICES, 2019). 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 & 2012). This is the fourteenth in a time series of UWTV surveys in the Celtic Sea FU22 "Smalls" ground has been carried out by the Marine Institute, Ireland.

The survey was multi-disciplinary in nature and and also covered TV stations in FU17 and FU19 the results of which are presented elsewhere (Doyle *et. al*., 2019 and Aristegui *et. al*., 2019). The specific objectives of the 2019 survey are listed below:

1. To complete a survey of 41 randomised fixed isometric grid UWTV stations, with 4.5 nautical mile (nmi) spacing, on the "Smalls" *Nephrops* ground (FU22).
2. To obtain 2019 quality assured estimates of *Nephrops* burrow distribution and abundance on the "Smalls" *Nephrops* ground (FU22) and compare them with those collected in 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 temperature and depth sensor
5. To sample *Nephrops* and macro benthos using a 3 metre beam trawl deployed at 10 stations once UWTV operations successfully completed.

This report details the final UWTV results of the 2019 survey and documents other data collected during the survey. Operational survey details are available in form of a survey narrative available from the scientist in charge (JD). The 2019 abundance estimate is used to generate catch scenarios for 2020 in line with procedures outlined in the stock annex for FU22 (ICES, 2017).

Material and methods

To maintain a CV < 20%, to achieve good spatial coverage over the ground and to generate burrow surface that reflects the underlying abundance of *Nephrops*, a survey grid of 4.5 nm spacing has been used since 2012. The 2019 randomised isometric grid, which resulted in 41 planned stations, was generated using using the "spsampl" function in the "sp" package

(Pebesma & Bivand, 2005) in "R" (R Core Team, 2017). These are overlaid on *Nephrops* directed fishing activity in Figure 2 (Gerritsen & Lordan, 2011). The boundary used to delineate the edge of the ground was based on information from VMS, habitat maps, and previous UWTV observations. The same boundary has been used through the time series.

The 2019 Celtic Sea survey took place on RV Celtic Voyager between the 13th June and the 17th June. The survey normally takes place in either July or August each year.

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 onboard 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 was collected with a 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 were quality controlled using an "R" script developed by the Marine Institute (ICES, 2009b) an example is shown in Figure 3. In 2019 the USBL navigational data were used to calculate distance over ground for 100% of stations

In line with recommendations of the Study Group on *Nephrops* Surveys (SGNEPS; ICES 2009b) all scientists were trained/re-familiarised using using 2019 image data as training material prior to recounting (ICES, 2009b). There is no FU22 specific reference footage available yet in high definition format. 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 to one another, which appear to be part of a single system and were counted once) for each one-minute interval. In addition, *Nephrops* activity in and out of burrows was also 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 to fulfil an OSPAR Special Request (ICES 2011).
Finally, if there was any time during the one-minute block where counting was not possible, due to sediment clouds or other reasons, this was also estimated so that the time could be removed from the distance over ground calculations.

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 0.6. 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 plots of survey count data for stations 145 to 147 is shown in Figure 4. When the count data fell below the threshold of 0.6 a third review was carried out. The paired count data that passed the Lin's CCC threshold was used in the analysis. When the paired counts did not pass the threshold an average of the three reviewers was deemed appropriate to use in the analysis.

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 m 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. From 2006-2014 the spatial co-variance and other spatial structuring a geo-statistical analysis of the mean and variance was carried out using SURFER Version 10.7.972. From 2015 the geostatistical analysis was carried out using the "RGeostats" package (Renard D., *et al*, 2015) and is available as a separate "R markdown" document. The same basic 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.

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.

Due to time constraints beam trawling was not carried out on the "Smalls" ground this year.

Results

In 2019 41 stations were completed successfully on the Smalls. A summary of the results is presented in Table 1. The density and estimated abundance increased by around 30% in 2019. The average density and the abundance were the second lowest in the time series. Figure 5 shows bubble plots of the variability between minutes and operators. These show that the burrow estimates are very consistent between minutes and counters. A combined violin and box plot of the observed burrow densities is presented in Figure 6. This shows that median and mean burrow densities are similar in most years. The inter-quartile range is between 0.2 - 0.7 in most years. However, in 2018 as in 2016, this inter-quartile range is in the region of 0.1 - 0.4. In 2019 the mean adjusted[1] burrow density was 0.40 burrows/m^2. One station had burrow densities > 1.0 burrows/m^2 observed in 2019.

[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).

The krigged and point density data for 2006-2019 are shown in Figure 7. The krigged contours correspond well to the observed data. Highest densities are in the centre of the ground in all years. In general, densities are higher towards the south and central area of the ground.

The summary statistics from this geo-statistical analysis are given in Table 1 and Figure 8. The 2019 estimate of 1121 million burrows is below the geometric mean of the series (geomean [2006-2019]: 1223 million burrows) and is above the MSY $B_{trigger}$ reference point of 990 million. The estimation of variance of the 2019 survey as calculated by RGeostats is low (with a CV or RSE of 9%), which is well below the SGNEPS recommendation for a CV <20% (ICES, 2012).

Figure 9 shows the standardised length frequency distributions of *Nephrops* caught using a beam trawl. Fishing operations were not carried out during 2010, 2013, 2014, 2015 and 2019 due to time constraints. For plotting purposes, the individuals <10mm caught were split evenly between males and females as it is not possible to accurately assign sex to individuals of this size. A strong cohort was apparent in the 2006 catches of around 17mm and can be tracked in catches in subsequent years. There was a shift to larger sizes in 2011 and 2012, with a shift back again to smaller sizes in 2016 to 2018.

Sea-pen presence/absence distribution across the Smalls *Nephrops* grounds is mapped in Figure 10. One sea-pens were identified from the image data in 2019, that is, *Virgularia mirabilis*. Trawl marks were noted at 57% of the stations surveyed.

The UWTV abundance data together with data from the fishery; landings, discards and removals in number, were used to calculate the harvest rate for 2018 of 13.8%. The mean weight in the landings and discards and the proportions of removal retained are also shown (Table 2).

