The Labadie, Jones and Cockburn Banks *Nephrops* Grounds (FU2021) 2022 UWTV Survey Report and catch scenarios for 2023.

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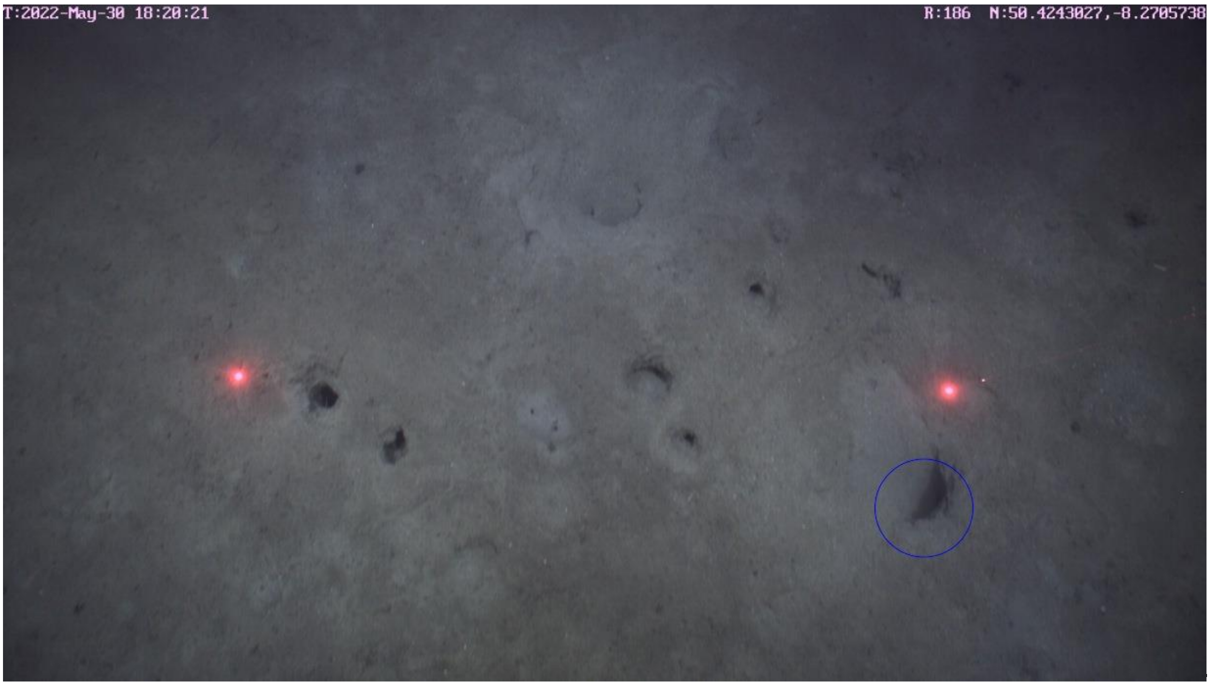

Ireland's European Structural and Investment Funds Programmes 2014-2020
Co-funded by the Irish Government and the European Union

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

EUROPEAN MARITIME AND FISHERIES FUND

Abstract

This report provides the main results of the 2022 underwater television survey on the 'Labadie, Jones and Cockburn Banks' ICES assessment area; Functional Unit 2021. The 2022 annual survey was multi-disciplinary in nature collecting UWTV and other ecosystem data. A total of 92 UWTV stations were completed at 6 nm intervals over a randomised isometric grid design. The mean burrow density was 0.10 burrows/m^2 compared with 0.12 burrows/m^2 in the year 2021. The 2022 geostatistical abundance estimate was 1032 million, a 14% decrease on the abundance from 2021, with a CV of 5%, which is well below the upper limit of 20% recommended by SGNEPS 2012. Low to medium densities were observed throughout the ground. Using the 2022 estimate of abundance and updated stock data implies catch in 2023 that correspond to the ICES MSY approach of 1803 tonnes assuming that discard rates and fishery selection patterns do not change from the average of 2019–2021. One species of sea-pen (*Virgularia mirabilis*) was recorded as present at the stations surveyed. Trawl marks were observed at 20% of the stations surveyed.

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

Suggested citation:
Doyle, J., Aristegui, M., Sullivan, M., O'Connor, S., Kinneen, M., Sugrue, S., Derbyshire C., Ryan, G., Bentley, K., Graham, J., Oliver, P., and O'Brien, B. 2022. The Labadie, Jones and Cockburn Banks *Nephrops* Grounds (FU2021) 2022 UWTV Survey Report and catch scenarios for 2023. Marine Institute UWTV Survey report.