The basis to 2020 catch scenarios are given in Table 3. 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, 2019) using the 2019 survey abundance (Table 3). The latest estimate of stock abundance (value from June 2019 survey, 1121 million) is above the MSY $B_{trigger}$ value (990 million). 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 2247 and 2820 t (Table 3). This assumes that discard rates and fishery selection patterns do not change from the average of 2016–2018.

Discussion

Since 2006 a dedicated annual UWTV survey has taken place which gives abundance estimates for this ground with high precision. The burrow abundance estimates have increased significantly in 2019 to a similar level observed in 2011. Density estimates throughout the ground were higher with high density estimates in the central area. Fluctuations in density has also been observed in the adjacent FU20-21 and FU19 this year (White *et. al*, 2018 and 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).

Nephrops 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 13% in recent years. The provision of catch advice and scenarios for 2020 based on 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 was 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).

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 this ground 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 FU22. 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 fourteenth successive year. The UWTV coverage and footage quality was excellent throughout the survey. This was mainly due to good survey planning to coincide with slack tides. The multi-disciplinary nature of the survey means that the information collected is highly relevant for a number of research and advisory applications.

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Institute for organising survey logistics, and also Gordon Furey and Damian Crean (P&O Maritime) for shore side support.

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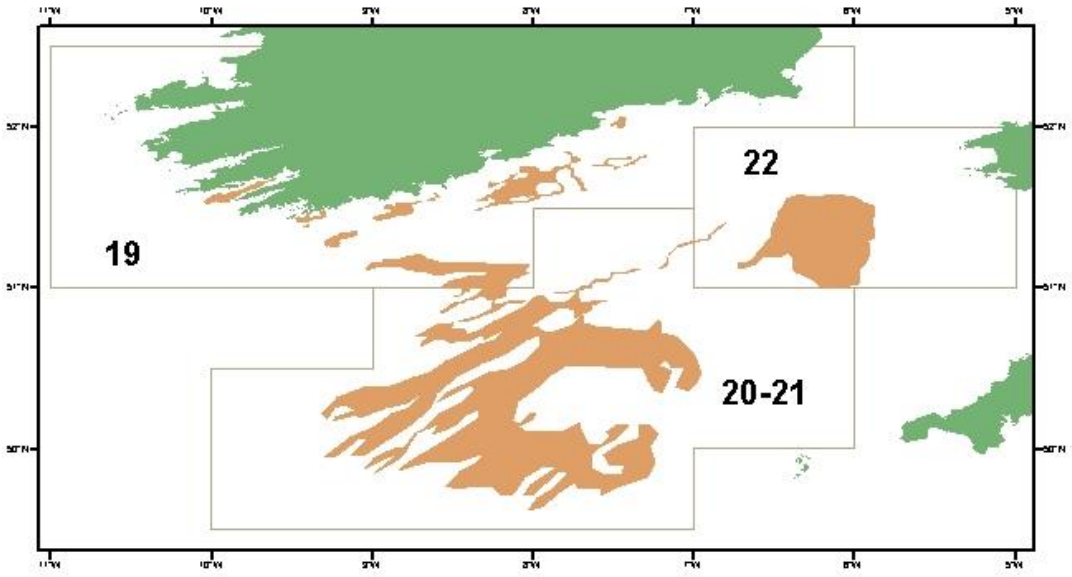

Figure 1: FU22 Smalls grounds: *Nephrops* Functional Units (FUs) and *Nephrops* grounds (area polygons) in the greater Celtic Sea.

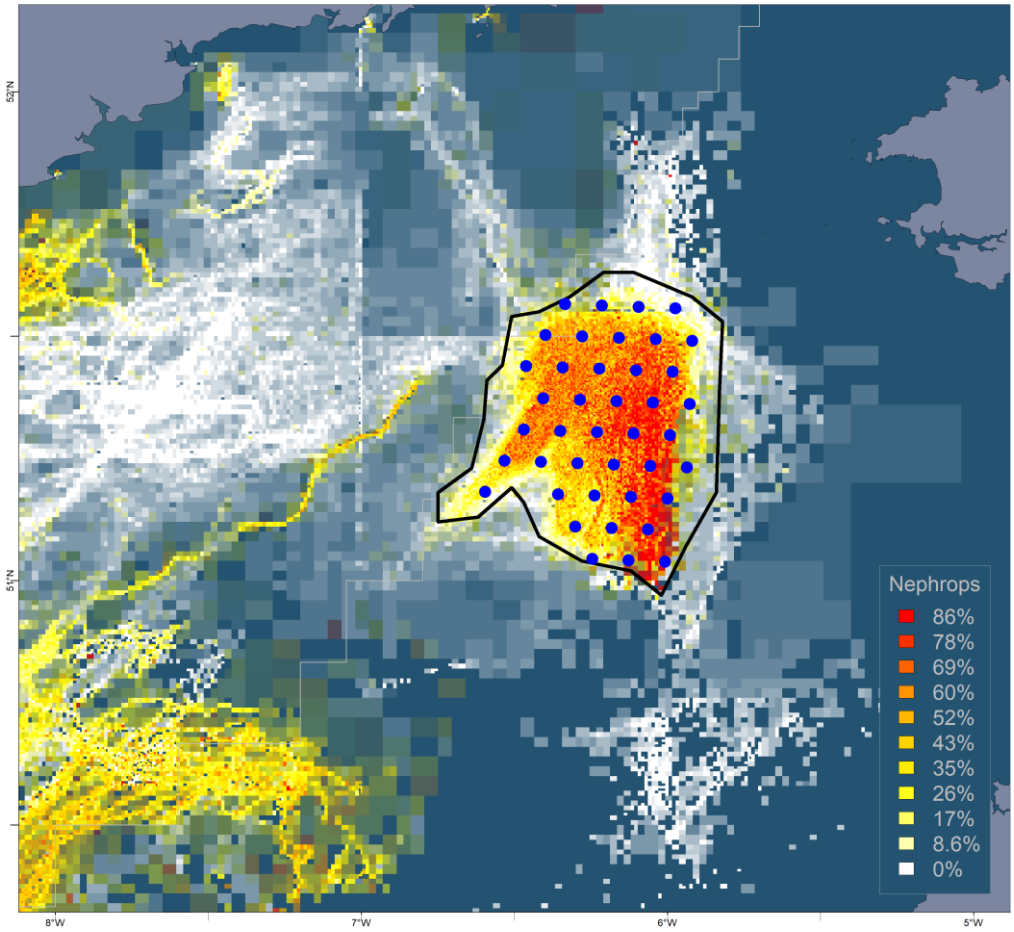

Figure 2: FU22 Smalls grounds: TV stations (blue dots) completed on the 2019 survey overlaid on a heat map of *Nephrops* directed Irish fishing activity 2014-2018.

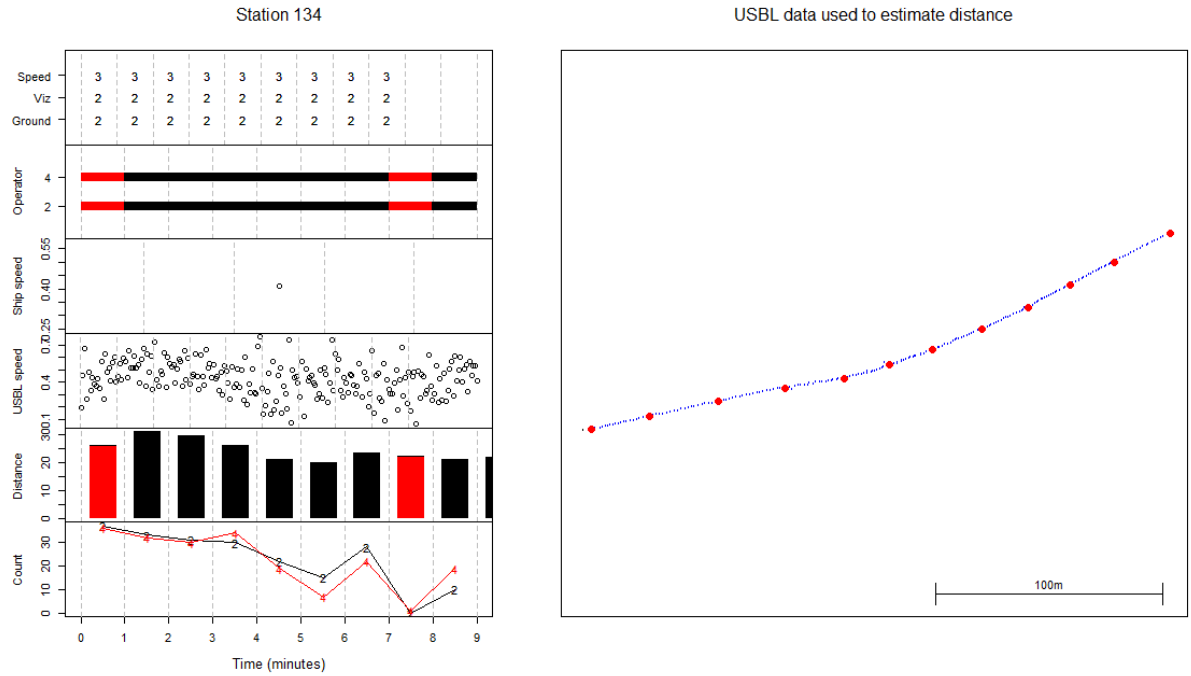

Figure 3 : FU22 Smalls grounds: R - tool quality control plot for station 134 of the 2019 survey.