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 2020 worth around €54 million at first sale. The Celtic Sea area (Functional Units 19-22; Figure 1) support 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, 2022). This ground has become increasingly important to the Irish demersal fleet, which now accounts for around 80% of the total international FU2021 *Nephrops* landings (ICES, 2022). 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, Leocardia *et al.*, 2018). This is the tenth UWTV survey in the Celtic Sea FU2021 grounds carried out by the Marine Institute, Ireland.

The survey was multi-disciplinary in nature and also covered UWTV stations in FU 17, FU 19 and FU 22 the results of which are presented elsewhere (Aristegui *et. al*., 2022, Doyle *et.al*., 2022 a&b).

The 2022 specific objectives are listed below:

1. To complete 92 UWTV stations with 6.0 nautical mile (nm) spacing on the Labadie, Jones and Cockburn *Nephrops* ground (FU2021).
2. To obtain 2022 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.

This report details: the survey design, the final UWTV results of the 2022 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 (MA). The 2022 survey abundances are used to generate catch advice scenarios for 2023 in line with the recommendations and procedures outlined in the stock annex for FU 20-21 (ICES, 2022).

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 and the stations completed on the 2022 survey.

The 2022 randomised isometric grid resulted in 92 planned stations and was generated using the "spsampl" function in the "sp" package (Pebesma & Bivand, 2005) in "R" (R Core Team, 2017). Station depths varied from 81 to 135 metres and the completed stations ranged from 52 to 126 nm offshore. In 2022, this *Nephrops* ground was surveyed onboard the RV. *Celtic Voyager* from the 23rd May to the 4th June.

In 2022 image data were collected by a custom built camera system recording High Definition (HD) 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 ashore through an in-house developed Image annotation R Shiny app (Aristegui, M., 2020). 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 follow internationally agreed standards as recommended in the Manual for the *Nephrops* Underwater TV Surveys (TIMES) (Dobby *et al*., 2021). These protocols are employed on other UWTV surveys in Irish waters and 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 1.0 metre (24 stations). Time referenced standard definition image data with FOV of 0.75 metre (73 stations). 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 2022 USBL navigational data were used to calculate distance over ground or 'DOG' for all the stations.

A new HD reference set was developed in 2020 for training material and reference set (ICES, 2021). In line with recommendations of the Workshop on *Nephrops* Burrow Counting (WKNEPS), all scientists were trained/re-familiarised (ICES, 2018). All counts were conducted by trained scientists independent of each other onboard. The numbers of *Nephrops* burrows systems (multiple burrows in close proximity which appear to be part of a single system) were counted as one. *Nephrops* activity in and out of burrows were counted and recorded for each station. Following the recommendation of SGNEPS the time for verified recounts was 7 minutes (ICES, 2009).

During the review numbers of *Nephrops* burrows systems were counted, where multiple burrows in close proximity which appear to be part of a single system were counted as one. *Nephrops* activity in and out of burrows were counted and recorded for each station. Following the recommendation of SGNEPS the time for verified recounts was 7 minutes (ICES, 2009a).

Presence / absence for the occurrence of trawl marks, fish and other species were also recorded at each station. Presence / absence of sea-pen species were recorded to fulfil 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 3).

In 2022 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 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 considered appropriate to carry out a third review. The paired count data that passed the threshold were used in the analysis. When 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 183, 184 and 186 are shown in Figure 4.

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 and assumed 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.

The approach to work up the abundance estimates each year has been documented in previous survey reports. Since 2013 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

92 stations were completed successfully on the FU20-21 *Nephrops* grounds (Figure 2). Figure 5 shows bubble plots of the variability between minutes. The variability is slightly higher between minutes reflecting the underlying change in densities due to the local sediment composition and this is notable on stations towards the edge of the grounds typically.

The adjusted burrow densities from 2013 to 2022 are shown in Figure 6 as a combined violin and box plot. These show that density has decreased slightly in 2022 from the previous year. The highest station density observed in 2022 was 0.37 burrows/m^2 while the majority were in the lower range of < 0.15 burrows/m^2. The 2022 mean adjusted[1] density of 0.10 burrows/m^2 is the second lowest in the time series to date, and a 13% decrease on the 2021 estimate of 0.12 burrows/m^2.

Combined bubble and contour plots of the krigged densities from 2013 to 2022 are presented in Figure 7. 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 since 2019.

The summary empirical and geo-statistical results are given in Table 1. Stations surveyed in 2012 should be viewed as exploratory and were 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 2022 geo-statistical abundance estimate is 1032 million, which is 14% lower than in 2021 (Figure 8). The geo-statistical CVs are in the order of 3 to 8%, which are well below the upper recommended limit of 20% (ICES, 2012). The geostatistical abundance estimate adjusted using the FU specific correction factor is derived using the mean of the krigged grid and the mean density is the mean of the observation data presented in Table 1.