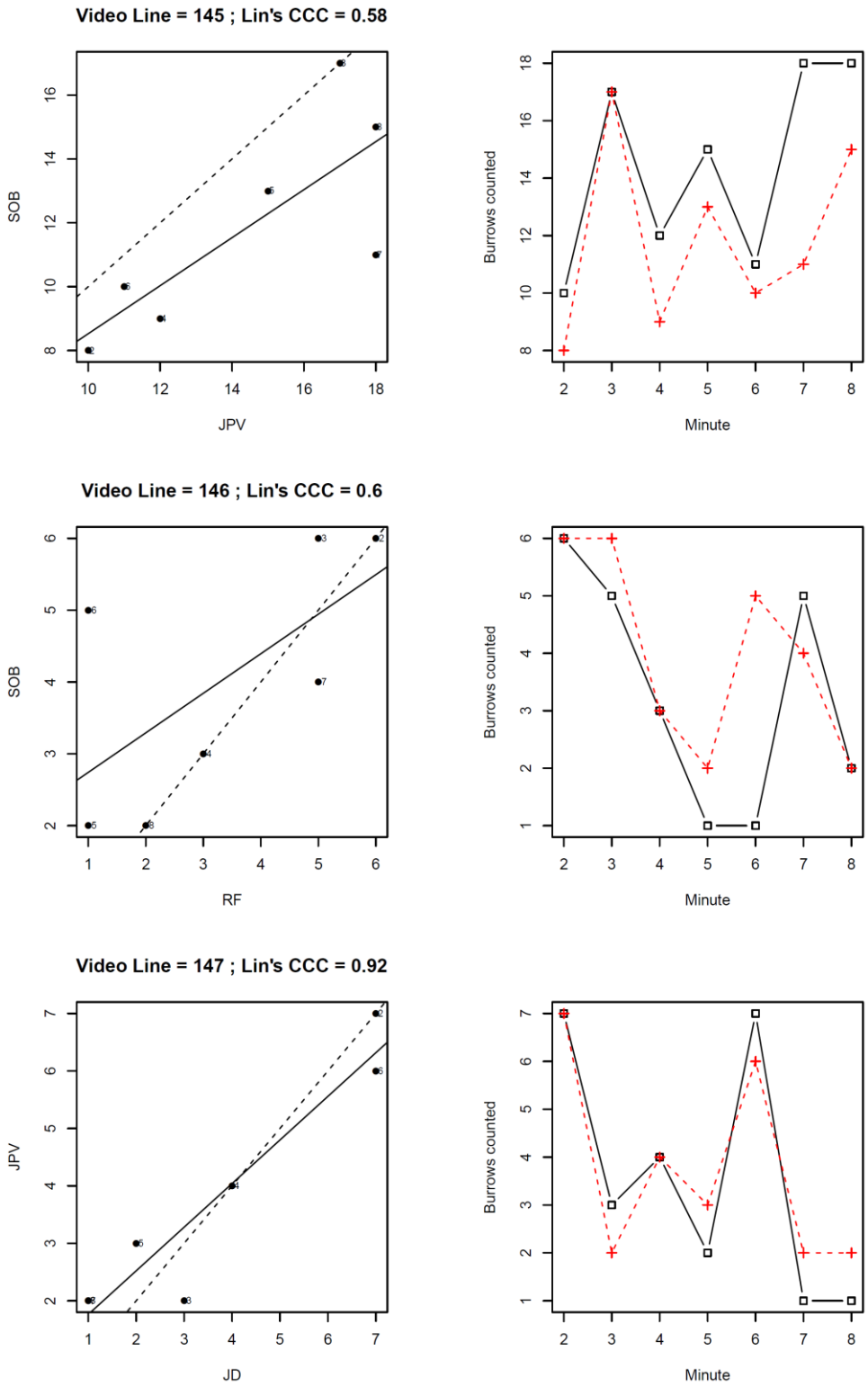

Figure 4 : FU22 Smalls grounds: Lin's CCC quality control plots of count data for stations 145 to 147 of the 2019 survey.

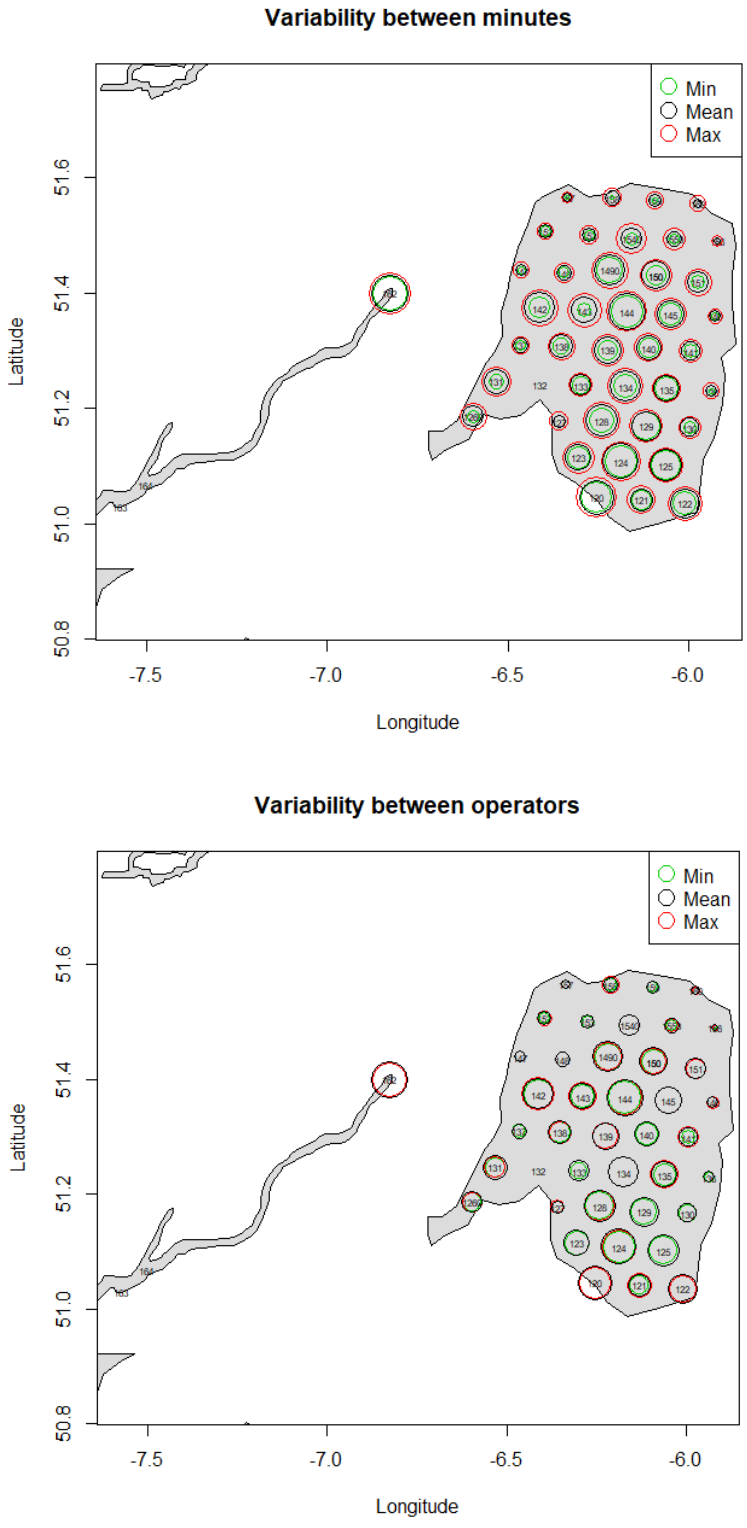

Figure 5 : FU22 Smalls grounds: Plots of the variability in density between minutes (top panel) and between operators (counters) (bottom panel) for each station in 2019.

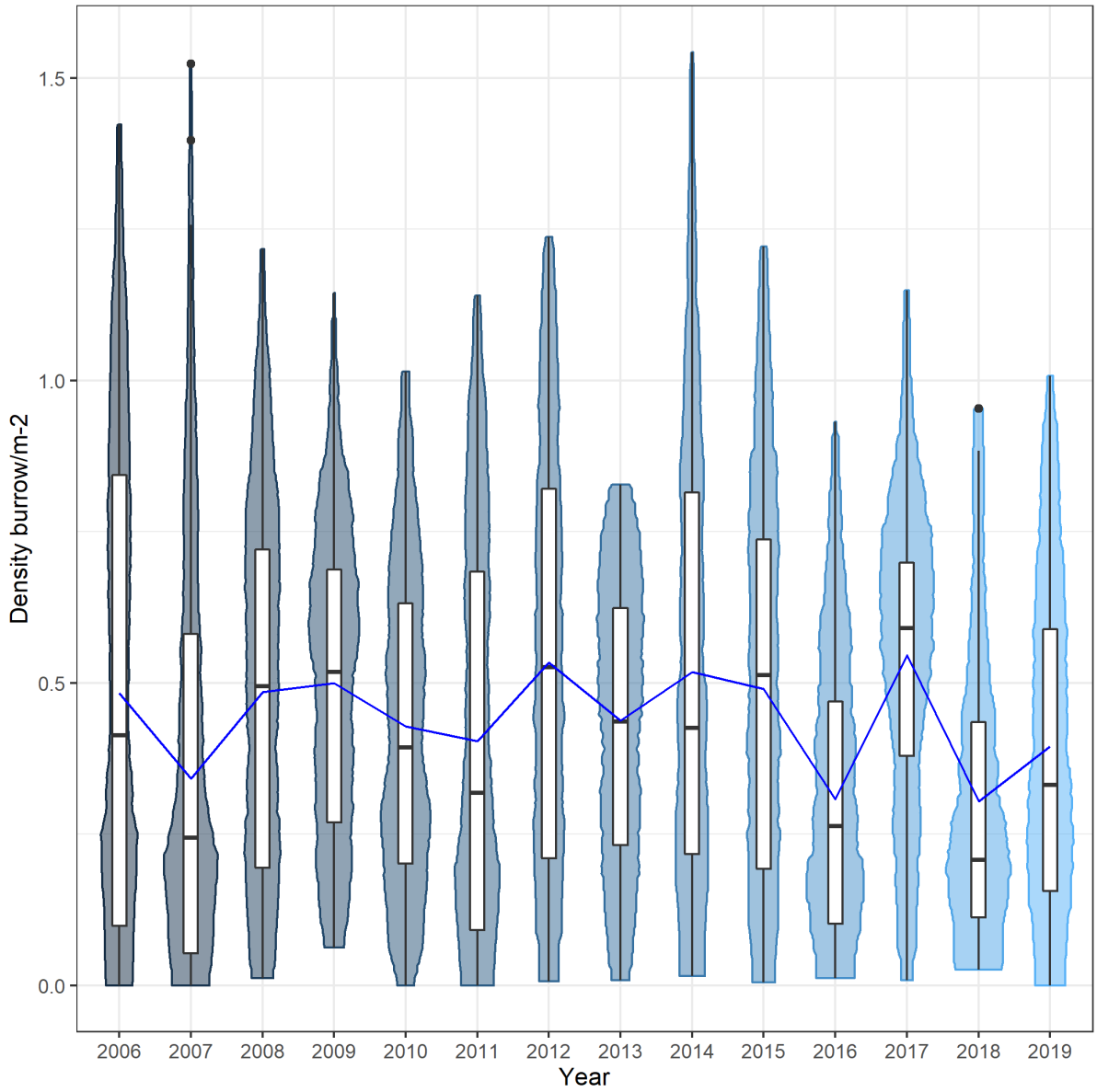

Figure 6: FU22 Smalls grounds: Violin and box plot of adjusted burrow density distributions by year from 2006-2019. The blue line indicates the mean density over time. The horizontal black lines represent medians, white boxes the inter quartile ranges, the black vertical lines the range and the black dots are outliers.