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/UWTV abundance) in 2021, which was 2.0% (Table 2). 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 - 2021 and are based on available sampling data (ICES, 2022). The basis to the catch scenarios is given in Table 3. The latest estimate of stock abundance (value 1032 million) is above the MSY $B_{trigger}$ value (450 million). The catch scenarios and associated harvest rates are presented in Table 4. When the ICES MSY approach is applied (EU, 2019), catches in 2023 should be no more than 1803 tonnes. This assumes that discard rates and fishery selection patterns do not change from the average of 2019–2021.

Sea-pen distribution across the *Nephrops* grounds is mapped in Figure 9. All sea-pens were identified from the image data as *Virgularia mirabilis*.-Trawl marks were noted at 20% 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 2022 survey achieved full coverage of the stock area for the eighth 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 and 2019 density across FU2021 decreased. There was also a general decrease in density in the Celtic Sea *Nephrops* grounds in FU19 (Aristegui *et al.*, 2018a) and FU22 (Aristegui *et al.*, 2018b). In 2022 density across FU2021 decreased slightly and represents the second lowest abundance estimate of the time series. Fluctuations in density were also observed in the adjacent FU19 and FU22 in recent years (Doyle *et al.*, 2019a; Doyle *et al.*, 2019b; Aristegui *et al.*, 2020b; Aristegui *et al.*, 2020a). 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).

In 2018, a partial review of historical survey data was undertaken given the large fluctuations observed in the short time series to date for this survey, though checking a randomly chosen 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 FU2021 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 (TIMES) Dobby *et al*., 2021). 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; McGeady *et al*., 2019). 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 EU landings obligation since 2016 with several exemptions. In 2022, this stock is still under a landing obligation and there are still exemptions in place. Discard rates in weight for this FU have been around 10% in recent years.

The provision of catch advice and scenarios for 2023 based on the ICES MSY approach assumes that discard rates and fishery selection patterns do not change from the average of 2019–2021.

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 impacts exactly. 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 2022 have been observed on previous surveys of FU2021. 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 tenth 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

We would like to express our thanks and gratitude to the Master and crew of the RV. *Celtic Voyager* for their good will and professionalism throughout the survey. Thanks also to the P&O Maritime IT & Instrumentation Technician Ian Murphy who maintained the UWTV system throughout the survey. Thanks to Aodhán Fitzgerald, Rosemarie Butler and Tricia McManus (RVOPs) and Dave Tully FEAS at the Marine Institute for organising survey logistics. Thanks to Gordon Furey, Damian Crean, Barry Kavanagh, John Barry (P&O Maritime) for shore side support. Thanks to Chris Allsop (OCIS/FEAS) for supporting the UWTV database management.

Photography credits

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Disclaimer

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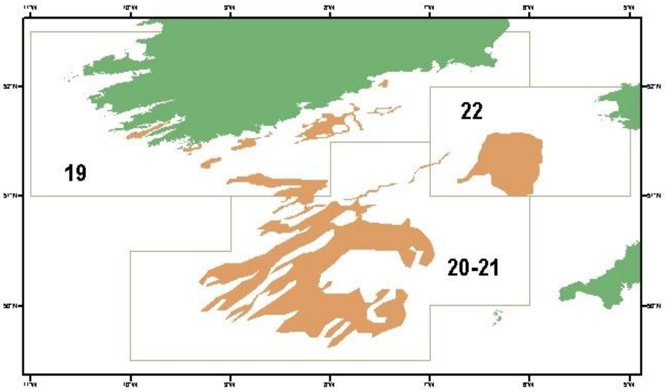

Figure 1: FU2021 UWTV. *Nephrops* Functional Units (FUs) and *Nephrops* survey area polygons in the greater Celtic Sea.

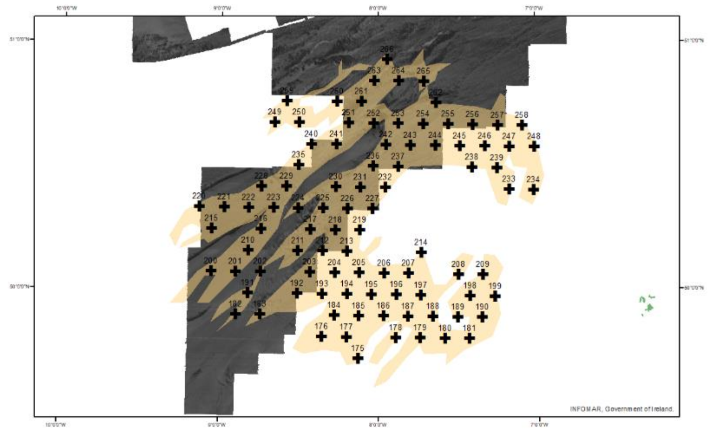

Figure 2: FU2021 UWTV. Multibeam backscatter data from INFOMAR mapping programme to date. Dark (+) are the 2022 planned and completed UWTV stations. Orange shading is the extent of UWTV survey area.
Source: INFOMAR is the Department of Communications, Climate Action and Environment (DCCAE) funded national seabed mapping programme, jointly managed and delivered by Geological Survey Ireland and Marine Institute