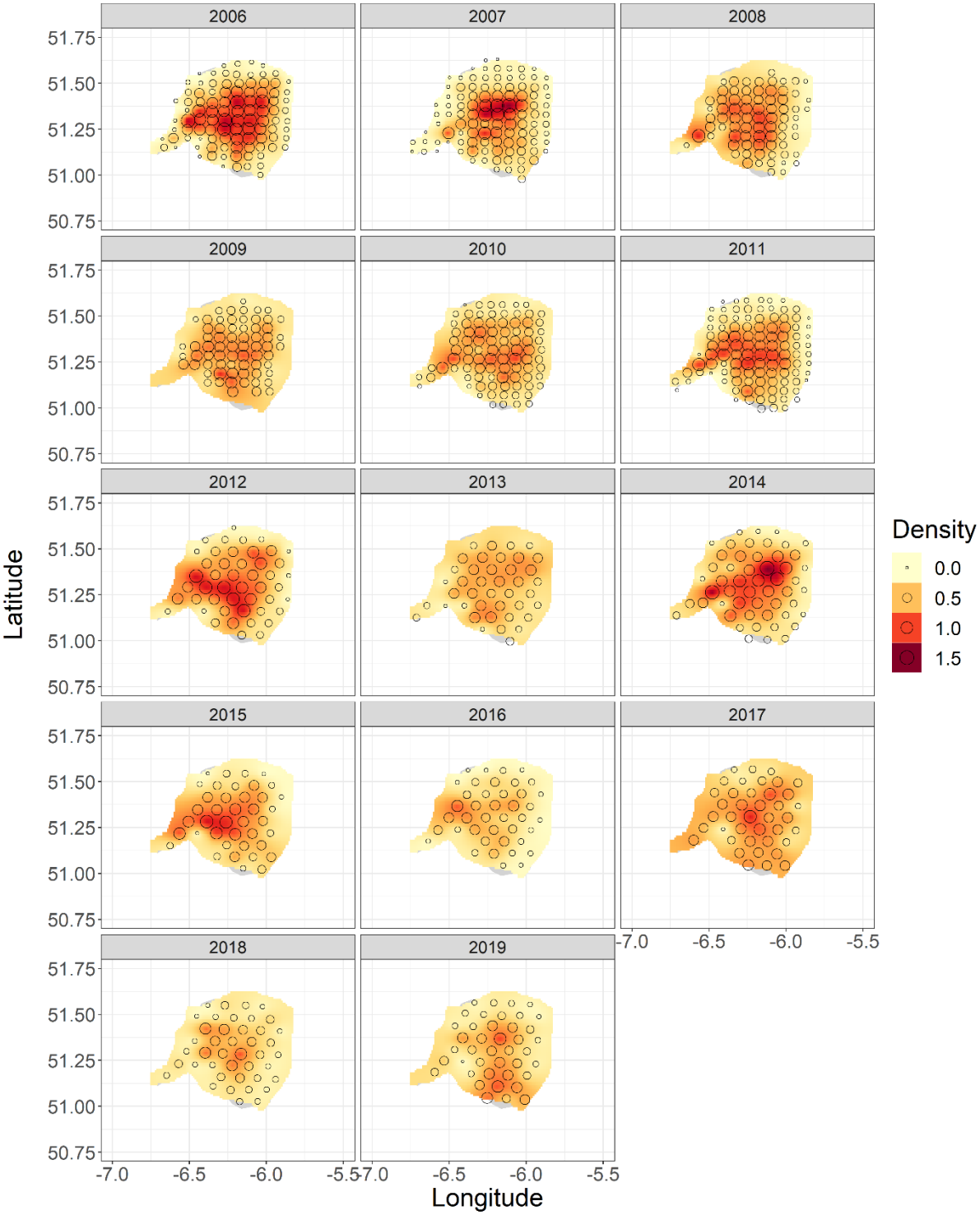

Figure 7: FU22 Smalls grounds: Contour plots of the krigged density estimates by year from 2006 (top left) - 2019 (bottom left).

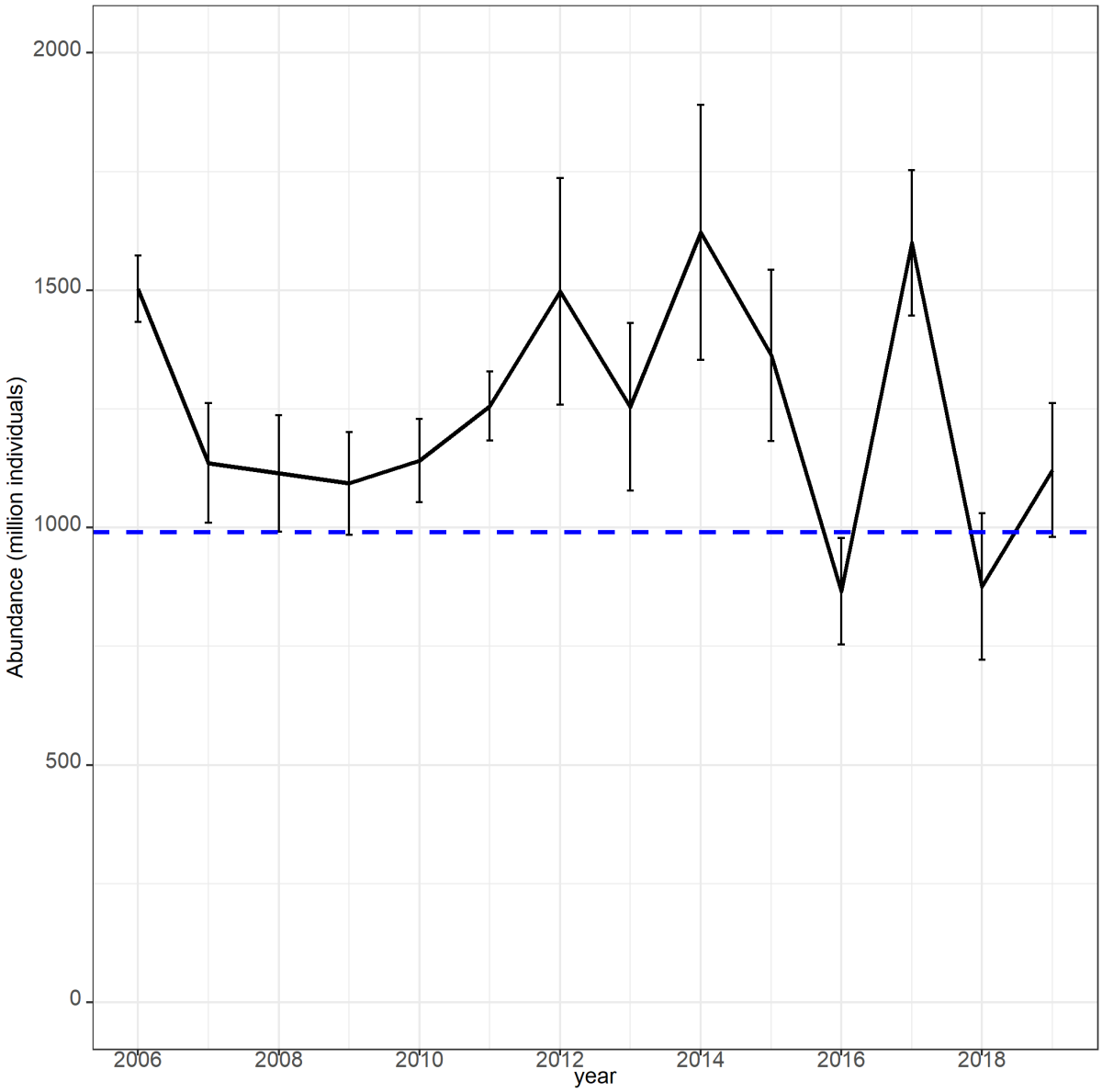

Figure 8: FU22 Smalls grounds: Time series of geo-statistical adjusted abundance estimates (in millions of burrows). The error bars indicate the 95% confidence intervals and $B_{trigger}$ is dashed blueline.

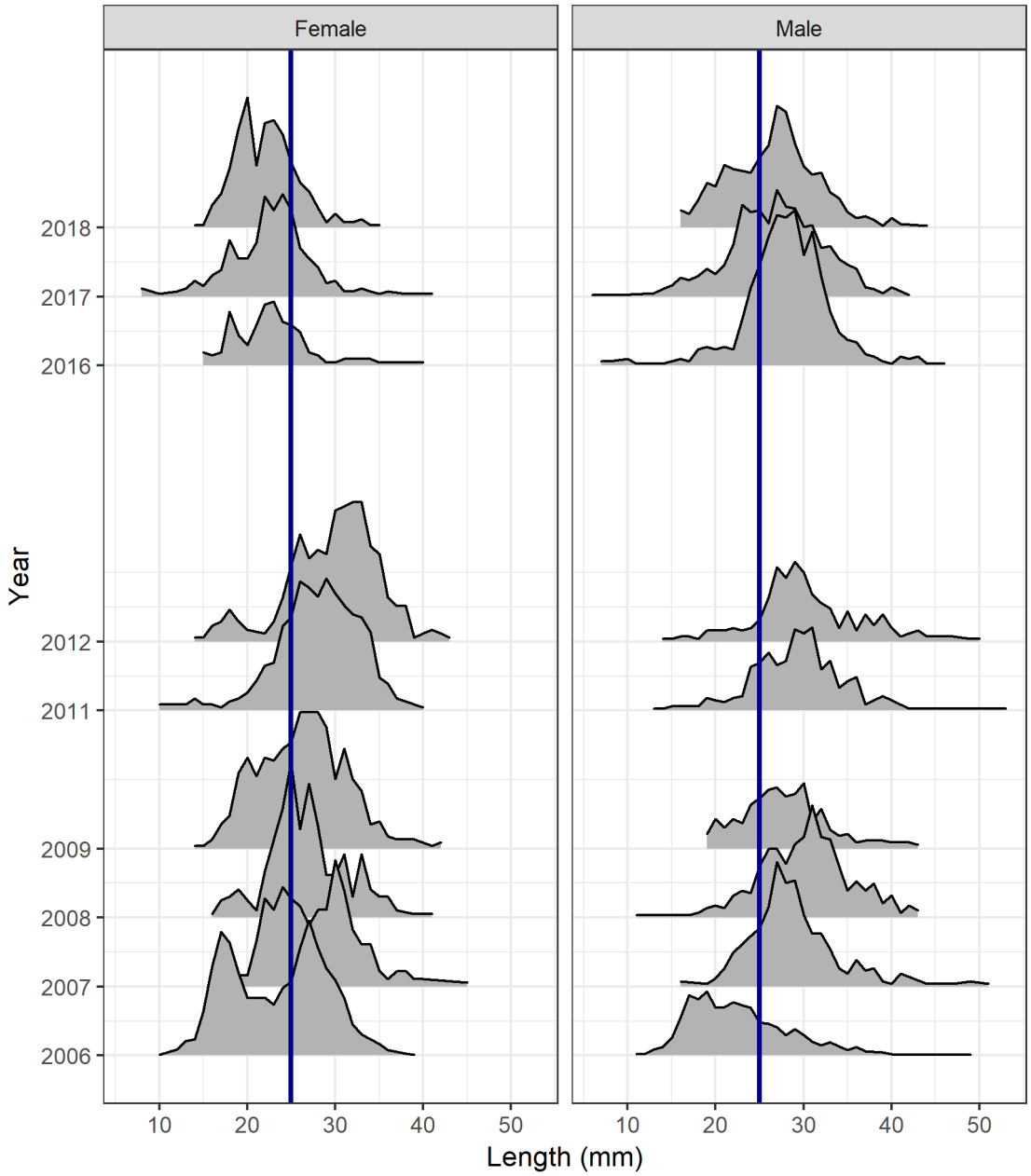

Figure 9: FU22 Smalls grounds: Standardised length frequency distributions for male and female *Nephrops* caught using beam trawl during 2006 to 2018 UWTV surveys (except years 2010, 2013 - 2015 and 2019). Blue line indicates minimum conservation reference size 25 mm carapace length.