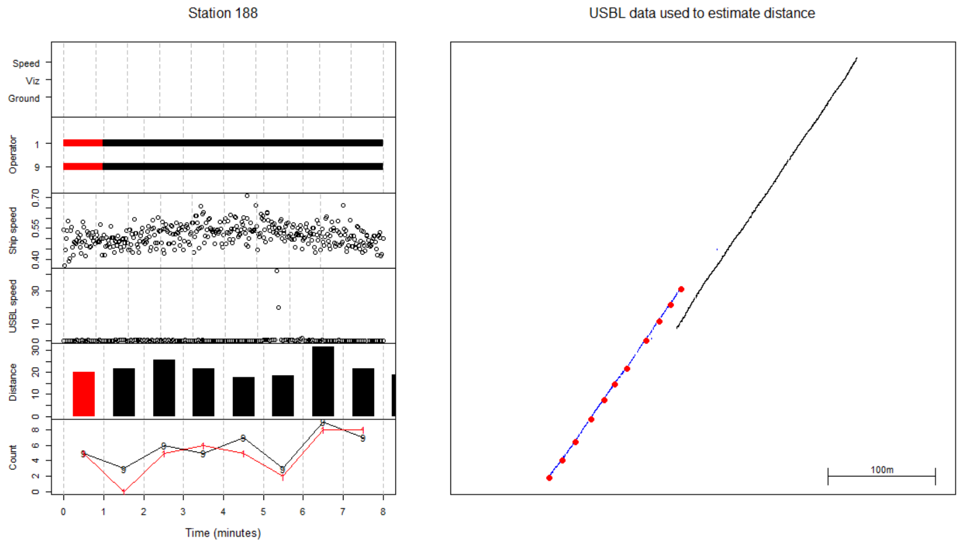

Figure 3: FU2021 UWTV. R - tool quality control plot for station 188 of the 2022 survey.

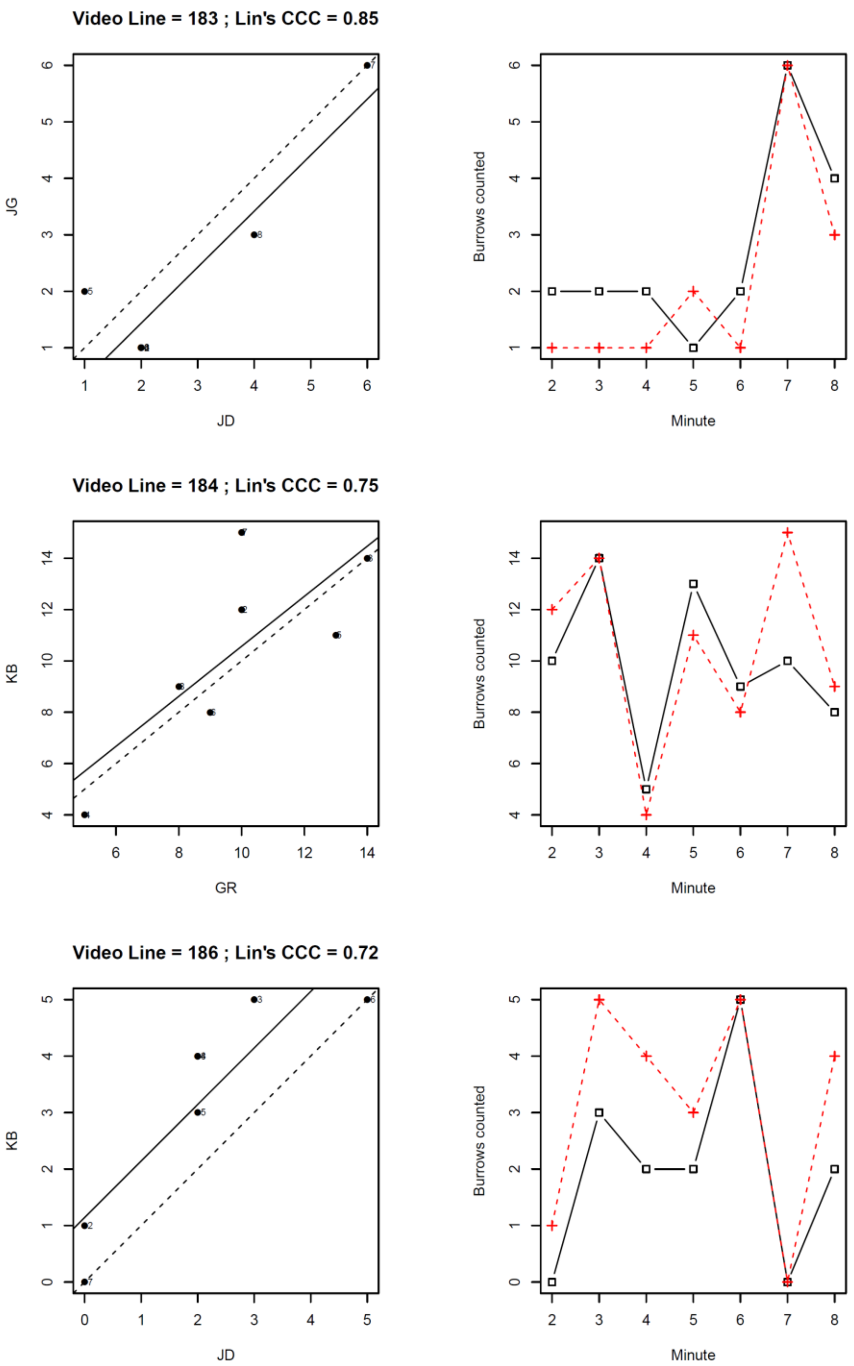

Figure 4: FU2021 UWTV. Lin's CCC quality control plots of count data for stations 183, 184, 186 from the 2022 survey.

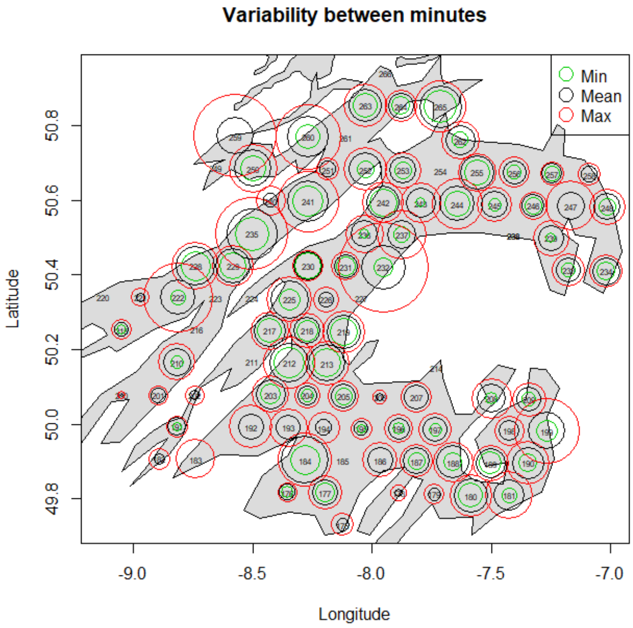

Figure 5: FU2021 UWTV. Plots of the variability in density between minutes for each station in 2022.