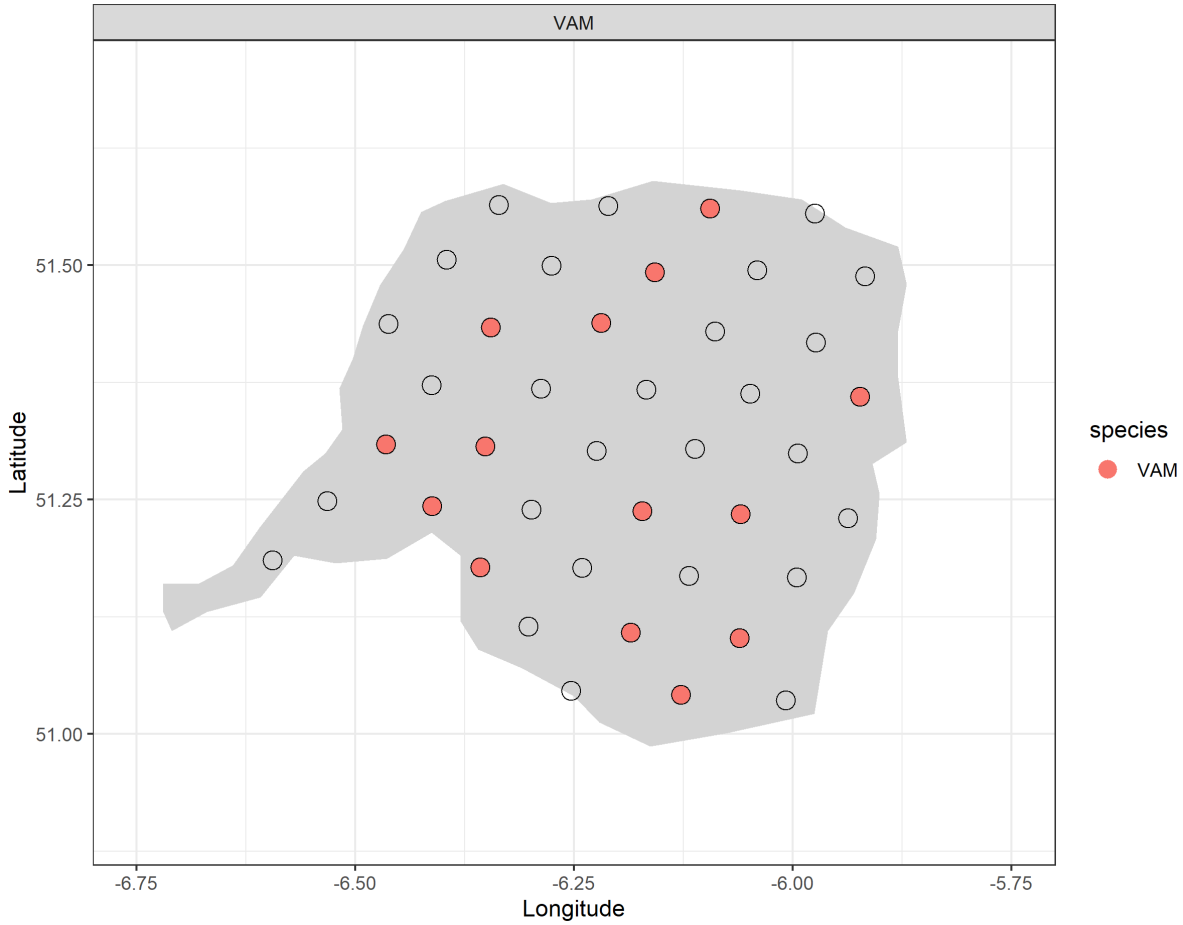

Figure 10: FU22 Smalls grounds: 2019 stations where *Virgularia mirabilis* (VAM) were identified. Closed circles indicated presence and open circles denotes TV stations with no sea-pen observations.

Table 1: FU22 Smalls grounds: Overview of geostatistical results from 2006-2019.

Year	Number of stations	Mean Density adjusted (burrow/m²)	Domain Area (km²)	Geostatistical Abundance adjusted (millions of burrows)	CV on Burrow estimate (%)
2006	100	0.49	2962	1503	2
2007	107	0.37	2955	1136	6
2008	76	0.36	2698	1114	6
2009	67	0.36	2824	1093	5
2010	90	0.37	2861	1141	4
2011	107	0.41	2881	1256	3
*2012	47	0.49	2934	1498	8
*2013	41	0.41	2975	1254	7
*2014	52	0.53	2970	1622	8
*2015	40**	0.49	3064	1363	7
*2016	41	0.31	3063	866	7
*2017	40	0.55	3063	1600	5
*2018	42	0.31	3063	876	9
*2019	41	0.40	3063	1121	6

*reduced randomised isometric grid

** In 2015 seven of the stations were filled in with an estimate based on the mean density of historical stations within 2nmi of the planned station.

Table 2: FU22 Smalls grounds: Inputs to catch scenarios table.

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	
2003	1503	70	95	68	146		2065	720	41.5	34.7	21.7	10.7
2004	1136	126	71	13	80		1828	202	15.6	12.2	25.9	15.4
2005	1114	123	119	129	216		2533	1648	51.9	44.7	21.2	12.8
2006	1093	108	100	45	134	8.9	1761	454	31.1	25.3	17.6	10.1
2007	1141	88	165	181	301	26.5	2950	1906	52.3	45.1	17.9	10.5
2008	1256	72	144	26	163	14.6	3090	289	15.3	12.0	21.5	11.1
2009	1498	239	92	33	117	10.7	2185	371	26.4	21.2	23.7	11.3
2010	1254	177	122	45	155	13.6	2714	636	26.8	21.5	22.3	14.3
2011	1622	268	60	13	70	5.6	1636	196	18.0	14.1	27.3	14.9
2012	1363	180	120	31	144	9.6	2618	347	20.7	16.3	21.8	11.1
2013	866	112	94	40	124	9.9	2257	497	30.0	24.3	24.1	12.4
2014	1600	153	100	33	125	7.7	2526	460	25.0	20.0	25.2	13.8
2015	876	154	114	44	147	10.8	2350	450	28.0	22.6	20.6	10.1
2016	1121	141	160	54	200	23.1	3329	519	25.1	20.0	20.8	9.7
2017	1503	70	164	39	194	12.1	3560	424	19.2	15.2	21.7	10.8
2018	1136	126	98	31	121	13.8	1975	350	24.2	19.3	20.2	11.2
2019	1114	123										

Table 3: The basis for the catch scenarios.

Variable	Value	Notes
Stock abundance (2020)	1121 million	UWTV survey 2019 (number of individuals)
Mean weight in wanted catch	22.1 g	Average 2003-2018
Mean weight in unwanted catch	11.9 g	Average 2003-2018
Unwanted catch	22.8%	Average 2016–2018 (proportion by number).
Discards survival	25.0%	Proportion by number
Dead unwanted catch	18.2%	Average 2016–2018 (proportion by number).

Table 4: FU22 Smalls grounds: Annual catch advice and scenarios; Discarding assumed to continue at recent average.

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}	2820	2728	2452	276	92	12.8	35
F = MAP $F_{MSY\ lower}$	2247	2174	1954	220	73	10.2	7.8
F = MAP $F_{MSY\ upper}$ ***	2820	2728	2452	276	92	12.8	35
Other scenarios							
MSY approach	2820	2728	2452	276	92	12.8	35
F_{2018}	3048	2949	2650	298	99	13.84	46

^ EU multiannual plan (MAP) for Western Waters (EU, 2019).
* By number.
** Advice value for 2020 relative to advice value for 2019 (2084 tonnes).
*** $F_{MSY\ upper}$ =F_{MSY} for this stock.