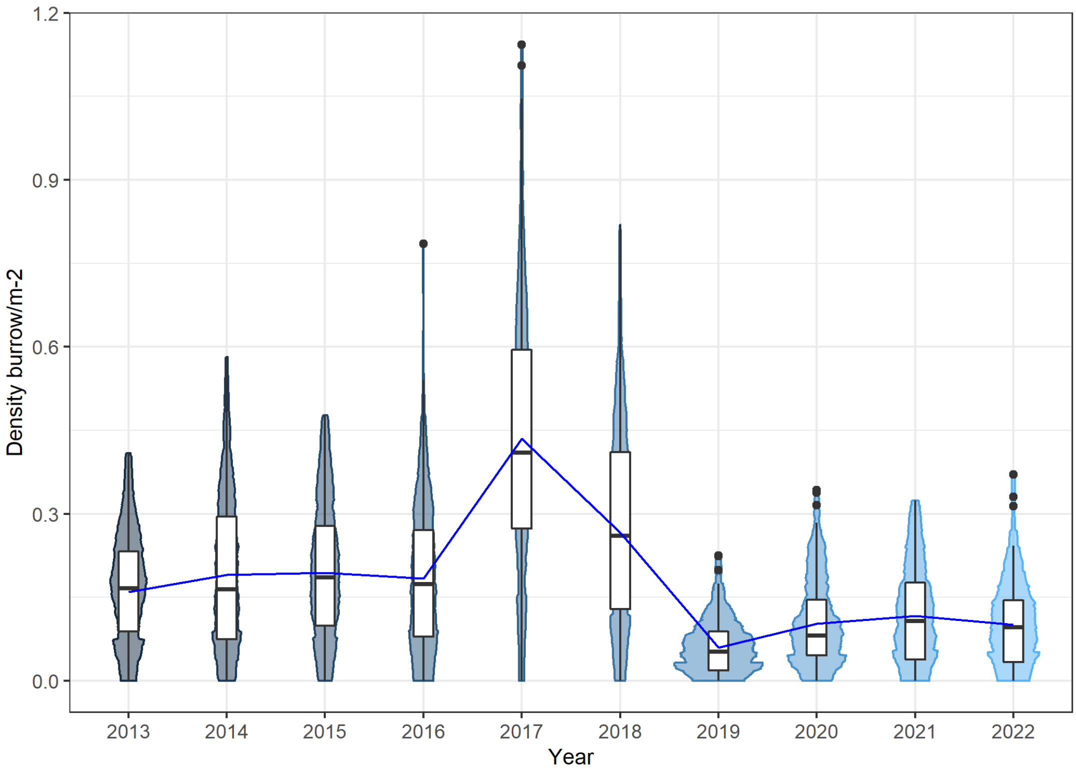

Figure 6: FU2021 UWTV. Violin and box plot of adjusted burrow density distributions by year from 2013-2022. The blue line indicates the mean density over time. The horizontal blacks lines represents medians, white boxes the inter quartile ranges, the black vertical lines are the range and the black dots are outliers.

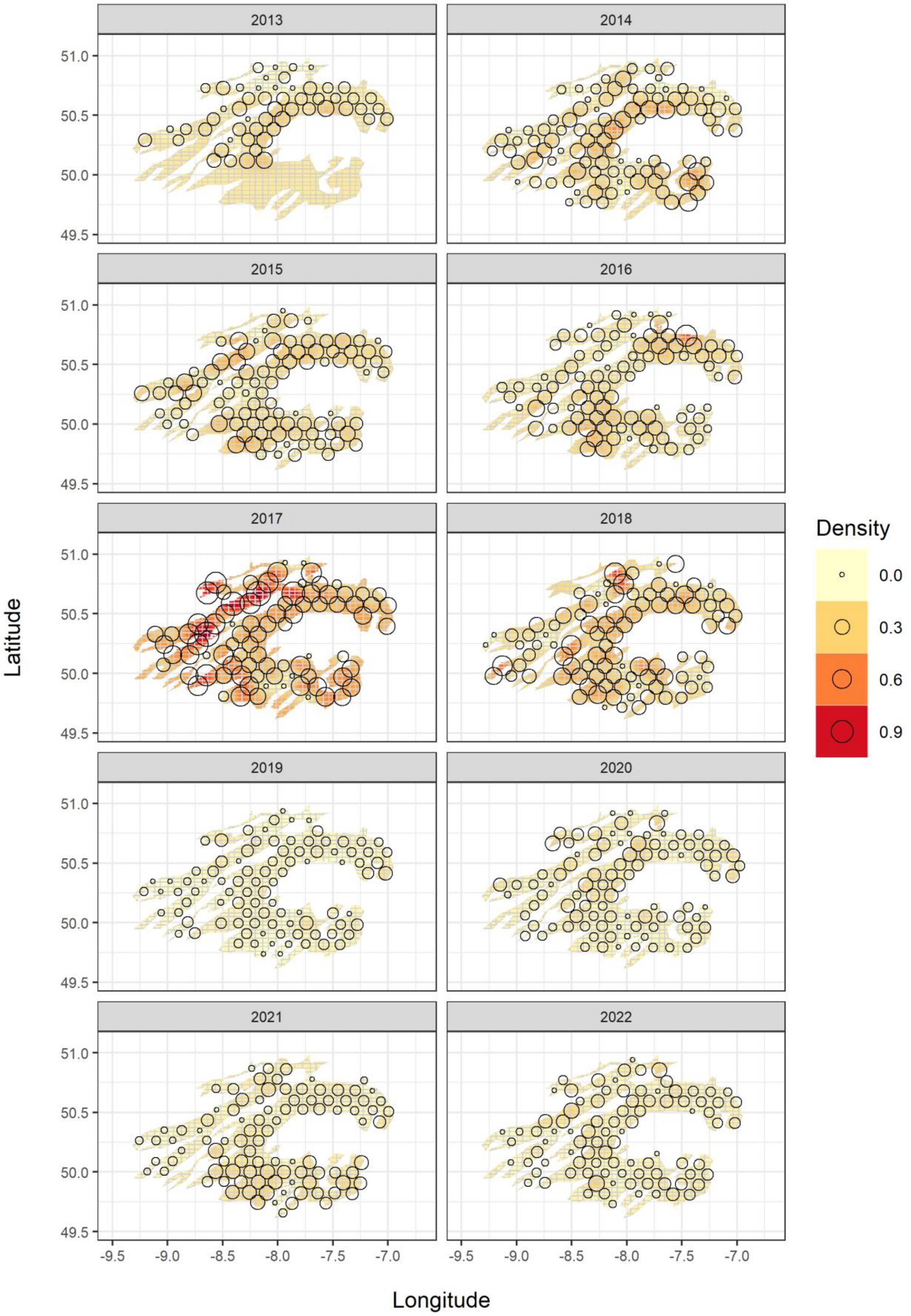

Figure 7: FU2021 UWTV. Contour plots of the krigged density estimates by year from 2013 (top-left) - 2022 (bottom-right).

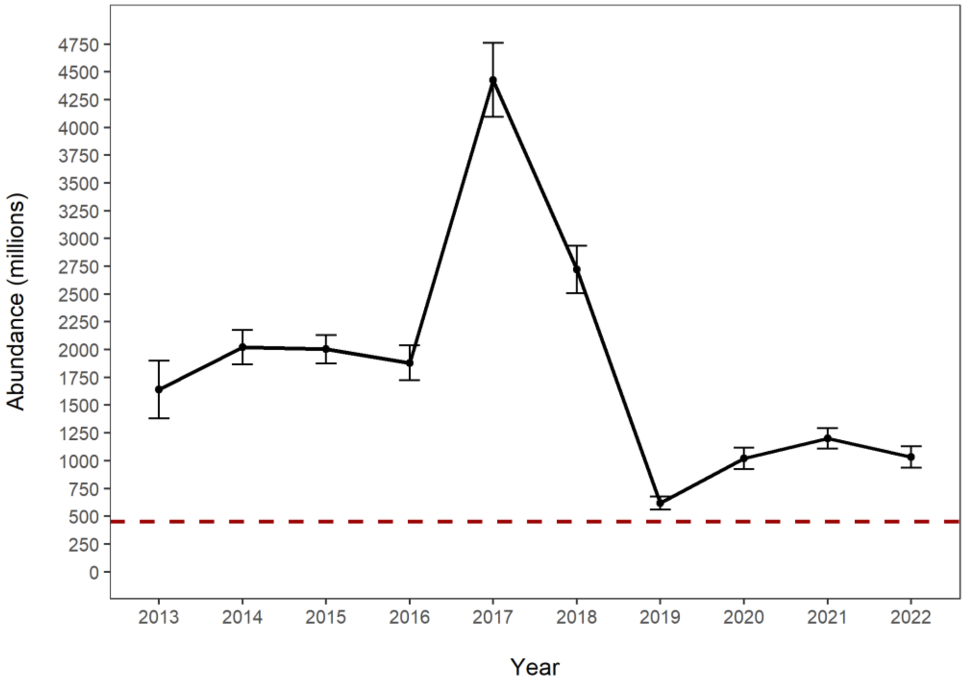

Figure 8: FU2021 UWTV. Time series of raised abundance estimates (in millions of burrows) for FU2021. The error bars indicate the 95% confidence intervals and the dashed line the MSY $B_{trigger}$ reference point.

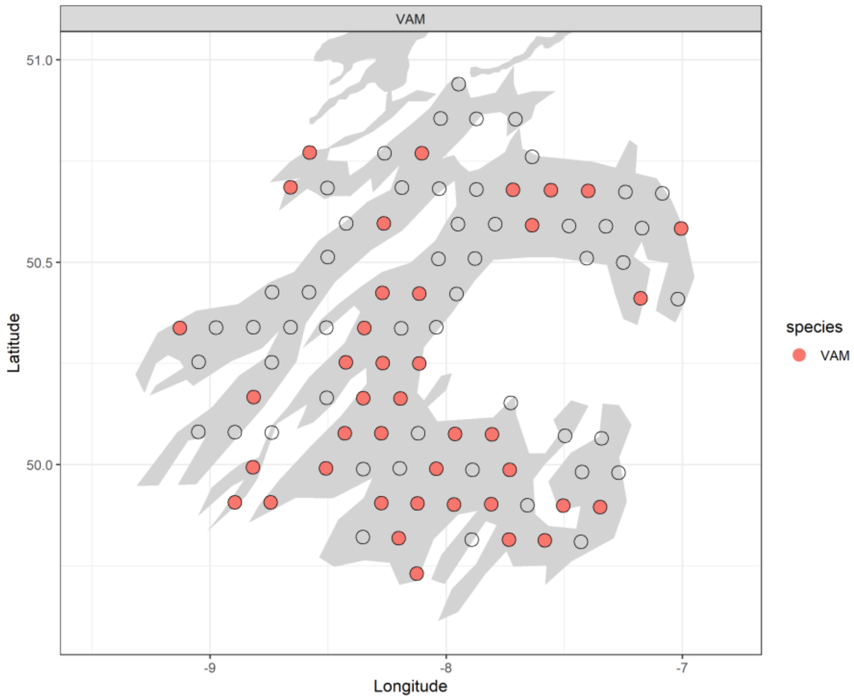

Figure 9: FU2021 UWTV. 2022 stations where *Virgularia mirabilis* (VAM) were identified. Pink circles indicated presence and open circles denotes UWTV stations with no sea-pen observations.

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 % confidence interval on Abundance (million burrows)	Domain area	CVs %
2012	54	0.57	0.25	nr	nr	nr	nr
2013*^	55	0.16	0.015	1640	261	9931	8.1
2014^	98	0.19	0.024	2021	154	9980	3.9
2015	96	0.2	0.020	2003	129	9835	3.2
2016	93	0.18	0.025	1879	157	9974	4.3
2017	86	0.44	0.079	4428	332	9978	3.8
2018	96	0.27	0.041	2721	212	9987	4.0
2019	95	0.06	0.004	617	58	9982	4.8
2020	97	0.10	0.009	1020	96	9978	4.8
2021	97	0.12	0.010	1202	92	9987	3.9
2022	92	0.10	0.008	1032	96	9981	4.8

* 2013 survey achieved partial coverage ~60% of the total area. The abundance has been scaled up to the entire area since densities in the un-surveyed part of the ground were not significantly different in 2014.
^ Revised data for 2013 to 2014.
nr = no reliable abundance estimate could be calculated because survey coverage was partial.

Table 2: The inputs for the catch scenarios.

Year	Low	UWTV abundance estimate	High	Landings in number	Total discards in number*	Removals in number	Harvest rate by number	Landings	Total discards*	Discard rate (by number)	Dead discard rate (by number)	Mean weight in landings	Mean weight in discards
	millions						%	tonnes		%		grammes	
2012				38.2	36.1	65.3		1189	542	49	41	31.10	15.01
2013	1379	1640	1901	34.8	19.2	49.2	3.0	1387	327	36	29	39.68	17.04
2014	1867	2021	2175	50.6	55.5	92.2	4.6	1836	834	52	45	36.35	15.02
2015	1874	2003	2132	59.4	28.1	80.5	4.0	2116	442	32	26	35.71	15.71
2016	1722	1879	2036	60.2	37.5	88.3	4.7	2453	801	38	32	40.74	21.37
2017	4096	4428	4760	60.1	19.2	74.5	1.70	1849	306	24	19.4	30.78	15.91
2018	2509	2721	2933	64.7	21.5	80.8	3.0	1803	381	25	20	27.88	17.72
2019	559	617	675	91.8	35.8	119	19.2	2723	539	28	23	29.65	15.04
2020	924	1020	1116	14.6	2.0	16.2	1.60	413	34	12.3	9.5	28.24	16.70
2021	1110	1202	1294	22.3	2.9	24.4	2.0	736	49	11.5	8.9	33.03	16.95
2022	936	1032	1128										

* Dead + surviving discards.
^ Values updated in 2021 due to minor revisions in UWTV abundance estimate from kriging method review.

Table 3: The basis for the catch scenarios.

Variable	Value	Notes
Stock abundance (2023)	1032	UWTV survey 2022; numbers of individuals in millions
Mean weight in projected landings	30.31	Average 2019–2021 in grammes
Mean weight in projected discards	16.23	Average 2019–2021 in grammes
Projected discards	17.3	Average 2019–2021; percentage by number of the total catch
Discards survival	25	Percentage by number of the discards

Table 4: Catch advice and scenarios for 2023; Discarding assumed to continue at recent average. All weights are in tonnes.

Basis	Total catch	Dead removals	Projected landings	Projected dead discards	Projected surviving discards	% harvest rate*	% advice change**
	PL + PDD + PSD	PL + PDD	PL	PDD	PSD	for PL + PDD	
ICES advice basis							
MSY approach	1803	1757	1620	137	46	6.0	−8.8
Other scenarios							
$F_{MSY\ lower}$	1773	1728	1593	135	45	5.9	−10.4
$F_{MSY\ upper}$ ***	1803	1757	1620	137	46	6.0	−8.8
F_{2021}	611	596	549	47	16	2.04	−69

* By number.
** Advice values for 2023 are relative to the 2022 advice (F_{MSY} advice of 1978 tonnes).
*** $F_{MSY\ upper}$ = F_{MSY} for this stock.